Annual Report of the Board of Regents

of the

SMITHSONIAN INSTITUTION

PUBLICATION 4111

Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended June 30

1952

UNITED STATES
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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 29, 1952.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, on 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 ended June 30, 1952. I have the honor to be,

Respectfully,

A. WETMORE, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1952

Presiding Officer ex officio.—HARRY S. TRUMAN, President of the United States.
Chancellor.—FRED M. VINSON, Chief Justice of the United States.
Members of the Institution:
HARRY S. TRUMAN, President of the United States.
ALBEN W. BARKLEY, Vice President of the United States.
FRED M. VINSON, Chief Justice of the United States.
DEAN C. ACHESON, Secretary of State.
JOHN W. SNYDER, Secretary of the Treasury.
GEORGE C. MARSHALL, Secretary of Defense.
JAMES P. MCGRANERY, Attorney General.
JESSE M. DONALDSON, Postmaster General.
OSCAR CHAPMAN, Secretary of the Interior.
CHARLES F. BRANNAN, Secretary of Agriculture.
CHARLES SAWYER, Secretary of Commerce.
MAURICE TOBIN, Secretary of Labor.
Regents of the Institution:
FRED M. VINSON, Chief Justice of the United States, Chancellor.
ALBEN W. BARKLEY, Vice President of the United States.
WALTER F. GEORGE, Member of the Senate.
CLINTON P. ANDERSON, Member of the Senate.
LEVERETT SALTONSTALL, Member of the Senate.
CLARENCE CANNON, Member of the House of Representatives.
JOHN M. VORYS, Member of the House of Representatives.
E. E. COX, Member of the House of Representatives.
HARVEY N. DAVIS, citizen of New Jersey.
ARTHUR H. COMPTON, citizen of Missouri.
VANNEVAR BUSH, citizen of Washington, D. C.
ROBERT V. FLEMING, citizen of Washington, D. C.
JEROME C. HUNSAKER, citizen of Massachusetts.
Executive Committee.—ROBERT V. FLEMING, *chairman*, VANNEVAR BUSH, CLARENCE CANNON.
Secretary.—ALEXANDER WETMORE.
Assistant Secretaries.—JOHN E. GRAF, J. L. KEDDY.
Administrative assistant to the Secretary.—MRS. LOUISE M. PEARSON.
Treasurer.—J. D. HOWARD.
Chief, editorial division.—PAUL H. OEHSER.
Librarian.—MRS. LEILA F. CLARK.
Chief, accounting division.—THOMAS F. CLARK.
Superintendent of buildings and labor.—L. L. OLIVER.
Assistant Superintendent of buildings and labor.—CHARLES C. SINCLAIR.
Chief, personnel division.—JACK B. NEWMAN.
Chief, publications division.—L. E. COMMERFORD.
Chief, supply division.—ANTHONY W. WILDING.
Photographer.—F. B. KESTNER.

UNITED STATES NATIONAL MUSEUM

Director.—A. Remington Kellogg.
Chief, office of correspondence and records.—Helena M. Weiss.
Editor.—John S. Lea.

SCIENTIFIC STAFF

Department of Anthropology:

Frank M. Setzler, head curator; A. J. Andrews, J. E. Anglim, exhibits preparators; W. W. Taylor, Jr., collaborator in anthropology.

Division of Archeology: Waldo R. Wedel, curator; Clifford Evans, Jr., associate curator; Mrs. M. C. Blaker, museum aide; J. Townsend Russell, Jr., honorary assistant curator of Old World archeology.

Division of Ethnology: H. W. Krieger, curator; J. C. Ewers, C. M. Watkins, associate curators; R. A. Elder, Jr., assistant curator.

Division of Physical Anthropology: T. Dale Stewart, curator; M. T. Newman, associate curator.

Associate in Anthropology: Neil M. Judd.

Department of Zoology:

Waldo L. Schmitt, head curator; W. L. Brown, chief exhibits preparator; C. H. Aschemeier, W. M. Perrygo, E. G. Laybourne, C. E. East, J. D. Biggs, exhibits preparators; Mrs. Aime M. Awl, scientific illustrator.

Division of Mammals: D. H. Johnson, H. W. Setzer, associate curators; Charles O. Handley, Jr., assistant curator; A. Brazier Howell, collaborator; Gerrit S. Miller, Jr., associate.

Division of Birds: Herbert Friedmann, curator; H. G. Deignan, associate curator, Samuel A. Arny, museum aide; Alexander Wetmore, custodian of alcoholic and skeleton collections; Arthur C. Bent, collaborator.

Division of Reptiles and Amphibians: Doris M. Cochran, associate curator.

Division of Fishes: Leonard P. Schultz, curator; E. A. Lachner, associate curator; W. T. Leapley, Robert H. Kanazawa, museum aides.

Division of Insects: Edward A. Chapin, curator; R. E. Blackwelder, W. D. Field, O. L. Cartwright, Grace E. Glance, associate curators; Sophy Parfin, junior entomologist; W. L. Jellison, collaborator.

Section of Hymenoptera: W. M. Mann, Robert A. Cushman, assistant custodians.

Section of Diptera: Charles T. Greene, assistant custodian.

Section of Coleoptera: L. L. Buchanan, specialist for Casey collection.

Division of Marine Invertebrates: F. A. Chace, Jr., curator; Frederick M. Bayer, associate curator; Mrs. L. W. Peterson, museum aide; Mrs. Harriet Richardson Searle, Max M. Ellis, J. Percy Moore, collaborators; Mrs. Mildred S. Wilson, collaborator in copepod Crustacea.

Division of Mollusks: Harald A. Rehder, curator; Joseph P. E. Morrison, R. Tucker Abbott, associate curators; W. J. Byas, museum aide; Paul Bartsch, associate.

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Associates in Zoology: T. S. Palmer, W. B. Marshall, A. G. Böving, C. R. Shoemaker, W. K. Fisher, Austin H. Clark.

Collaborator in Zoology: R. S. Clark.

Collaborator in Biology: D. C. Graham.

DEPARTMENT OF BOTANY (NATIONAL HERBARIUM):

Jason R. Swallen, head curator.

Division of Phanerogams: A. C. Smith, curator; E. C. Leonard, E. H. Walker, Lyman B. Smith, associate curators; Velva E. Rudd, assistant curator; E. P. Killip, research associate.

Division of Ferns: C. V. Morton, curator.

Division of Grasses: Ernest R. Sohns, associate curator; Mrs. Agnes Chase, F. A. McClure, research associates.

Division of Cryptogams: C. V. Morton, acting curator; Paul S. Conger, associate curator; John A. Stevenson, custodian of C. G. Lloyd mycological collections and honorary curator of Fungi; David G. Fairchild, custodian of Lower Fungi.

DEPARTMENT OF GEOLOGY:

W. F. Foshag, head curator; J. H. Benn, museum aide; Jessie G. Beach, junior geologist.

Division of Mineralogy and Petrology: W. F. Foshag, acting curator; E. P. Henderson, G. S. Switzer, associate curators; F. E. Holden, museum technician; Frank L. Hess, custodian of rare metals and rare earths.

Division of Invertebrate Paleontology and Paleobotany: Gustav A. Cooper, curator; A. R. Loeblich, Jr., David Nicol, Arthur L. Bowsher, associate curators; W. T. Allen, museum aide; J. Brookes Knight, research associate in paleontology.

Section of Invertebrate Paleontology: T. W. Stanton, custodian of Mesozoic collection; J. B. Reeside, Jr., custodian of Mesozoic collection; Preston Cloud, research associate.

Section of Paleobotany: Roland W. Brown, research associate.

Division of Vertebrate Paleontology: C. L. Gazin, curator; D. H. Dunkle, associate curator; F. L. Pearce, A. C. Murray, exhibits preparators.

Associates in Mineralogy: W. T. Schaller, S. H. Perry, J. P. Marble.

Associate in Paleontology: R. S. Bassler.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Frank A. Taylor, head curator.

Division of Engineering: Frank A. Taylor, acting curator; William H. Dunn, Jr., museum aide.

Section of Civil and Mechanical Engineering: Frank A. Taylor, in charge.

Section of Marine Transportation: Frank A. Taylor, in charge.

Section of Electricity: K. M. Perry, associate curator.

Section of Physical Sciences and Measurement: Frank A. Taylor, in charge.

Section of Land Transportation: S. H. Oliver, associate curator.

Division of Crafts and Industries: W. N. Watkins, curator; Edward C. Kendall, associate curator; E. A. Avery, museum aide; F. L. Lewton, research associate.

Section of Textiles: Grace L. Rogers, assistant curator.

Section of Wood Technology: W. N. Watkins, in charge.

Section of Manufactures: Edward C. Kendall, associate curator.

Section of Agricultural Industries: Edward C. Kendall, associate curator.

Division of Medicine and Public Health: [Vacancy], associate curator.

Division of Graphic Arts: J. Kainen, curator; J. Harry Phillips, Jr., museum aide.

Section of Photography: A. J. Wedderburn, Jr., associate curator.

DEPARTMENT OF HISTORY:

Mendel L. Peterson, acting head curator.

Divisions of Military History and Naval History: M. L. Peterson, associate curator; J. R. Sirlouis, assistant curator.

Division of Civil History: Margaret W. Brown, associate curator.

Division of Numismatics: S. M. Mosher, associate curator.

Division of Philately: Franklin R. Bruns, Jr., associate curator.

NATIONAL GALLERY OF ART

Trustees:

FRED M. VINSON, Chief Justice of the United States, *Chairman.*
DEAN C. ACHESON, Secretary of State.
JOHN W. SNYDER, Secretary of the Treasury.
ALEXANDER WETMORE, Secretary of the Smithsonian Institution.
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FERDINAND LAMMOT BELIN.
DUNCAN PHILLIPS.
CHESTER DALE.
PAUL MELLON.

President.—SAMUEL H. KRESS.
Vice President.—FERDINAND LAMMOT BELIN.
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Director.—DAVID E. FINLEY.
Administrator.—HARRY A. MCBRIDE.
General Counsel.—HUNTINGTON CAIRNS.
Chief Curator.—JOHN WALKER.
Assistant Director.—MACGILL JAMES.

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Director.—THOMAS M. BEGGS.
Curator of ceramics.—P. V. GARDNER.
Chief, Smithsonian Traveling Exhibition Service.—MRS. JOHN A. POPE.
Exhibits preparators.—G. J. MARTIN, ROWLAND LYON.

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Director.—A. G. WENLEY.
Assistant Director.—JOHN A. POPE.
Assistant to the Director.—BURNS A. STUBBS.
Associate in Near Eastern art.—RICHARD ETTINGHAUSEN.
Associate in technical research.—RUTHERFORD J. GETTENS.
Assistant in research.—HAROLD P. STERN.
Research associate.—GRACE DUNHAM GUEST.
Honorary research associate.—MAX LOEHR.

BUREAU OF AMERICAN ETHNOLOGY

Director.—MATTHEW W. STIRLING.
Associate Director.—FRANK H. H. ROBERTS, Jr.
Anthropologists.—H. B. COLLINS, Jr., PHILIP DRUCKER.
Ethnologist.—JOHN P. HARRINGTON.
Collaborators.—FRANCES DENSMORE, JOHN R. SWANTON, A. J. WARING, Jr.
Scientific illustrator.—E. G. SCHUMACHER.
INSTITUTE OF SOCIAL ANTHROPOLOGY.—G. M. FOSTER, Jr., *Director.*
RIVER BASIN SURVEYS.—FRANK H. H. ROBERTS, Jr., *Director.*

INTERNATIONAL EXCHANGE SERVICE

Chief.—D. G. WILLIAMS.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.
Assistant Director.—ERNEST P. WALKER.
Head Animal Keeper.—FRANK O. LOWE.

ASTROPHYSICAL OBSERVATORY

Director.—LOYAL B. ALDRICH.
DIVISION OF ASTROPHYSICAL RESEARCH:
Chief.—WILLIAM H. HOOVER.
Instrument makers.—ANDREW KRAMER, D. G. TALBERT, J. H. HARRISON.
Research associate.—CHARLES G. ABBOT.
DIVISION OF RADIATION AND ORGANISMS:
Chief.—R. B. WITHROW.
Plant physiologists.—WILLIAM H. KLEIN, LEONARD PRICE, V. B. ELSTAD, MRS. ALICE P. WITHROW.

NATIONAL AIR MUSEUM

Advisory Board:
ALEXANDER WETMORE, *Chairman.*
MAJ. GEN. DONALD L. PUTT, *U. S. Air Force.*
REAR ADM. T. S. COMBS, *U. S. Navy.*
GROVER LOENING.
WILLIAM B. STOUT.
Head curator.—Paul E. GARBER.
Associate curator.—R. C. STROBELL.
Manager, National Air Museum Facility.—W. M. MALE.
Museum aides.—STANLEY POTTER, WINTHROP S. SHAW.

CANAL ZONE BIOLOGICAL AREA

Resident Manager.—JAMES ZETEK.

BUREAU OF AMERICAN ETHNOLOGY

Director—Matthew W. Stirling.
Associate Director—Frank H. H. Roberts, Jr.
Anthropologists—H. B. Collins, Jr., William N. Fenton.
Ethnologist—John P. Harrington.
Collaborators—Frances Densmore, John R. Swanton, [illegible]
River Basin Surveys—Frank H. H. Roberts, Jr., Director.
Institute of Social Anthropology—G. M. Foster, Jr., Director.
[illegible]

INTERNATIONAL EXCHANGE SERVICE

Chief—D. G. Williams.

NATIONAL ZOOLOGICAL PARK

Director—William M. Mann.
Assistant Director—Ernest P. Walker.
First Animal Keeper—Frank O. Lowe.

ASTROPHYSICAL OBSERVATORY

Director—Loyal B. Aldrich.
Division of Astrophysical Research:
Chief—William H. Hoover.
Instrument makers—Andrew Kramer, D. G. Talbert, J. H. Harrison.
Research associate—Charles G. Abbot.
Division of Radiation and Organisms:
Chief—R. B. Withrow.
Plant physiologists—[illegible]
Alice P. Withrow.

NATIONAL AIR MUSEUM

Advisory Board:
Alexander Wetmore, Chairman.
Maj. Gen. Donald L. Putt, U.S.A.F.
Rear Adm. T. S. Combs, U.S.N.
Grover Loening.
William B. Stout.
Head curator—Paul E. Garber.
Associate curator—R. C. Strobell.
[illegible]
[illegible]

CANAL ZONE BIOLOGICAL AREA

Resident Manager—James Zetek.

Report of the Secretary of the Smithsonian Institution

ALEXANDER WETMORE

For the Year Ended June 30, 1952

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and its branches during the fiscal year ended June 30, 1952.

GENERAL STATEMENT

The period covered in the present annual report has been one of steady and progressive activity along the established lines that have become the functions of the Smithsonian Institution as the years since its foundation in 1846 have multiplied. Although no additional responsibilities have been assumed beyond those entailed by the steady increase in the national collections of history, science, and art, in visitors to the public exhibitions, and in requests for information and other assistance, there has been much consideration and effort given to improvement in methods of operation and to better coordination of our affairs. Having held administrative positions concerned with the direction of the Smithsonian Institution since 1925, first as Assistant Secretary, and since 1945 as Secretary, I find it of interest to examine the current status of the Institution and its position at the present time, when I have requested release from these responsibilities in order to be free for the scientific investigations that have been a major activity throughout my life.

It should be stated clearly that whatever has been accomplished in betterment in the Institution during this period of years has been due to the combined interest and devotion of all the Institution's personnel and not to the work of any one individual alone. The staff of the Smithsonian throughout its modern history has been the dynamic part of the organization, in contrast to the material holdings of land, buildings, and collections that form its possessions. The staff, while constantly changing in individual members, in its entirety has been the firm foundation of the structure. The varied forces exerted in this staff form a steadily flowing stream of effort whose force and direction have changed from decade to decade, but whose impetus as a whole does not slacken. It is this working group that is the heart

of the Smithsonian Institution at any given moment in its operations. In my quarter-century and more with the Smithsonian it has been repeatedly impressed upon me that it has been the loyalty and spirit and abilities of these workers that have helped most to achieve the Institution's prime purpose—"the increase and diffusion of knowledge among men."

The original endowment fund received under the will of James Smithson, with several later additions, is held in the United States Treasury as a permanent trust and stands as official recognition of the position held by the Smithsonian in relation to our Nation. The Institution has deep and increasing pride in its position as guardian of historical and scientific treasures that belong to all who now are citizens of our country and that, equally, belong to the generations of the future. It is our great responsibility to maintain these holdings safely, to investigate and make known their values for the public good, and to add to them in those ways that will enhance their worth for the increase of knowledge. This responsibility is particularly acute in times of national emergency, as during World War II or at the present time when many peacetime activities must give place in the Federal budget to matters of national defense. Smithsonian administrators would not be faithful to their trust if even during such periods they relaxed in their efforts to assure adequate support through public funds for safeguarding and preserving for future generations the treasures entrusted to them by the American people.

Growth in the responsibilities of the Smithsonian since 1925 may be better understood when it is known that the collections in its charge have more than doubled during that time, while their value has increased in even greater degree because they include so many thousands of unique objects. It is not practicable to place a definite monetary value on all these things, since for most there is no true market in the sense of ordinary barter and sale. For many, particularly in the historical field, no real price in dollars may be set, as their actual worth—for example, the relics of Washington, Jefferson, and other national heroes—lies in the patriotic sentiment in which they are held. It is sufficient to say that the more than 33,000,000 catalog entries now found in these collections may be valued at upward of a billion dollars, but with the further explanation that no sum of money, regardless of how great it might be, could ever replace these materials should damage come to them.

Many shifts and changes in our administrative alignment have been made for improvement in procedures, for more efficient assignment of staff, and for better utilization of the space available to us for housing. The result has been an increased efficiency without which we would not be able to meet the demands now laid upon us. The scope of all

Smithsonian bureaus and their constituent units is now described in a detailed account of the work of the Institution, prepared in January 1951, which includes a survey of the duties and responsibilities that pertain to each.

Present needs of the Smithsonian remain those that have been of perennial pressure, namely, additional personnel, increased space for housing, and further support for operation. All require funds if they are to be adequately met. Through increased pay, necessary and greatly deserved under present-day living costs, and through changes in work hours, the annual payroll of the Institution has more than doubled in the past 20 years. At the same time the available man hours of service per week now actually are less. In 1942 we had 20,592 man hours available. For the same service now in 1952 (with greatly increased work load) we may command only 20,200 man hours. This situation is one that needs remedy without delay, or the Institution will lag decidedly in its required duties and in its services to our people.

As for space, through careful planning we are now utilizing fully all that is available to us. Additional buildings for the United States National Museum and the National Air Museum, for the collections in art, and for our research operations in natural history and other fields are essential whenever funds may be provided. For a number of years it has become increasingly important that a research center of considerable size be built in the area outside of but reasonably near Metropolitan Washington, to which the study collections of the National Museum might be removed and where laboratory space would be available for our scientists. The present buildings in the Mall area would then be accessible to the public to be used wholly for exhibition. The research area should be arranged to provide storage for the most important objects in the exhibition series, should threat of war demand their removal to safety. It will be a great day in the history of the Smithsonian and in the history of American science when plans for these buildings materialize. They have been the dream of many who believe that the Smithsonian Institution is one of the great American traditions that not only must be preserved but must be accorded the physical facilities to meet its obligations of leadership in this modern age of science.

Through the income of its endowments the Smithsonian has a permanence in parts of its operation that it may maintain in no other way. Its activities under most of its endowment funds are now far too modest, since only in a few instances of special funds does it have the income that it requires. We should look forward also to substantial growth here, to provide larger funds for research and publication and for the general maintenance of central administration.

What lies ahead in the next century for the Smithsonian Institution no one can safely predict. It was my privilege in 1946 to help celebrate the one-hundredth anniversary of the Institution's founding, and at that time I wrote: "The Smithsonian had a definite beginning but has no foreseeable end. Its stated purpose knows no time or space limits, and it will go on through the centuries, changing with a changing world and so adjusting itself that it may fill a useful role in the upward struggle of mankind." It has been one of the greatest satisfactions of my life to have served an organization with such a prospect and with such potentialities.

THE ESTABLISHMENT

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

THE BOARD OF REGENTS

No changes in personnel occurred on the Board of Regents in the past year. The vacancy in the class of citizen regents still exists. The roll of regents at the close of the fiscal year, June 30, 1952, was as follows: Chief Justice of the United States, Fred M. Vinson, Chancellor; Vice President Alben W. Barkley; members from the Senate: Walter F. George, Clinton P. Anderson, Leverett Saltonstall; members from the House of Representatives: Clarence Cannon, John M. Vorys, E. E. Cox; citizen members: Harvey N. Davis, Arthur H. Compton, Vannevar Bush, Robert V. Fleming, and Jerome C. Hunsaker.

On the evening of January 17, preceding the annual meeting, an informal dinner meeting of the Board was held in the main hall of the Smithsonian Institution, with the Chancellor, Chief Justice Vinson, presiding. This occasion gave opportunity for members of the Smithsonian staff to make a fuller presentation of the scientific work of the Institution than was practicable at the regular meeting the next day.

The Board held its regular annual meeting in the Regents' Room on January 18, 1952. The Secretary presented his annual report covering the activities of the Institution and its bureaus, including the

financial report of the Executive Committee, for the fiscal year ended June 30, 1951, and this was accepted by the Board. The usual resolution authorized the expenditure by the Secretary of the income of the Institution for the fiscal year ending June 30, 1953.

At the Chancellor's suggestion, the meeting of January 18 was recessed until April 9, at which time the report of the special committee to select a successor to the Secretary was given before the full Board. Robert V. Fleming, chairman of the special committee, presented the resolution electing Dr. Leonard Carmichael, president of Tufts College, Medford, Mass., as Secretary of the Smithsonian Institution, effective on January 1, 1953.

Dr. Wetmore, who retires from administrative duties at his own request, will continue his scientific work with the Institution, under the title of research associate.

FINANCES

A statement on finances, dealing particularly with Smithsonian private funds, will be found in the report of the executive committee of the Board of Regents, page 169.

APPROPRIATIONS

Funds appropriated to the Institution for the fiscal year ended June 30, 1952, total $2,553,200, obligated as follows:

Management	$63,051
United States National Museum	780,260
Bureau of American Ethnology	62,890
Astrophysical Observatory	116,223
National Collection of Fine Arts	47,265
National Air Museum	177,147
Canal Zone Biological Area	16,647
International Exchange Service	74,678
Maintenance and operation of buildings	893,851
General services	319,084
Estimated savings	2,104
Total	2,553,200

In addition, $1,240,000 was appropriated to the National Gallery of Art, a bureau of the Institution but administered by a separate board of trustees; and $620,800 was provided in the District of Columbia appropriation act for the operation of the National Zoological Park.

Besides these direct appropriations, the Institution received funds by transfer from other Federal agencies, as follows:

From the Department of State, from the appropriation International Information and Educational Activities, 1952, a total of $42,000 for the period July 1 through December 31, 1951, for the planning and

preparation of a series of educational exhibits in German schools and museums, and from the Institute of Inter-American Affairs a total of $45,705 for the period January 1 through June 30, 1952, for the operation of the Institute of Social Anthropology, including the issuance of publications resulting from its work.

From the National Park Service, Department of the Interior, $157,803 for archeological projects in connection with the River Basin Surveys.

VISITORS

Visitors to the Smithsonian group of buildings during the year 1951–52 reached an all-time high total of 3,425,987, more than half a million more than the previous year. April 1952 was the month of largest attendance, with 490,983; May 1952 was the next largest, with 461,750. Largest attendance for 1 day was 50,329 on May 31, 1952. A summary of attendance records for the five buildings is given in table 1. These figures do not include 3,294,569 estimated at the National Zoological Park and 1,522,596 at the National Gallery of Art.

TABLE 1.—*Visitors to the Smithsonian buildings during the year ended June 30, 1952*

Year and month	Smithsonian Building	Arts and Industries Building	Natural History Building	Aircraft Building	Freer Gallery of Art	Total
1951						
July	83,251	108,583	87,618	30,346	9,861	409,659
August	84,600	214,620	92,867	31,918	10,714	434,809
September	53,235	125,845	73,173	22,563	7,052	281,868
October	43,510	104,923	59,341	15,570	5,870	229,214
November	34,001	72,822	49,022	12,668	3,872	172,385
December	20,771	39,956	29,810	8,581	2,507	101,634
1952						
January	24,667	60,337	40,026	10,518	2,972	138,520
February	32,087	73,516	48,885	13,230	3,781	171,499
March	34,723	75,917	57,113	15,437	3,992	187,182
April	92,611	245,755	111,754	31,167	9,696	490,983
May	92,430	212,643	118,030	31,559	7,088	461,750
June	65,302	162,993	86,815	23,839	7,535	346,484
Total	661,278	1,587,910	854,463	247,396	74,940	3,425,987

During the last 4 months of the fiscal year a special record was kept of groups of school children visiting the Smithsonian. The count showed that 159,784 school children came in 4,289 groups, or at an average of 37 to each group. By months the figures are: March, 420 groups, 12,066 children; April, 1,022 groups, 38,286 children; May, 2,207 groups, 85,881 children; June, 640 groups, 23,551 children. For the 4-month period, therefore, 10.7 percent of all visitors were in this category.

NINETEENTH ANNUAL JAMES ARTHUR LECTURE ON THE SUN

In 1931 the Institution received a bequest from James Arthur, of New York, a part of the income from which was to be used for an annual lecture on some aspect of the study of the sun. The nineteenth Arthur lecture was delivered in the auditorium of the Natural History Building on April 3, 1952, by Rear Adm. L. O. Colbert, director of the Washington office of the Arctic Institute of North America, formerly Director of the U. S. Coast and Geodetic Survey. The subject of Admiral Colbert's address was "The Sun, the Moon, and the Tides." This lecture will be published in full in the General Appendix of the Annual Report of the Board of Regents of the Smithsonian Institution for 1952.

HALL OF NAVAL HISTORY

Special ceremonies were held on the evening of June 19, 1952, in connection with the opening of the hall of naval history in the Arts and Industries Building. In this new exhibit, designed and assembled under the direction of Mendel L. Peterson, National Museum curator of military and naval history, the story of American naval development, from the privateer of the War of Independence to the present-day battleship, is told by means of ship and other models, paintings, prints, and original objects relating to celebrated naval craft and leaders. Through the years collections of such material have come to the Smithsonian. Now, for the first time, they are exhibited as an organized whole. Outstanding ship models in the collection, illustrating the advances from one war to another, are the *Bon Homme Richard*, *Constitution*, *Kearsage*, the *Olympia* of Admiral Dewey, the cruiser *Wichita*, and the battleship *Missouri*.

Speakers at the opening ceremonies included Rear Adm. John B. Heffernan, United States Navy; Dr. Remington Kellogg, Director of the United States National Museum; and Dr. Alexander Wetmore, Secretary of the Smithsonian Instiution.

POLICING OF SMITHSONIAN BUILDINGS

On October 24, 1951, the President approved a bill passed by the Eighty-second Congress (Public Law 206) "relating to the policing of the buildings and grounds of the Smithsonian Institution and its constituent bureaus." Among other provisions, this act authorizes the Secretary of the Institution to designate Smithsonian employees as special policemen with power to enforce regulations and make arrests in connection with the policing of our buildings and grounds. This authorization places us in a firm position relative to the protection of the many thousands of visitors who come to the Institution

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annually and serves to safeguard the tremendously valuable materials in our collections that by law are our responsibility.

MARY VAUX WALCOTT FUND FOR PUBLICATIONS IN BOTANY

Acting upon a proposal by the Secretary, the executive committee of the Board of Regents during the year authorized the establishment of the Mary Vaux Walcott Fund for Publications in Botany. This fund, amounting to $60,000, is derived from the sales of "North American Wild Flowers," the 5-volume quarto portfolio of 400 water-color plates of wild flowers painted from nature by Mrs. Charles D. Walcott. The plates were reproduced in color by a special process and were published under her supervision and generous subsidy. A large number of sets of the plates have been sold by the Institution in the 27 years since their publication, and it seems especially fitting that the income from the proceeds of their sale should now be used for publication by the Smithsonian of contributions to the science of botany, in which Mrs. Walcott had a deep interest. It is planned that the publications issued under this fund will be principally technical in nature and will relate to the researches of the United States National Herbarium. They will appear from time to time in the Smithsonian Miscellaneous Collections.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—More than 607,000 specimens, twice as many as last year, were received and distributed among the Museum's six departments, bringing the total catalog entries to 33,184,494. Some of the year's more noteworthy accessions included: In anthropology, an eighteenth-century wampum belt of the Wyandot Indians, a collection of Javanese puppets, and 78 Indian skeletons from burial sites on Buggs Island in the Roanoke River, Va.; in zoology, important mammals from Borneo, Alaska, and the United States, birds from Colombia and Panamá, reptiles and amphibians from Egypt and Borneo, and large collections of fishes, insects, marine invertebrates, and mollusks from many parts of the world; in botany, gifts of plants especially from Honduras, Colombia, Perú, Ryukyu Islands, Florida, and Canada, and many others received in exchanges with other institutions; in geology, five minerals heretofore unrepresented in the mineralogical collections, a collection of 250,000 fresh-water Mesozoic and Cenozoic mollusks, and vertebrate fossils from Washington, Montana, Wyoming, South Dakota, and North Dakota; in engineering and industries, a fanning mill used in West Virginia about 75 years ago, a corn planter of about 1860, an 1878 oil engine, a collection of early radio apparatus, and a series of stones and prints illustrating the mak-

ing of a lithograph; and in history, a walnut chest of drawers once owned by Jonathan Edwards, an unusual group of ship models for the new hall of naval history, and the saddles and equine equipment and the library of Gen. John J. Pershing.

Members of the staff conducted field work in Honduras, Dominican Republic, Panamá, Colombia, British North Borneo, Brazil, Ryukyu Islands, México, Alaska, and many sections of the United States. The Museum issued 27 publications during the year.

National Gallery of Art.—Visitors to the Gallery during the year numbered 1,522,596, a slight increase over the previous year. The Gallery received 1,891 accessions, by gift, loan, or deposit. Works of art accepted included paintings by Winslow Homer, J. J. and J. W. Audubon, Thomas Stephens, Tintoretto, Corot, Healy, Turner, Trumbull, Hogarth, Sargent, and Alvan Clark; 15 bronzes by Daumier; and several groups of prints and drawings. Ten special exhibits were held at the Gallery during the year. Traveling exhibitions of prints from the Rosenwald Collection were circulated to 19 galleries and museums in this country, and one exhibit traveled in Germany. Exhibitions from the "Index of American Design" were shown 78 times in 20 States and the District of Columbia and also in Europe. More than 36,000 persons attended the Gallery's special tours and the "Picture of the Week" talks; more than 14,000 the Sunday afternoon lectures. The Sunday evening concerts were continued. Construction of five new galleries, begun in 1950, was completed.

National Collection of Fine Arts.—The Smithsonian Art Commission met on December 4, 1951, and accepted for the National Collection 2 oil paintings, 2 sculptures, 5 pieces of ceramics, several items of glassware, and 1 water-color miniature on ivory. Eight miniatures were acquired through the Catherine Walden Myer fund. Fifty-four oil paintings by Edwin Scott were added to the Alice Pike Barney Memorial Collection, and $5,000 was added to the Barney fund. The Gallery held 10 special exhibits during the year. Under the direction of Mrs. John A. Pope, a Smithsonian traveling exhibition service was inaugurated, financed partly through the Barney fund and partly from a grant made by the Department of State.

Freer Gallery of Art.—Purchases for the Freer collections included Chinese bronzes, paintings, and pottery; an Egyptian bronze incense burner; Persian metalwork; an Indian painting with Persian verse; and a seventh-century Japanese bronze sculpture. The staff members studied new accessions, examined objects contemplated for purchase, and pursued their researches in oriental and Islamic art. A technical research laboratory, with Rutherford J. Gettens in charge, was completed and began a new phase of Gallery activity—the investigation of material and techniques of the artists and craftsmen represented

in the Freer collections. Dr. Ettinghausen continued his work abroad, particularly in the Near East. The final number of *Ars Islamica*, under Dr. Ettinghausen's editorship, was published in August 1951. Visitors to the Gallery numbered approximately 75,000.

Bureau of American Ethnology.—Members of the Bureau staff continued their ethnological and archeological researches, Director Stirling on Mexican and Panamanian archeology, Dr. Collins on the Eskimo and on the archeology of Cornwallis Island, Dr. Harrington on the Maya language, Dr. Fenton on the Iroquois, and Dr. Drucker on Meso-American archeology. Dr. Roberts continued as Director of the River Basin Surveys. Since the beginning of this project 7 years ago, 3,105 archeological sites have been located and recorded, and 578 of these have been recommended for excavation or limited testing. This year's excavation work covered 13 reservoir areas in 11 States, with 22 excavating parties in the field.

The Institute of Social Anthropology, an autonomouse unit of the Bureau financed through transfer of funds from the Department of State, carried on its field programs in Brazil, Colombia, México, and Perú. During the year activities of the Institute were integrated with those of the Institute of Inter-American Affairs, whereby ISA anthropologists participated in IIAA public-health programs in Latin America.

International Exchange Service.—The International Exchange Service is the official United States agency for the interchange of governmental, scientific, and literary publications between this country and other nations of the world. During the past year the Exchange Service handled 1,001,614 packages of such publications, weighing 825,627 pounds—9,386 packages less than last year but 36,854 pounds more. Consignments are now made to all countries except China and Rumania. The number of sets of United States official publications sent abroad in exchange for similar publications of other countries is 104 (62 full and 42 partial sets). Eighty-seven copies of the Federal Register and 94 of the Congressional Record are also sent abroad through the Exchange Service.

National Zoological Park.—Visitors to the Zoo totaled approximately 3,300,000 for the year. At the close of the fiscal year there were 2,675 animals in the Zoo collections, the removals during the year (1,721) somewhat exceeding the additions (1,575). Fourteen species of animals were received that had not previously been exhibited in the National Zoological Park. Among these were an Australian copperhead, an albino great gray kangaroo, a Bornean porcupine, and a pair of MacQueen's bustards. The United States Fish and Wildlife Service and the United States Army Medical Unit in

Malaya continued to send desirable specimens. In all, 142 creatures were born or hatched at the Zoo—72 mammals, 55 birds, and 15 reptiles.

Astrophysical Observatory.—The research work of the APO progressed in both of its divisions—astrophysical research and radiation and organisms. In addition to their regular programs, both divisions are conducting cooperative projects under contract with other Government agencies. Solar-radiation studies continued at the Observatory's two field stations, one at Table Mountain, Calif., and the other at Montezuma, Chile. Five silver-disk pyrheliometers were constructed and furnished at cost to institutions in France, Finland, Central Africa, Greece, and Rhode Island. The division of radiation and organisms continued its investigations of the biochemical reactions involved in the absorption of light energy in green plants.

National Air Museum.—Owing to the necessity of vacating all the NAM's storage facility at Park Ridge, Ill., space had to be found elsewhere in order to preserve the storage collection. Through the assistance of the National Capital Planning Commission, a plot was made available at Suitland, Md., near Washington, D. C. Several prefabricated buildings will be erected there to house the nearly 4,000 specimens in the storage collection until the permanent National Air Museum Building is provided. Accessions for the year brought additions to many phases of the aeronautical collection, including full-sized aircraft, engines, instruments, experimental and scale-model aircraft, parachutes, and trophies. In all, 110 specimens from 21 sources, comprising 30 separate accessions, were received during the year. These are listed in the full report of the Museum (Appendix 9, p. 136). Members of the staff made special surveys for materials desirable for the collections. As space and facilities permitted, improvements were made in the public exhibits in the Arts and Industries and Aircraft Buildings.

Canal Zone Biological Area.—The new laboratory building begun last year at the Barro Colorado Island station was completed. During the year, 602 visitors came to the island; 48 of these were scientists who used the facilities of the island to carry on studies in various biological fields. One such study, carried on over a period of years, by Dr. Eugene Eisenmann, resulted during the year in the publication "Annotated List of Birds of Barro Colorado Island, Panama Canal Zone," issued by the Smithsonian Institution. This lists 306 species. Other than birds, seven species of vertebrate animals have been added to the known fauna of the area since the list was published in the 1950 report—two mammals, four reptiles, and one amphibian—making in all 486 vertebrate forms known from the island.

PUBLICATIONS

The publications of the Smithsonian Institution are in two categories—those issued from federally appropriated funds (particularly the publications of the National Museum and the Bureau of American Ethnology, and the Smithsonian Report) and those issued under income from the Institution's various endowment funds (Smithsonian Miscellaneous Collections, publications of the Freer Gallery of Art, and special publications). Eight regular series are issued, plus six others that appear less frequently. Publications are distributed free to more than a thousand libraries, both in this country and abroad, as well as to a large list of educational and scientific organizations and specialists in various fields. The Smithsonian publications program is a major part in the Institution's endeavor to fulfill the diffusion-of-knowledge function prescribed by its founder. In all, 144,166 copies of Smithsonian publications were distributed during the year.

Seventy-six publications appeared under the Smithsonian imprint during the year. Outstanding among these were: "Biological Investigations in Mexico," by Edward A. Goldman; "Middle Cambrian Stratigraphy and Faunas of the Canadian Rocky Mountains," by Franco Rasetti; "The Butterflies of Virginia," by Austin H. and Leila F. Clark; "The Mysidacea of the United States National Museum," by Walter M .Tattersall; and "Symposium on Local Diversity in Iroquois Culture," edited by William N. Fenton. A complete list of the year's publications will be found in the report of the chief of the editorial division, Appendix 12.

Smithsonian tables.—There were also issued two numbers in the Institution's series of tables—the sixth revised edition of the Smithsonian Meteorological Tables, compiled by Robert J. List, of the United States Weather Bureau; and Smithsonian Logarithmic Tables, prepared by G. W. Spenceley, Rheba M. Spenceley, and E. R. Epperson, of Miami (Ohio) University, presenting 23-decimal-place values of common and natural logarithms. In addition, the ninth revised edition of the Smithsonian Physical Tables, compiled by W. E. Forsythe, of Cleveland, was partly in galley proof at the end of the year.

First Ladies' Gowns.—Also in press at the close of the fiscal year was a book on "The Dresses of the First Ladies of the White House," by Margaret W. Brown, National Museum historian. The book (8 x 10 inches in size) describes this popular collection of costumes as they are displayed in the Arts and Industries Building. Each of the 35 gowns of the First Ladies, from Martha Washington to Eleanor Roosevelt, is reproduced in full color from color photographs. There are also brief biographies and portraits of the First Ladies. Because of the high cost of producing the volume, it will not be sent free to the

Institution's regular mailing lists but will be on sale in Smithsonian buildings in Washington and may also be purchased by mail.

LIBRARY

A major organizational change in the Smithsonian library was effected during the year when the largest of its branches, the National Museum library, was physically merged with the general library formerly located in the Smithsonian Building, and all major library functions were consolidated. The consolidated library and offices are housed in the Natural History Building. The library received 60,512 publications during the year, mostly by gifts and through exchanges with other institutions and organizations. Noteworthy among the gifts were more than a thousand volumes from the library of the late Gen. John J. Pershing and more than 1,500 publications on stamps from Franklin R. Bruns, Jr., National Museum curator of philately. Nearly 23,000 publications were transferred to the Library of Congress, about 3,000 to the Army Medical Library, and 425 to other Government libraries. From the library's huge collection of duplicates, 11,420 pieces were sent to the United States Book Exchange. At the close of the year the library's holdings totaled 938,740 volumes, including 584,213 in the Smithsonian deposit at the Library of Congress but exclusive of incomplete volumes of serials and separates and reprints from serials.

APPENDIX 1

Report on the United States National Museum

SIR: I have the honor to submit the following report on the condition and operations of the United States National Museum for the fiscal year ended June 30, 1952:

BUILDINGS AND EQUIPMENT

Construction was completed on the conversion of the southwest court in the Arts and Industries Building to a modern storage facility, providing 8,000 square feet of space on the ground, mezzanine, second, and third floors. Outside contracts amounting to $13,582 were let for the construction of wooden frames for storage cases and drawers. The frames of the storage cases will be covered with sheets of thin steel by the Institution's own mechanics.

COLLECTIONS

During the year 607,354 specimens (approximately twice as many as last year) were added to the national collections and distributed among the six departments as follows: Anthropology, 4,852; zoology, 251,290; botany, 62,476; geology, 279,968; engineering and industries, 1,638; and history, 7,130. Most of the accessions were acquired as gifts from individuals or as transfers from Government departments and agencies. The complete report on the Museum, published as a separate document, includes a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 33,184,494.

Anthropology.—A well-documented symbolic wampum belt, which had served as a token of peace and friendship after the eighteenth-century wars between the Seneca and Wyandot (Huron) Indians, was presented by Howard W. Elkinton. An outstanding addition to the archeological collection is the gift by Robert C. Cook of a carved and painted wooden cup, which was referred to as a kero (wooden beer cup) by the Inca Indians.

By a bequest from the late Mrs. Emily V. Taylor, the Museum received a Philadelphia high chest or highboy of unusual design and workmanship of the period 1760–70. A recent noteworthy gift from Mr. and Mrs. Robert C. Pierson, Jr., consists of a complete

miniature theater set of 130 appurtenances of the Javanese puppet show, *wayang*, which they obtained from a puppet master in the Sundanese village of Tjiawi, West Java. Mrs. Hoffman Philip gave a collection of religious objects, weapons, jewelry of silver filigree, and accessories of dress, obtained in Abyssinia by her husband, the late Hoffman Philip, while in the diplomatic service. John Smithson and John Smithson, Jr., presented a George II silver tankard, a George III basting spoon, a traveler's silver wine cup, and two English silver luster teapots.

By transfer from River Basin Surveys, the division of physical anthropology received 78 Indian skeletons selected from 106 burials on Buggs Island in the Roanoke River, near Clarksville, Va. This burial area will be inundated when the dam for the reservoir is completed.

Zoology.—Received during the year were more than 251,000 zoological specimens, obtained in Alaska, Algeria, Anglo-Egyptian Sudan, Arabia, Assam, Australia, Belgian Congo, Bolivia, Borneo, Canada, Colombia, Costa Rica, Cuba, Egypt, French West Africa, Gilbert Islands, Japan, Manchuria, Martinique, México, Mozambique, Northern Rhodesia, Panamá, Philippines, Southern Rhodesia, Turkey, United States, and Venezuela.

The fishery investigations of the United States Fish and Wildlife Service vessel *Oregon* in the Gulf of Mexico, under the leadership of Stewart Springer, resulted in the transfer to the Museum of important and diverse collections of fishes, crustaceans, and other marine invertebrates from the deeper waters of the gulf.

An important accession of 579 mammals, including many forms previously not represented in the collection, from Mount Kinabalu, northern Borneo, was received by transfer from the Army Medical Service Graduate School. With the aid of funds furnished by the Office of Naval Research, Dr. Henry W. Setzer of the Museum staff obtained 141 mammals along the Arctic slope of Alaska. Charles O. Handley, Jr., presented nearly 600 mammals, chiefly from the eastern United States. Several shipments of mammals, totaling 133 specimens, were received from Dr. W. L. Jellison, of the Rocky Mountain Laboratory, United States Public Health Service. A collection of 183 mammals from Labrador was purchased from Dana P. Snyder under the income from the Spencer Fullerton Baird fund. The Biological Surveys collection was increased by 685 specimens, including a series of Alaskan sea otters, of which a family group will be used in the preparation of a habitat group for display in the Natural History Building.

Ornithological field work in northern Colombia by M. A. Carriker, Jr., financed for several years by the income from the W. L. Abbott

fund, came to a close during the past year. The Abbott fund also financed in part the continuance of the Panamanian ornithological survey by Dr. A. Wetmore and his assistant, W. M. Perrygo. The Colombian collection comprised 1,073 bird skins, 9 skeletons, and 8 eggs; the Panamanian, 675 skins, 9 skeletons, 5 alcoholics, 9 eggs, and 1 nest. Worthy of mention this year are the 379 bird skins from Mozambique received from Donald W. Lamm, the gift of 675 skins of birds from Colombia by Father Antonio Olivares, and the presentation by the Musée du Congo Belge, Tervueren, of 2 specimens of the Congo peacock, *Afropavo congensis*. The E. J. Brown bequest provided funds for the purchase of 60 bird skins from the Algerian Sahara. From the Arctic Health Research Center the Museum received by transfer 302 skins of birds from northern Alaska which had been collected by Dr. Laurence Irving and his assistants.

A large collection, comprising 1,165 reptiles and amphibians collected by Dr. R. E. Kuntz in Egypt and adjoining countries, was received from the Naval Medical Research Unit No. 3, and 75 reptiles and amphibians from Mount Kinabalu, northern Borneo, were transferred to the Museum from the Army Medical Service Graduate School. Types and paratypes of new forms of salamander, toad, and snake were received, respectively, from M. B. Mittleman, Ottys Sanders, and W. Auffenberg.

The generous gift of 16,417 fishes from eastern United States by Dr. E. A. Lachner, associate curator, represents the largest single accession received by the division of fishes during the year. Dr. Lachner, with the assistance of William T. Leapley, also obtained more than 15,000 fishes, as well as crustaceans, insects, amphibians, and reptiles, in the southeastern States. As exchanges there were obtained from the Museum of Comparative Zoology, through William C. Schroeder, 104 holotypes, cotypes, and paratypes of fishes; from Dr. George Moore, Oklahoma A. & M. College, 5,115 named freshwater fishes from the Arkansas and Red Rivers; from Dr. J. J. Hoedeman, Zoologisch Museum, Amsterdam, 11 paratypes of 3 West Indian species; from Dr. N. B. Marshall, British Museum of Natural History, 5 paratypes; and from Drs. J. Böhlke and John C. Briggs, of Stanford University, 7 paratypes of new species of fishes being described by them. Dr. Clark Hubbs, University of Texas, sent a gift of 83 fishes, and Cecil Miles, Ministeria de Agricultura, Bogotá, Colombia, donated the holotype of a new pomadasid fish from the Colombian Caribbean. Through Stewart Springer, Harvey R. Bullis, Jr., Isaac Ginsburg, and Dayton Lee Alverson, the United States Fish and Wildlife Service transferred 1,154 fishes this fiscal year. Dr. H. B. Goodrich, Wesleyan University, Middletown, Conn., returned

about 1,400 fish specimens in their original jars which were sent to Wesleyan University in the early 1880's by Dr. G. Brown Goode.

The division of insects received as its most important accession the collection of O. L. Cartwright of approximately 6,000 miscellaneous insects, a large portion of which was made on the grounds of the Inter-American Institute of Agricultural Sciences, Costa Rica. Another noteworthy accession comprised about 4,300 Neotropical bugs which were donated by Dr. Luis F. Martorell, of the agricultural experiment station, University of Puerto Rico, and Dr. John S. Caldwell, of Centerville, Ohio. By transfer from the Department of Agriculture the division acquired nearly 2,000 insects from Alaska, collected by Dr. R. I. Sailer.

As gifts, the division of marine invertebrates received more than 10,979 specimens of barnacles and other marine invertebrates, as well as publications, notes, and lantern slides from the collections of the late Dr. J. Paul Visscher, presented by Mrs. J. Paul Visscher and children, Cleveland, Ohio; and from Dr. Stillman Wright, Washington, D. C., more than 533 lots of copepods and other fresh-water plankton from South America. Dr. E. A. Lachner collected for the Museum 247 crayfishes and 2 shrimps from the southern United States. Through David C. Nutt, the Museum received 1,387 specimens of miscellaneous marine invertebrates collected by the *Blue Dolphin* Expedition along the coast of Labrador. As exchanges, through Dr. H. B. Goodrich there were added to the collections more than 2,141 specimens of marine invertebrates from Wesleyan University; and from the Rijksmuseum van Natuurlijke Historie, Leiden, Holland, through Dr. L. B. Holthuis, 10 paratypes of crayfishes from New Guinea, and 4 paratypes and 19 other specimens of fresh-water shrimps from Surinam. By transfer, more than 1,410 miscellaneous invertebrates were acquired from the United States Navy Arctic Research Laboratory, through J. Böhlke.

The largest accession received this fiscal year in the division of mollusks consisted of 22,000 specimens collected by Dr. Joseph P. E. Morrison in the area from Pennsylvania to Virginia, west to Missouri. Among the outstanding gifts received were 1,380 marine mollusks, largely from western Australia, presented by Mr. and Mrs. James A. Grigg; 264 marine mollusks from the Red Sea, a gift from Sozon Vatikiotis; 55 specimens of rare Japanese marine mollusks from the Kyoto University through Dr. Tadashige Habe. There were received in exchanges from the Museum of Comparative Zoology, Harvard University, 1,543 mollusks; and from the Institut Français d'Afrique Noire of Dakar, French West Africa, 169 marine mollusks. Noteworthy also was a transfer of several rare shells from the Gulf of

Mexico by the Fish and Wildlife Service through Stewart Springer and Harvey R. Bullis, Jr.

The most outstanding accession of echinoderms comprised 26 specimens from the Gulf of Mexico received by transfer from the Fish and Wildlife Service through Stewart Springer.

Botany.—Jason R. Swallen, head curator of the department, collected 1,764 grasses in Honduras; Dr. E. H. Walker obtained 6,356 plants in the Ryukyu Islands and Japan on his botanical survey of Okinawa and adjacent islands; 232 miscellaneous specimens from Minnesota and California were collected for the Museum by C. V. Morton; and E. P. Killip added to the collections 1,367 specimens, mostly from the Florida Keys and Cuba. Gifts included 1,419 specimens from the Arctic Institute of North America, collected by L. A. Spetzman in Alaska; 1,436 specimens from the Museo de Historia Natural "Javier Prado," Lima, Perú, collected by Dr. Ramón Ferreyra; 1,133 plants of Florida from the Archbold Biological Station, Lake Placid, Fla., collected by L. J. Brass; Oscar L. Haught, Littleton, W. Va., presented 1,494 specimens of Colombian plants, representing the most recent results of his productive field work in South America. In exchange, 2,072 specimens, mostly phanerogams and cryptogams of unusual historical interest were received from the Conservatoire et Jardin Botaniques, Geneva, Switzerland; 1,137 miscellaneous Canadian plants from the Department of Agriculture, Ottawa, Canada; 800 plants from the New York Botanical Garden, collected in Nyasaland by L. J. Brass; 982 specimens from the University of California collected by Annie M. Alexander and Louise Kellogg; 659 specimens from V. L. Kamarov, of the Botanical Institute of the Academy of Sciences of the Union of Soviet Socialist Republics, representing various collections from western Siberia; and 515 plants from the Instituto de Botánico of the Universidad Nacional de Tucumán, Argentina, collected in Patagonia by H. Sleumer. The National Arboretum transferred to the Museum 567 specimens from Colombia and Ecuador.

Geology.—Five new minerals not formerly represented in the mineralogical collections were received as gifts and three as exchanges.

The Roebling bequest provided funds for the purchase of a large gem spodumene crystal from Brazil, a fine topaz crystal from Colorado, and several etched masses of gem-quality beryl from Brazil. A pink octahedron of fluorite on smoky quartz from Switzerland, wolframite on cassiterite from Bolivia, and vanadinite from México were purchased under the Canfield fund. A 53.8-carat spessartite garnet from Brazil was purchased under the Chamberlain fund for the gem collection. Mrs. C. Drage, in memory of her father, Dr. Frank Wigglesworth Clarke, for many years honorary curator of minerals in this Museum, presented a fine cat's-eye chrysoberyl from Ceylon.

Dr. Stuart H. Perry donated five meteorites. Of these, three from the following localities are new to the Museum collections: Dayton, Ohio; Loreta, Baja California; and Keen Mountain, Va.

A rare Japanese rock, miharaite, was received in exchange from the National Science Museum, Tokyo, Japan.

Important accessions were received as gifts, exchanges, or transfers by the division of invertebrate paleontology and paleobotany, including 75 type specimens of Foraminifera from Trinidad from Dr. P. Bronnimann; the types of 14 Cretaceous Foraminifera and 39 Paleocene Radiolaria from Dr. D. L. Frizzell; 58 type Foraminifera from the Lower Cretaceous of Algeria from Dr. A. ten Dam; 51 types of Devonian ostracods from Iowa from Lee B. Gibson; and 90 types of Mississippian crinoids from Dr. L. R. Laudon.

During the year 288 crinoids, including a number of types, were purchased under the Springer fund from Harrell L. Strimple. Income from the Walcott fund provided funds for paleontological field work which resulted in considerable collections from Alabama, Ohio, Pennsylvania, southern Appalachians, Tennessee, Texas, and Virginia.

Transfers from the United States Geological Survey include 1,800 types of Ozarkian and Canadian cephalopods described by A. K. Miller, Dr. E. O. Ulrich, and others; and 2 additional large lots of types of cephalopods. The Office of Naval Research transferred approximately 250,000 fresh-water Mesozoic and Cenozoic mollusks collected by Dr. T. C. Yen.

By exchange the Museum acquired Foraminifera from Algeria, Aruba Island, Estonia, Gotland, Germany, Austria, and Japan, as well as invertebrate fossils from Germany, Holland, Sicily, Australia, Tasmania, and Canada.

A representative collection of Oligocene and Miocene mammals from the Canyon Ferry Reservoir area in Montana, a Cretaceous mosasaur from South Dakota, and a Paleocene pantolambdid from North Dakota were included in the collections obtained by Dr. T. E. White and transferred by the River Basin Surveys. Significant collections transferred by the United States Geological Survey included fish remains from the Paraná Basin of Brazil, mastodont and other remains from the Ringold formation in Washington, and a variety of fossils from Eocene and Oligocene localities in Wyoming and Montana. Paleontological field work by Dr. C. L. Gazin under the Walcott fund resulted in the collection of nearly 270 small mammals in several lower Eocene and lower Oligocene deposits of western Wyoming.

Engineering and industries.—Two examples of labor-saving machines that served the farmer during the nineteenth century were received as gifts. One of these, a crank-operated fanning mill for separating chaff from grain and hulls from beans, which was used in

West Virginia about 75 years ago, was received from Arden Wilson. The other, a 2-row corn planter dated about 1860, was presented by Warren Hammond. A beautiful round tablecloth, 10 feet 10 inches in diameter, made of linen eyelet lace and hand-made filet medallions, was acquired as a bequest from Lena L. Jones. Eight pieces of American embroidery and drawn work of the eighteenth and nineteenth centuries were presented by Mrs. Helen F. McMickle. The United States Forest Products Laboratories transferred to the section of wood technology 17 woods from eastern United States and México and 8 new wood products resulting from laboratory research. Joseph L. Stearns presented 25 woods from Indochina.

An oil engine built before 1878 by George B. Brayton, American inventor and manufacturer, was presented by Brown University at the suggestion of Professor Emeritus William H. Kenerson. The engine, which was purchased by the university to drive an arc-light dynamo, is a 1-cylinder kerosene beam engine weighing about 1,500 pounds. Stephen C. Van Fleet presented a collection of early radio apparatus, including a complete 10-watt transmitter of 1922–23, a Jenkins Radiovisor of 1930, and a See-All Television Scanner.

Russell T. Limbach made a series of stones and prints to illustrate the making of a lithograph. Several notable prints, including two fifteenth-century niello prints, "Christ on the Cross" and "Portrait of a Pope," were purchased through the Dahlgreen fund. The section of photography received from Dr. Lowrain McCrea his original cytoscope camera. Additions to the print collection include "Awakening," an engraving by Gabor Peterdi, and "Furnace," a wood engraving by Charles Quest, both purchased under the Dahlgreen fund, and "Winter," a lithograph by Russell T. Limbach, the gift of the artist. Fifteen prints by Wood Whitesell and 14 prints by A. Aubrey Bodine were presented by the artists for the photographic print collection. A keratometer or opthalmometer designed to measure the amount of corneal astigmatism was received from Dr. Arthur O. Morton.

History.—A walnut chest of drawers once owned by Jonathan Edwards, New England scholar and theologian (1703–1758), came as a gift from Louise Taylor Andrews to the division of civil history.

During the year an unusual group of ship models, including the *Bon Homme Richard*, frigate *Constitution*, sloop *Kearsarge*, cruiser *Olympia*, cruiser *Brooklyn*, destroyer *Manley*, and heavy cruiser *Wichita* were transferred by the Department of the Navy for incorporation in the hall of naval history.

As a bequest, the division of military history received the saddles and horse equipment of Gen. John J. Pershing, and his son, Francis Warren Pershing, presented the General's library comprising some 1,800 volumes.

The heirs of Edward C. Tarbell (1862–1938) gave 12 medals, which had been awarded to this American artist, to the division of numismatics. The Reverend Hugh Miller collection of 544 oriental coins and 110 Korean amulets was received as a transfer from the Treasury Department.

The philatelic collections were increased during the year by gifts from the Universal Postal Union, the United States Post Office Department, and agencies of other governments. The dies of George F. Nesbitt & Co. (1853–70) which were used in the production of early United States envelopes were presented by B. H. Homan, Jr., of New York City. The library of this division was increased by important gifts from the Essay-Proof Society, the Bureau Issues Association, and Scott Publications, Inc.

EXPLORATION AND FIELD WORK

Through the cooperation of the National Geographic Society and the United States Air Force, Frank M. Setzler made a survey of the human and animal effigies located along the Colorado River near the towns of Blythe and Ripley, Calif., and near Topock, Ariz. During the year Dr. W. W. Taylor, Jr., directed six trips for the prehistoric Pueblo ecology survey in the Four Corners district of Arizona, Utah, Colorado, and New Mexico. As the representative of the Smithsonian Institution, H. W. Krieger attended the Fifth Interamerican Congress of Municipal History at Ciudad Trujillo, Dominican Republic, and subsequently revisited and examined the site of the first planned settlement in the New World, which had been established by Christopher Columbus in December 1493, on his second voyage, at La Isabella. A Neosha grant enabled John C. Ewers to continue his field studies of Blackfoot crafts on reservations in Alberta, Canada, and Montana. Dr. Waldo R. Wedel was detailed to the Smithsonian River Basin Surveys for an archeological field investigation of the Oahe Reservoir area along the Missouri River in Stanley County, S. Dak.

Field work of recent years on the distribution and variation of the bird life of the Republic of Panamá, by Dr. Alexander Wetmore, Secretary, assisted by Watson M. Perrygo, of the United States National Museum, was continued during February and March. Following several days occupied with business matters relating to the Canal Zone Biological Area, Dr. Wetmore crossed to the Caribbean side of the Isthmus where his field outfit, through the cooperation of the United States Air Force at Albrook Field, was transported by truck to the road end at the mouth of the Río Salud, west of the Canal Zone. Here porters were hired for transport along the beach trail to the mouth of the Río Indio in the western edge of the Province of Colón. The Río Indio is one of the longest rivers in western Panamá, as it

heads in the mountains to the north of El Valle de Antón, where collections were made on the headwaters last year. Field work begun on February 14 covered the coastal area inland to Chilar, and on February 21 the party moved inland to the head of canoe navigation at El Uracillo in northern Coclé Province. After two weeks' work there, and a further week at the mouth of the river, work terminated on March 12.

The region is still one of forest, though clearing and cultivation are going forward rapidly. Vegetation was heavy, and although this was the dry season there were daily rains except in the immediate area of the coast. The collections obtained give much valuable data on distribution, particularly since the region has been unknown ornithologically.

Following this, the party worked from March 14 to 24 on Taboga Island, opposite the Pacific end of the Panama Canal, a region as dry as the Caribbean area was humid. The avifauna is extremely limited but has yielded interesting and unexpected information that will be embodied in a short paper covering Taboga and the adjacent islands of Taboguilla and Uravá, to be published during next fiscal year in the Smithsonian Miscellaneous Collections.

The ornithological survey of Colombia, carried on for several years through M. A. Carriker, Jr., opened this season at the end of January in the southern part of the republic near Puracé. Operations in the main covered regions accessible from Popayán, with one excursion to the lowland areas in the Territory of Caquetá. The work has been highly successful, and this season completes the survey. The specimens obtained this year from the Departments of Cauca and Huila will be especially important in assistance in the study of the earlier collections from farther north.

The detail of Dr. David H. Johnson to the Army Medical Service Graduate School research unit, engaged in a study of mammalian and other hosts involved in the transmission of scrub typhus in the vicinity of Mount Kinabalu, British North Borneo, was continued from June to August 1951. The ecological survey of the mammals of the Arctic slope of Alaska, commenced by Dr. Henry W. Setzer under a cooperative arrangement with the Arctic Research Laboratory, Office of Naval Research, Point Barrow, Alaska, was concluded in August 1951. Charles O. Handley, Jr., in continuation of his studies on the mammals of eastern United States, especially of the southern Appalachian highlands, conducted field work in the Great Smoky Mountains National Park during April 1952. On June 15, 1952, Mr. Handley sailed from New York as a member of an expedition, sponsored and led by Laurence K. Marshall, of Cambridge, Mass., which will be engaged

in anthropological and zoological field work over a period of several months in the Kalahari Desert region of South-West Africa.

During April 1952, Dr. E. A. Lachner and William T. Leapley investigated the ecology and life history of fresh-water fishes in the streams draining the mountain and Piedmont plateau sections of the Atlantic slope from Virginia southward to Georgia and thence westward in the streams of the Gulf coast drainage to Alabama. After crossing the Mississippi flatlands, field work was continued in the river systems of northeastern Texas and Oklahoma. On the return trip collections were made in the streams of the Ozark uplands in Arkansas and also in those of Kentucky. A collecting trip which extended from near Shreveport, La., to Kerrville and Laredo, Tex., and thence down the Rio Grande Valley to Padre Island and eastward along the Gulf coast, to procure insects prevalent only in the fall months, was made by Oscar L. Cartwright during September–October 1951. At the request of the Pacific Science Board, National Research Council, Dr. Joseph P. E. Morrison of the division of mollusks was detailed early in June 1952 to make an ecological survey of Raroia Atoll in the Tuamotu Islands.

From February to May 1952, Dr. Lyman B. Smith, through the cooperation of the Rockefeller Foundation and various Brazilian agencies, notably the Serviço Nacional de Malaria, the Herbario "Barbosa Rodrigues," the Museu Nacional, the Jardin Botânico do Rio de Janeiro, and the Instituto de Botânico do São Paulo, carried on a field study of the relation of the Bromeliaceae to malarial control in eastern Brazil between Pará and Santa Catarina. Dr. Egbert H. Walker returned to Washington, D. C., on September 30, 1951, after the completion of the botanical field work on the Ryukyu Islands sponsored by the Pacific Science Board, National Research Council. In October 1951, Jason R. Swallen arrived in Honduras where, as the guest of the Escuela Agrícola Panamericana, he was provided transportation that enabled him to collect grasses in the pine forests, open grasslands, and cloud forests, principally in the Departments of Morazán and El Paraíso.

During the year seven field trips were made for the purpose of collecting fossils and studying geological strata. A. L. Bowsher and William T. Allen, with the assistance of members of the staff of the New Mexico Bureau of Mines, assembled invertebrate fossils from the Mississippian, Pennsylvanian, and Permian strata in the Sacramento Mountains, N. Mex. In the latter half of October, Dr. G. A. Cooper joined Dr. B. N. Cooper, of the Virginia Polytechnic Institute, in a study of the facies relationships of nonmarine Ordovician beds in the southern Appalachians. Late in October 1951, A. L. Bowsher accom-

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panied Dr. Edwin Kirk, of the United States Geological Survey, to Alabama and Tennessee to obtain Mississippian crinoids. Dr. A. R. Loeblich, Jr., secured foraminiferal samples from the uppermost Lower Cretaceous and basal Upper Cretaceous beds in northern Texas. Mississippian and Pennsylvanian invertebrate fossils were collected in northern Ohio and western Pennsylvania by A. L. Bowsher and William T. Allen in April 1952. Dr. C. L. Gazin continued his investigation, during the summer of 1951, of the mammalian faunal horizons of the lower Eocene Knight formation in the Green River or Bridger basins of southwestern Wyoming and the lower Oligocene deposits in the Wind River basin. During October 1951, Dr. David H. Dunkle examined briefly reported occurrences of Cretaceous fishes at Xilitla, San Luis Potosí, and Tlaxiaco, Oaxaca, México.

A grant of funds from Edwin A. Link, of Binghamton, N. Y., enabled Mendel L. Peterson to join Mr. Link at Marathon, Fla., and participate in a survey of seventeenth- and eighteenth-century Spanish and British ships which had been wrecked on the reefs between Tavernier Key and Vaca Key, and on West Sambo Reef lying off Key West. The 65-ton diesel-powered boat, *Sea Diver*, owned and equipped by Mr. Link for this survey, afforded a base for diving operations. Cannon barrels and balls, iron hull fittings, iron nails, cast-iron ingots, and fragments of wood hulls were recovered from the wrecks on these reefs.

VISITORS

During the fiscal year 1952 there were 3,103,651 visitors to the Museum buildings, an increase of 486,425 over the attendance for 1951. The average daily number of visitors was 8,767. On one day, May 31, 1952, 50,329 visitors were recorded. Attendance records for the three buildings show the following numbers of visitors: Smithsonian Building, 661,278; Arts and Industries Building, 1,587,910; and Natural History Building, 854,463. April 1952 was the month of the largest attendance with 450,120 visitors; May 1952 was the next largest with 423,103; and August 1951 was third with 392,177. For the last 4 months of the fiscal year, March to June inclusive, a record was kept of groups of school children visiting the Museum buildings. During this 4-month interval, 159,784 children in 4,289 groups were recorded.

CHANGES IN ORGANIZATION AND STAFF

Dr. Paul L. Illg, associate curator, division of marine invertebrates, resigned on March 13, 1952, to accept a position in the department of zoology of the University of Washington at Seattle. On October 19, 1951, Eugene J. Fite, assistant curator, division of graphic

arts, transferred to the Federal Security Agency. George S. Thomas, associate curator, division of medicine and public health, resigned August 31, 1951, to enter private business. The vacancy in the section of manufactures and agricultural industries was filled on September 17, 1951, by the appointment of Edward C. Kendall as associate curator.

Respectfully submitted.

REMINGTON KELLOGG, *Director.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 2

Report on the National Gallery of Art

SIR: I have the honor to submit, on behalf of the Board of Trustees, the fifteenth annual report of the National Gallery of Art, for the fiscal year ended June 30, 1952. This report is made pursuant to the provisions of section 5 (d) of Public Resolution No. 14, Seventy-fifth Congress, first session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION

The statutory members of the Board of Trustees of the National Gallery of Art are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio. The five general trustees continuing in office during the fiscal year ended June 30, 1952, were Samuel H. Kress, Ferdinand Lammot Belin, Duncan Phillips, Chester Dale, and Paul Mellon. The Board of Trustees held its annual meeting on May 6, 1952. Samuel H. Kress was reelected President and Ferdinand Lammot Belin Vice President, to serve for the ensuing year. Donald D. Shepard continued to serve during the year as Advisor to the Board.

All the executive officers of the Gallery continued in office during the year:

Huntington Cairns, Secretary-Treasurer.
David E. Finley, Director.
Harry A. McBride, Administrator.
Huntington Cairns, General Counsel.
John Walker, Chief Curator.
Macgill James, Assistant Director.

The three standing committees of the Board, as constituted at the annual meeting May 6, 1952, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Fred M. Vinson, Chairman.
Samuel H. Kress, Vice Chairman.
Ferdinand Lammot Belin.
Secretary of the Smithsonian Institution, Dr. Alexander Wetmore.
Paul Mellon.

FINANCE COMMITTEE

Secretary of the Treasury, John W. Snyder, Chairman.
Samuel H. Kress, Vice Chairman.
Ferdinand Lammot Belin.
Chester Dale.
Paul Mellon.

ACQUISITIONS COMMITTEE

Ferdinand Lammot Belin, Chairman.
Duncan Phillips.
Chester Dale.
Paul Mellon.
David E. Finley.

At the annual meeting on May 6, 1952, the Board of Trustees proposed an amendment to section 5, article VI of the bylaws of the Trustees' "Constitution of Acquisitions Committee" reducing the number of ex officio members from three to two and increasing the elected members from two to three. The amendment provided further that the Vice President of the Gallery shall be Chairman of the Acquisitions Committee. On June 10, 1952, the Board of Trustees adopted the proposed amendment and elected Paul Mellon to fill the vacancy existing on the Committee as the result of the amendment.

PERSONNEL

On June 30, 1952, the Government employees on the staff of the National Gallery of Art numbered 301, as compared with 308 employees as of June 30, 1951. The United States Civil Service regulations govern the appointment of employees paid from appropriated public funds.

APPROPRIATIONS

For the fiscal year ended June 30, 1952, the Congress of the United States appropriated for the National Gallery of Art $1,240,000 to be used for salaries and expenses in the operation and upkeep of the Gallery, the protection and care of works of art acquired by the Board of Trustees, and all administrative expenses incident thereto as authorized by section 4 (a) of Public Resolution 14, Seventy-fifth Congress, first session, approved March 24, 1937 (50 Stat. 51). This sum includes the regular appropriation of $1,154,000 and a supplemental appropriation of $86,000. The supplemental appropriation was necessitated by increased pay costs authorized by Public Law 201, Eighty-second Congress, approved October 24, 1951.

From these appropriations the following expenditures and encumbrances were incurred:

Personal services	$1,096,425.00
Printing and reproduction	4,528.75
Supplies, equipment, etc	137,863.11
Unobligated balance	1,183.14
Total	1,240,000.00

ATTENDANCE

During the fiscal year 1952 there were 1,522,596 visitors to the Gallery, an average daily attendance of about 4,183. This compares with 1,503,148 visitors during 1951, an increase of 19,448. Since March 17, 1941, when the Gallery was opened to the public, to June 30, 1952, there have been 20,284,013 visitors.

ACCESSIONS

During the fiscal year the Gallery received 1,891 accessions as gifts, loans, or deposits. Most of the paintings and a number of the prints were placed on exhibition.

GIFTS

PAINTINGS

The Board of Trustees on July 11, 1951, accepted two paintings: "Right and Left" by Winslow Homer and "John James Audubon" by John Woodhouse Audubon, both gifts from the Avalon Foundation. On the same date the Board accepted from E. J. L. Hallstrom 10 paintings by Audubon: Farmyard Fowls, Black-footed Ferret, Bull, Arctic Hare, Weasel, Long-tailed Red Fox, Sharp-tailed Sparrow, Orchard Oriole, Yellow Warbler, and Arctic Three-toed Woodpecker. On August 24 the Board accepted for a National Portrait Gallery from an anonymous donor the portrait of Gen. George C. Marshall by Thomas Stephens. On December 5 the Board of Trustees accepted "Portrait of a Man and Boy" by Tintoretto, the gift of Samuel L. Fuller, and "Gypsy Girl with Mandolin" by Corot, the gift of Count Pecci-Blunt. Also on this date the Board accepted a portrait of John Cardinal McCloskey by Healy from Miss Elizabeth McCloskey Cleary. On December 17 the Board accepted the painting "Rape of Proserpine" by Turner from Mrs. Watson B. Dickerman. On January 15, 1952, the Board accepted from the Avalon Foundation the portrait of Alexander Hamilton by Trumbull. The Board accepted on May 6 the gift of two paintings from Duncan Phillips: "Singing Party" by Hogarth and "Allegorical Landscape" by a follower of Parmigianino. On this same date the Board received the portrait of Mrs.

Mathilde Townsend Welles by Sargent, the bequest of Mrs. Welles. The Board received two portraits by Alvan Clark, "Thomas Whittemore" and "Lovice C. Whittemore," from the Thomas Whittemore estate.

SCULPTURE

On December 5, 1952, the Board of Trustees accepted from Lessing J. Rosenwald a group of 15 bronzes by Daumier.

PRINTS AND DRAWINGS

On July 11, 1951, the Board of Trustees accepted from E. J. L. Hallstrom 18 miscellaneous prints by Audubon. On October 16 the Board accepted from Lessing J. Rosenwald a group of 244 prints and drawings and a group of 1,006 historical portrait prints, to be added to his gift to the Gallery. On the same date the Board accepted from Mrs. Andrew Carey 23 prints and drawings, and from Paul Rosenberg a drawing for the painting "Mme. Moitessier" by Ingres. The Board on December 5 accepted 202 prints and drawings from Lessing J. Rosenwald, and on December 17 the Board approved the addition of 41 prints by Alphonse Legros to the gift of George Matthew Adams.

EXCHANGE OF WORKS OF ART

On October 16, 1951, the Board of Trustees accepted the offer of Lessing J. Rosenwald to exchange the Rembrandt etching "The Presentation in the Temple" for a superior impression of the same work.

WORKS OF ART ON LOAN

During the fiscal year 1952 the following works of art were received on loan by the National Gallery of Art.

From	*Artist*
C. S. Gulbenkian, Lisbon, Portugal:	
Eight gold medallions	Greco-Roman, third century A. D.
Chester Dale, New York, N. Y.:	
Lady Liston	Stuart.
The Lone Tenement	Bellows.
The Hunter	J. L. David.
The Laundresses	Steinlen.
Houses of Parliament	Monet.
New York Street Scene in Winter	Henri.
Portrait of a Lady in Red	Theus.
Portrait said to be Mrs. Thomas Palmer	Feke.
The Artist's Garden	Blakelock.
Black Hawk	C. King.
Spring Woods	Ranger.
Boy on the Rocks	Rousseau.
The Windmill	Ryder.
Moonlight	Weir.

From	*Artist*
Chester Dale, New York, N. Y.—Continued	
The Basket	Dufy.
View of Fez	Dufy.
The Communicant	Carriere.
Seated Nude	Matisse.
In the Rain	Hassam.
Seated Nude	Hassam.
Cafe Scene	Rouault.
Nude with Raised Arms	Rouault.
Oranges and Marigolds	Vallotton.
Basque Landscape	Oudot.
Nude Woman with Flowers and Fruit	Braque.
Nude Woman with Fruit	Braque.
Peonies	Braque.
Still Life: The Table	Braque.
Still Life: le Jour	Braque.
Conversation among the Ruins	de Chirico.
Harlequin	Derain.
Woman in an Armchair	Derain.
Head of a Girl	Derain.
Still Life	Derain.
The Old Bridge	Derain.
Flowers in a Vase	Derain.
Head of a Woman	Derain.
Still Life	Dufresne.
Judgment of Paris	Dufresne.
Nude, Reclining	Dufy.
Saint Janet	Dufy.
Vendor of Ices	Gromaire.
Woman with Mirror	Leger.
In the Park	Laurencin.
The Big Cloud	Lurcat.
Odalisque with Raised Arms	Matisse.
Woman with Exotic Plant	Matisse.
Les Gorges du Loup	Matisse.
Still Life: Apples on Pink Table Cloth	Matisse.
The Plumed Hat	Matisse.
The Musician	Marcoussis.
Leon Bakst	Modigliani.
Mme. Amedee (Woman with Cigarette)	Modigliani.
Adrienne (Woman with Bangs)	Modigliani.
Woman with Red Hair	Modigliani.
Gypsy Woman with Baby	Modigliani.
The Market	Oudot.
The Lovers	Picasso.
The Tragedy	Picasso.
The Gourmet	Picasso.
Two Youths	Picasso.
Juggler with Still Life	Picasso.
Family of Saltimbanques	Picasso.
Still Life	Picasso.
Classical Head	Picasso.
Mme. Picasso	Picasso.

From	Artist
Chester Dale, New York, N. Y.—Continued	
Portrait of a Boy	Soutine.
The Stairway, Belleville	Quizet.
Bathers	Tondu.
Marizy-Sainte-Genevieve	Utrillo.
Church of Saint-Severin	Utrillo.
Vase of Flowers	Vlaminck.
The River	Vlaminck.
Still Life with Lemons	Vlaminck.
Old Port of Marseille	Vlaminck.
Carrieres-Saint-Denis	Vlaminck.
U. S. Department of State	
(Charles Loeser Bequest):	
Still Life of Apples	Cezanne.
Still Life with Skull	Cezanne.
La Sainte Victoire	Cezanne.
House Beside a Lake	Cezanne.
The Forest	Cezanne.
The Hill	Cezanne.
Boathouse on the River	Cezanne.
Landscape with a Tower	Cezanne.
Mrs. William C. Johnson, Frederick, Md.:	
Portrait of Monroe	Vanderlyn.
Patrick Tracy Jackson, Cambridge, Mass.:	
Patrick Tracy	Trumbull.
Walter C. B. Morse, Glenwood, Md.:	
Francis Goodloe Harper	Samuel F. B. Morse.
Robert Woods Bliss, Washington, D. C.:	
23 objects of Pre-Columbian art.	

LOANED WORKS OF ART RETURNED

The following works of art on loan were returned during the fiscal year 1952:

To	Artist
Chauncey Stillman, New York, N. Y.:	
A Halberdier	Pontormo.
Mrs. Robert Brookings, Washington, D. C.:	
Isabel Valle	Sargent.
Isabella H. Sargeant	Sargent.

WORKS OF ART LENT

During the fiscal year 1952 the Gallery lent the following works of art for exhibition purposes:

To	Artist
American Federation of Arts (Berlin Exhibition):	
George Washington (Vaughan-Sinclair)	Stuart.
Atlanta Art Association, High Museum, Atlanta, Ga.:	
Alexander Hamilton	Trumbull.
Jane Browne	Copley.
Williamina Moore	Feke.

To	*Artist*
Atlanta Art Association, High Museum, Atlanta, Ga.—Continued	
John Philip de Haas	Peal, C. W.
Matilda Cruger	Stuart.
George Pollock	Stuart.
Mrs. George Pollock	Stuart.
Robert Thew	Stuart.
Luke White	Stuart.
Ann Hopkinson	Sully.
Francis Hopkinson	Sully.
Self Portrait	West.
Mary Walton Morris	Wollaston.
William Rickart	Stuart.
William S. Mount	Elliott.
Josias Allston	Theus.
Thomas Paine	Jarvis.
Henry Clay	J. J. Audubon.
Henry Laurens	Copley.
Andrew Jackson	Ralph Earl.
General Moultrie	Peale, C. W.
Pocahontas	British School.
Worcester Art Museum, Worcester, Mass.:	
A Young Woman (Costume Study)	Durer.
National Audubon Society, New York, N. Y.:	
Bull	Audubon.
Arctic Hare	Audubon.
Portraits, Inc., New York, N. Y.:	
Andrew W. Mellon	Oswald Birley.
Phillips Gallery, Washington, D. C.:	
Storm over Taos (water color)	Marin.
Echo Lake (water color)	Marin.
Woodlawn Association, Woodlawn, Va.:	
William Thornton	Stuart.
Mrs. William Thornton	Stuart.
George Washington at Princeton	Polk.
Senate House Museum, Kingston, N. Y.:	
Zachariah Schoonmaker	Vanderlyn.
The Return of Rip Van Winkle	Quidor.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year 1952:

American Paintings from the Collection of the National Gallery of Art. Continued from previous fiscal year through September 10, 1951.

Audubon Paintings and Prints from the Collection of the National Gallery of Art. September 23 through October 28, 1951.

Index of American Design. Water-color renderings. November 4 through November 25, 1951.

Fifteenth-century Graphic Art. From the Rosenwald Collection, including woodcuts, broadsides, a famous printed textile, block books, and early illustrated woodcut books. December 2, 1951, through February 3, 1952.

French Paintings. Lent to the National Gallery of Art by Capt. Edward Molyneux of France. March 2 through May 11, 1952.

Lithographs by Toulouse-Lautrec. From the Rosenwald Collection. Opened May 18, 1952.

French Eighteenth-century Aquatints. From the Widener Collection. Opened June 3, 1952.

The following exhibitions were displayed in the cafeteria corridor of the National Gallery of Art during the fiscal year 1952:

Engravings by William Blake. Gift of anonymous donor. Continued from previous fiscal year through January 20, 1952.

Etchings by Jacques Callot. The Rosenwald Collection. January 22 through April 19, 1952.

Etchings and drypoints by Alphonse Legros. The George Matthew Adams Collection. Opened April 19, 1952.

TRAVELING EXHIBITIONS

Rosenwald Collection.—Special exhibitions of prints from the Rosenwald Collection were circulated to the following places during the fiscal year:

U. S. Department of State Exhibition in Germany:
Contemporary American Prints.
August 1951–January 1952.

University of Alabama, University, Ala.:
Exhibition of Picasso Prints.
September–October 1951.

University of Miami, Coral Gables, Fla.:
English Water-color Exhibition.
October 1951.

Maryville College, Maryville, Tenn.:
French Nineteenth-century Exhibition.
October 1951.

Pasadena Art Institute, Pasadena, Calif.:
Mary Cassatt Prints.
October 1951.

University of Pittsburgh, Pittsburgh, Pa.:
Selections from the Rosenwald Collection.
October 1951–January 1952.

Cleveland Museum of Art, Cleveland, Ohio:
Lyonel Feininger Prints.
October–November 1951.

Fogg Museum of Art, Cambridge, Mass.:
Cranach Woodcuts.
November 1951.

Carnegie Institute, Department of Fine Arts, Pittsburgh, Pa.:
Old Master Drawings, French Exhibition.
November–December 1951.

Worcester Art Museum, Worcester, Mass.:
The Practice of Drawing, Old Master Drawings.
November 1951–January 1952.

Philadelphia Art Alliance, Philadelphia, Pa.:
Beckmann Prints.
December 1951.

Carnegie Institute, Department of Fine Arts, Pittsburgh, Pa.:
Vollard Exhibition.
January 1952.
Milwaukee Art Institute, Milwaukee, Wis.:
Blake Exhibition.
January 1952.
Birmingham Museum of Art, Birmingham, Ala.:
Vollard Exhibition.
February–March 1952.
Philadelphia Museum of Art, Philadelphia, Pa.:
100 Masterpieces of the Print.
February–March 1952.
Minneapolis Institute of Arts, Minneapolis, Minn.:
Water Colors by Old Masters.
April 15–June 15, 1952.
Wesleyan University Art Department, Middletown, Conn.:
1 Picasso—Picasso-Klee Exhibition.
May 12–30, 1952.
Busch-Reisinger Museum, Harvard University, Cambridge, Mass.:
"Durer, Before and After," Sixteenth-century Prints.
May 9–June 19, 1952.
U. S. Department of State, Washington, D. C.:
4 American Contemporaries for Lugano.
The White House, Washington, D. C.:
Permanent loan exhibition of 21 prints.

Index of American Design.—During the fiscal year 1952, 38 traveling exhibitions of original water-color renderings of this collection, with 78 bookings, were sent to the following States and countries:

State	*Number of Exhibitions*
Alabama	3
Arkansas	2
Connecticut	4
District of Columbia	7
Florida	1
Iowa	4
Kentucky	1
Maryland	2
Massachusetts	2
Missouri	1
New Hampshire	11
New Jersey	1
New York	10
North Carolina	7
Pennsylvania	1
South Carolina	1
Tennessee	5
Utah	1
Vermont	9
Virginia	1
Wisconsin	1
Europe (except Western Germany)	1
Germany and Austria	1
Western Germany	1

CURATORIAL ACTIVITIES

The Curatorial Department accessioned 1,653 new gifts to the Gallery during the fiscal year 1952. Advice was given regarding 307 works of art brought to the Gallery for opinion, and 56 visits to other collections were made by members of the staff for either expert opinion or in connection with offers of gifts. About 2,000 inquiries requiring research were answered verbally and by letter. During the year seven individual lectures were given by members of the curatorial staff. Miss Elizabeth Mongan gave a lecture series to students of Beaver College, and Charles M. Richards conducted two courses in art history under the auspices of the Department of Agriculture. Mr. Richards attended the annual meeting of the American Association of Museums and served as an expert in a round-table discussion of registrarial problems. Miss Katharine Shepard was sent as a delegate from the Washington Society to the annual meeting of the Archaeological Institute of America. Perry C. Cott was elected to the Board of Governors of this Institute. Mr. Cott arranged a schedule of tours of United States museums for visiting foreigners under the International Exchange of Persons Division, State Department. Erwin O. Christensen made examinations of objects in the Widener collection in connection with the publication of the handbook, "Jewels and Rock Crystals." Mr. Christensen also made a survey and wrote a report on the condition of the marquetry of the furniture in the Widener collection for restoration purposes.

Special installations were prepared for the eight gold medallions lent to the Gallery by C. S. Gulbenkian, and for Pre-Columbian objects lent by Robert Woods Bliss.

The cataloging and filing of photographs in the Richter archive continued to make progress. The cataloging of photographs in the Stieglitz collection was completed in the spring; 1,436 cards were made.

RESTORATION AND REPAIR OF WORKS OF ART

Necessary restoration and repair of works of art in the Gallery's collections were made by Francis Sullivan, Resident Restorer to the Gallery. The work was completed in the Restorer's studio in the Gallery.

PUBLICATIONS

During the year Huntington Cairns contributed an article on "The Humanities and the Law" to the New York University Law Review, and reviews of volumes I, II, and III of "The Psychology of Art," by André Malraux, to the Virginia Quarterly Review; "Caravan: The Story of the Middle East," by Carleton S. Coon, to the Scientific Monthly; and "The Spirit of Liberty: Papers and Addresses of Learned Hand," edited by Irving Dilliard, to the Baltimore Evening

Sun. He also delivered a series of lectures at the Johns Hopkins University on "The Theory of Criticism."

An article by John Walker entitled "Your National Gallery of Art" appeared in the January issue of the National Geographic Magazine. Mrs. John Shapley contributed an article, "Benozzo Gozzoli's Dance of Salome," to the Gazette des Beaux-Arts, February 1952. Perry B. Cott contributed an article, "Italian Art in the National Gallery, Washington," for Le Vie del Mondo, May 1952. Mr. Cott also prepared the catalog "French Paintings from the Molyneux Collection," April 1952. Miss Elizabeth Mongan wrote "Introduction for Botanical Books, Prints and Drawings from the Collection of Mrs. Roy Arthur Hunt," October 1951. Miss Mongan also wrote "Introduction," Reder, New York, Borgenricht Gallery.

The new book "Great Paintings from the National Gallery of Art," by Huntington Cairns and John Walker, to be published by the Macmillan Co., will be ready for delivery in November 1952. A new Handbook, No. 3, on "Objects of Medieval Art" by Erwin O. Christensen, is also on order.

A book for hobbyists, entitled "Early American Designs: Ceramics," was written by Erwin O. Christensen; and two articles on adult art education programs were written by Miss Lois Bingham and Grose Evans for the Walters Art Gallery in Baltimore.

During the fiscal year 1952 the Publications Fund added five new color postcards and a new 11-x-14″ color reproduction to the list available, and 59 more of the large color plates were made for use in the new book "Great Paintings from the National Gallery of Art," and eventual use for 11-x-14″ prints. Four new Christmas card color plates were also produced.

A new guidebook, "Looking at Italian Pictures in the National Gallery of Art," was issued, and Mr. Walker's booklet "Paintings from America" was placed on sale. The Handbook No. 1 went into a third large printing, and a second printing of the "European Paintings from the Gulbenkian Collection" was received. Before Christmas, a calendar entitled "Famous Paintings" and a Spanish-language guide to collections of art in the United States, both including a large number of Gallery works of art, were placed on sale in the information rooms.

During this period, reproductions of 10 pieces of sculpture from the Gallery's collection were made available for the first time and have been well received. Three more recordings by the National Gallery Symphony Orchestra were also placed on sale, as well as a new set of Index of American Design playing cards. A checklist of the Molyneux paintings was made available during the exhibition here in the winter.

EDUCATIONAL PROGRAM

The attendance for the general, congressional, and special tours and the "Picture of the Week" totaled 36,756, while the attendance at the 48 auditorium lectures on Sunday afternoons was approximately 14,284 during the fiscal year 1952.

Special tours, lectures, and conferences arranged for by appointment were given to 213 groups and individuals. The total number of people served in this manner was 5,651, an increase of 2,093 over last year. These special appointments were made for such groups as Department of State trainees for overseas cultural service, Germans sponsored by the orientation program of the American Council of Education functioning under the point-4 program of the Department of State, groups from various other governmental departments, high-school and college students, women's clubs, Brownies, Scouts, Sunday school classes, and groups from national conventions meeting in the city. This service also included the training of Junior League volunteers who thereafter conducted tours for art students in the Washington high schools and a training program for members of the Arlington American Association of University Women who served as volunteer docents and conducted tours in the Gallery for all the Arlington public-school children in grades two through six.

The staff of the Education Office delivered 26 lantern-slide lectures and four film lectures, while guest speakers delivered 17 lectures. During March and April, Jacques Maritain delivered the first annual series of the A. W. Mellon Lectures in the Fine Arts on the theme "Creative Intuition in Art and Poetry."

During the past year 124 persons borrowed 4,853 slides from the lending collection, which contains more than 10,000 slides.

Two additional 16-mm. prints of the film "The National Gallery of Art" were made. Seven prints are now available for circulation. The film was lent 73 times during the year. Two sets of 2-x-2″-size slides, and one set of standard-size slides of the "Christmas Story in Art," a mimeographed lecture illustrated by 34 slides, were available for circulation. These were in constant use during the Christmas season.

The monthly Calendar of Events announcing all the Gallery activities, including notices of exhibitions, new publications, lectures, gallery talks, tours, and concerts, was mailed to more than 4,000 persons.

LIBRARY

Books, pamphlets, periodicals, and subscriptions purchased out of the fund presented to the National Gallery of Art by Paul Mellon totaled 438 during the fiscal year 1952. Gifts included 285 books and pamphlets, while 614 books, etc., were received on exchange from other

institutions. In addition 264 photographs of works of art were received on exchange. A total of 301 copies of the illustrated catalog of "Paintings and Sculpture from the Kress Collection," and 299 copies of the catalog "Renaissance Bronzes from the Kress Collection" were sent on exchange to other museums. The Library is the depository for photographs of the works of art in the collections of the National Gallery of Art. A stock of reproductions is maintained for use in research occupations by the curatorial and other departments of the Gallery; for the dissemination of knowledge to qualified sources; for exchange with other art institutions; for publicity; and for sale at the request of any interested individual.

The photographic collection has grown with new bequests and loans made to the National Gallery of Art during the year. A substantial addition has occurred in the instance of the new loans from Chester Dale. The photographic file continues to present a complete pictorial record for reference to all the objects in the Gallery as well as to provide limited quantities of 8-x-10″ prints for distribution.

During the year 641 persons other than the Gallery staff used the Library for research.

INDEX OF AMERICAN DESIGN

During the fiscal year 1952 a total of 9 new exhibits containing 396 renderings were completed. Permission was granted for the reproduction of 183 plates, while 743 photographs were distributed for use by designers, possible publication, research, study, and publicity. A total of 1,016 slides were circulated and several designs from the Index were adapted for commercial use on drapery material, furniture, and playing cards. The entire collection of 1,666 2-x-2″ color slides was organized into 20 loan sets and 1 miscellaneous group for loan to individual lecturers, museums, schools, and colleges.

MAINTENANCE OF THE BUILDING AND GROUNDS

The usual work in connection with the care and maintenance of the building, its mechanical equipment, and the grounds was continued throughout the year. Considerable redecorating was done, including the painting of several galleries and offices. Flowering and foliage plants, totaling in number 5,869 and valued at approximately $7,700, were grown in the moats and were used for decoration in the garden courts throughout the year.

The lawn-sprinkler system was extended to include several grass areas between Constitution Avenue and the sidewalk adjacent thereto.

During the winter months, all the refrigeration machines were given an annual overhauling which included the balancing of the rotors, the cleaning and testing of new parts, and the necessary repairs in

order to place them in condition for the summer months. During the process laboratory tests revealed that two of the machines needed certain replacements. This condition was called to the attention of the manufacturers, and the Gallery was informed by them on June 20, 1952, as well as by the Vermilya-Brown Co., that the condition was serious and it would be necessary to replace the condensers, compressors, and coolers in all three machines. Estimates obtained indicated that this work would cost about $187,500. These funds were made available in a supplemental appropriation bill by the Eighty-second Congress for use for this purpose during the fiscal year 1953.

Two sections of skylight, representing an area of approximately 850 square feet, were completely overhauled, and this work of skylight repair is being continued.

The American District Telegraph Co.'s automatic fire-alarm system was extended to the two storage areas on the 81-foot level north and south of the rotunda.

The Gallery's staff did a considerable amount of work in connection with the new storage vault, especially in the installation of steel storage racks.

CONSTRUCTION OF NEW GALLERIES

Work under the contract entered into on July 31, 1950, for the construction of galleries 35, 35A, 40, 41, and 41A in the southwest end of the building was completed in January 1952. Private funds were made available for this purpose.

CONSTRUCTION OF STORAGE FACILITIES

The completion of the work under the contract entered into March 1, 1951, for building a storage room adjacent to the Gallery building in the southeast moat, has been delayed because of the difficulty encountered in obtaining certain materials called for in the specifications, and it is now anticipated that this project will be completed late in the summer of 1952.

Work under the contract entered into on March 2, 1951, to build a storage building and reconstruct a cottage on the site of Randolph-Macon Woman's College, Lynchburg, Va., was completed in April 1952. Both of these projects were made possible by private funds donated for these purposes.

OTHER ACTIVITIES

A total of 43 Sunday evening concerts were given during the fiscal year in the West Garden Court. The National Gallery Orchestra, under the direction of Richard Bales, played 11 concerts at the Gallery

with 4 additional performances in Charlottesville and Middleburg, Va. Two of the orchestral concerts at the Gallery were made possible by the Music Performance Trust Fund of the American Federation of Musicians. The orchestra also gave two children's concerts at the Corcoran Gallery of Art. During April the Sunday evenings were devoted to the Gallery's Ninth Annual American Music Festival, featuring 34 works by 15 American composers. Most of the concerts were broadcast in their entirety by Station WCFM, Washington, and those of the National Gallery Orchestra and the American Music Festival were carried by the Continental FM Network. The National Gallery Orchestra made two long-playing records, one of which was selected by the New York Times for its list of outstanding recordings of the year 1951. During August and September 1951 the National Gallery Orchestra played the first regular series of symphonic music on television as part of the NBC "Heritage" programs of art and music originating in the Gallery. This was selected by the New York Times as the finest serious music program of 1951 on television.

The photographic laboratory of the Gallery produced 14,028 prints, 390 black-and-white slides, and 928 color slides during the fiscal year, in addition to 3,214 negatives, as well as X-rays, infrared, and ultraviolet photographs.

During the fiscal year 1952, a total of 2,698 press releases were issued with respect to Gallery activities, while 161 permits to copy paintings, and 240 permits to photograph in the Gallery were issued.

OTHER GIFTS

Gifts of books on works of art and related material were made to the Gallery by Paul Mellon and others. Gifts of money were made during the fiscal year 1952 by the A. W. Mellon Educational and Charitable Trust, the Avalon Foundation, and the Old Dominion Foundation. An additional cash bequest was received from the estate of the late William Nelson Cromwell.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit of the private funds of the Gallery has been made for the fiscal year ended June 30, 1952, by Price, Waterhouse & Co., public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds will be forwarded to the Gallery.

Respectfully submitted.

Huntington Cairns, *Secretary.*

The Secretary,
Smithsonian Institution.

APPENDIX 3

Report on the National Collection of Fine Arts

Sir: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1952:

THE SMITHSONIAN ART COMMISSION

The twenty-ninth annual meeting of the Smithsonian Art Commission was held in the Regents' Room of the Smithsonian Building on Tuesday, December 4, 1951. The members present were: Paul Manship, chairman; Alexander Wetmore, secretary (member, ex officio); Robert Woods Bliss, Gilmore D. Clarke, George H. Edgell, David E. Finley, George Hewitt Myers, Archibald Wenley, Lawrence Grant White, Andrew Wyeth, and Mahonri Young. Thomas M. Beggs, Director, National Collection of Fine Arts, and Paul V. Gardner, curator of ceramics, National Collection of Fine Arts, were also present.

The Commission recommended the reelection of George H. Edgell, Lloyd Goodrich, and Lawrence Grant White for the usual 4-year period. As James E. Fraser had been unable to attend the meetings for several years, his status was changed to that of member emeritus. The secretary was instructed to send a letter on behalf of the Commission expressing thanks for Mr. Fraser's services and a desire for his presence at its future meetings. The Commission recommended to the Board of Regents the appointment of Walker Hancock to membership.

The following officers were elected for the ensuing year: Paul Manship, chairman; Robert Woods Bliss, vice chairman, and Dr. Alexander Wetmore, secretary. The following were elected members of the executive committee for the ensuing year: David E. Finley, chairman, Robert Woods Bliss, Gilmore D. Clarke, and George Hewitt Myers. Paul Manship, as chairman of the Commission, and Dr. Alexander Wetmore, as secretary of the Commission, are ex officio members of the executive committee.

Mr. Beggs reported that gifts received during 1951 include a fund established by Mrs. Laura Dreyfus-Barney for the purpose of maintaining a lending collection to advance the appreciation and creation of art throughout the United States. The capital of $15,000 is to

be increased during the next 3 years by annual additions of $5,000. Ultimately the fund will help substantially the National Collection of Fine Arts in carrying out the authorization in its act of establishment for the circulation of traveling exhibitions.

The Barney fund, in conjunction with a grant made last June by the Department of State for the assembling of 12 exhibitions to be sent to West Germany and Austria, has permitted the Institution to obtain the services of Mrs. John A. Pope and Miss Gladys E. Acton, who will handle, under the direction of the National Collection of Fine Arts, the details of the new Smithsonian Traveling Exhibition Service. With the National Gallery of Art and the Freer Gallery of Art serving as national repositories for rare and valuable paintings, sculptures, and art objects of the best periods of European and oriental art, it is now the acknowledged responsibility of the National Collection of Fine Arts to encourage contemporary art and artists.

The Commission accepted the following objects for the National Collection of Fine Arts:

Oil, Nancy, by George DeForest Brush, N. A. (1855–1941). Henry Ward Ranger bequest.

Oil, The Figurine, by William M. Paxton, N. A. (1869–1941). Henry Ward Ranger bequest.

Two sculptures, Baboon (in limestone) and Antelope (in black Belgian marble), by Bessie S. Callender (1889–1951). Gift of her husband, Harold Callender.

Three pieces of modern glass, Tritonschale and Meerweibachale, both engraved, c. 1875, Austrian, made by Lobmeyer Factory, and an enameled perfume bottle, designed by Émile Gallé. Gift of Mr. and Mrs. Hugh J. Smith, Jr.

Five prize-winning pieces of ceramics from the Second Annual Exhibition of Ceramic Art, 1951: Large bowl, black glaze, by Mary Tilton Brammell; small rice bowl, brushwork, by Kathleen P. Lewis; stoneware bowl, green glaze, by Helen O'Brien; bowl, brown glaze, by Lisle Pursel; and jug with stopper, by Alta C. Fuller. Gift of the Kiln Club.

Miniature, water color on ivory, The Last Earl of Glencairn, by an undetermined artist. Gift of William Mouat Hannay.

THE CATHERINE WALDEN MYER FUND

Eight miniatures, water color on ivory, were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

79. Miss Margaret Liddell, by Nathaniel Plimer; from Edmund Bury, Philadelphia, Pa.

80. William Lampas, by undetermined artist; from Miss Jennie E. Doolittle, Washington, D. C.

81. Gentleman in Red Coat, attributed to Gervase Spencer.

82. Gentleman with a Black Coat, attributed to John Thomas Barber Beaumont.

83. James Wilson (1742–98), Signer of the Declaration of Independence, by undetermined artist; from T. R. Montgomery, Chagrin Falls, Ohio, and brothers.

84. Ed Scarlett, by James Scouler.
85. Mrs. John Jordan, Jr., by J. Henry Brown.
86. Unknown Woman, by undetermined artist.

Nos. 81 and 82 were acquired from Dr. Daniel B. Kirby, New York, N. Y., and Nos. 84, 85, and 86 were acquired from Dorsey Griffith, New Market, Md., through Ruel P. Tolman, Washington, D. C.

STUDY COLLECTION

A cameo glass vase, designed by Émile Gallé, France, 1895, the gift of Mr. and Mrs. Hugh J. Smith, Jr., was added to the study collection.

LOANS ACCEPTED

Twenty-two pieces of modern glass were lent by Mr. and Mrs. Hugh J. Smith, Jr., Scarsdale, N. Y., as follows: 7 French, 1 Finnish, 1 Dutch, 3 Swedish, and 4 American, on November 20, 1951; 4 Swedish on December 27, 1951, and 2 Swedish on March 17, 1952.

A jeweled collar of gold, designed with peacock-feather motif, and executed by Mellerio, Paris, was lent by Natalie Clifford Barney and Laura Dreyfus-Barney on June 13, 1952.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

Two oils, At Nature's Mirror, by Ralph A. Blakelock, and Moonlight, by Albert P. Ryder, were lent to the National Academy of Design, to be included in the exhibition American Tradition, 1800–1900, from December 2 to 23, 1951. (Returned January 3, 1952.)

Three oils, A Gentlewoman, Upland Pasture, and Portrait of Wyatt Eaton, by J. Alden Weir, were lent to the American Academy of Arts and Letters, for an exhibition during February and March 1952. (Returned April 8, 1952.)

Oil, At Nature's Mirror, by Ralph A. Blakelock, was lent to the American Federation of Arts, for their traveling show, the American Tradition, 1800–1900, on February 12, 1952.

Oil, Georgia Pines, by George Inness, was lent to The White House on March 18, 1952, for a period not to exceed 4 years.

Three oils, Indian Summer, by John Francis Murphy; Spring, by Alexander H. Wyant; and Portrait of John Tyler, by G. P. A. Healy, were lent to the Bureau of the Budget on March 18, 1952, for a period not to exceed 4 years.

Five oils, portraits of members of the National Academy of Sciences: Louis Agassiz, by Walter Ingalls; Joseph Henry, by Walter Ingalls; Spencer F. Baird, by Henry Ulke; Charles D. Walcott, by Hattie Burdette, and Charles G. Abbot, by Samantha L. Huntley, were lent to the National Academy of Sciences on April 25, 1952, for a period of 4 years.

Two oils, portraits of Maj. Gen. Henry Tureman Allen and Maj. Gen. Robert Lee Bullard, by Seymour M. Stone, were lent to the Department of the Army on May 23, 1952, for a period not to exceed 4 years.

WITHDRAWALS BY OWNERS

One pastel painting, The Tennessee Madonna, by James Ross Bryson, lent by Mrs. B. S. Williams in 1931, was withdrawn by the owner on November 23, 1951, and delivered to the National Shrine of the Immaculate Conception, Washington, D. C.

Two panels of stained glass, Dante and Beatrice, designed and executed by William Willet, were withdrawn by the artist's daughter, Mrs. Thomas H. English, Atlanta, Ga., on March 17, 1952.

Eighteen pieces of ceramics and one teakwood stand were withdrawn by Mrs. H. Foster Bain and shipped to the University of Nevada, Reno, Nev., on June 16, 1952.

One oil painting, portrait of Sr. Benito Juárez, by Tom Lea, lent by the State Department in 1949, was returned to the Blair Lee House on June 16, 1952.

SMITHSONIAN LENDING COLLECTION

Fifty-four paintings in oil, by Edwin Scott (1863–1929), were added to the Alice Pike Barney Memorial Collection presented last year to the Smithsonian Institution by Natalie Clifford Barney and Laura Dreyfus-Barney, as the nucleus of a loan collection for the embellishment of Federal buildings, museums, libraries, colleges, and other educational institutions in this country.

One oil painting, Early New Mexican Village (probably Lemitar), by an undetermined artist, transferred from the Bureau of American Ethnology, was lent to the Museum of New Mexico Art Gallery, Santa Fe, through Senator Clinton P. Anderson, Regent of the Smithsonian Institution, February 27, 1952, for an indefinite period.

Ten paintings by Alice Pike Barney (1860–1931) were lent to the Prairie View Agricultural and Mechanical College, Prairie View, Tex., on February 27, 1952, for a special exhibition. (Returned June 3, 1952.)

Fourteen paintings (12 by Alice Pike Barney, 1 by E. Ray, and 1 by A. Kinder) were lent to Lehigh University, Bethlehem, Pa., on June 16, 1952, for special exhibition.

One oil painting, Small Port, Puerto Montt, by Arturo Pacheco Altamirano, the gift of the people of Chile to the United States through Señor Felix Nieto del Río, the Chilean Ambassador, after its initial exhibition of 5 months in the lobby of the Natural History Building, was lent to Lehigh University, June 23, 1952, for a period of six months.

Eleven paintings by Alice Pike Barney were lent to the Dayton Art Institute, Dayton, Ohio, June 25, 1952, for a special exhibition.

ALICE PIKE BARNEY MEMORIAL FUND

An addition of $5,000 to the fund established in 1951 by Miss Natalie Clifford Barney and Mrs. Laura Dreyfus-Barney, in memory of their mother, for the purpose of encouraging the appreciation and creation of art in the United States, was received in January 1952.

THE HENRY WARD RANGER FUND

According to a provision in the Ranger bequest that paintings purchased by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest and assigned to American art institutions may be claimed during the 5-year period beginning 10 years after the death of the artist represented, two paintings, listed earlier in this report, were recalled and accepted by the Smithsonian Art Commission at its meeting December 4, 1951.

The following paintings, purchased by the Council of the National Academy of Design in 1951, have been assigned as follows:

Title and Artist	*Assignment*
126. New Lebanon Railroad Station, by Louis Bouche, N. A.	Art Museum, New Britain, Conn.
127. The City—No. 2, by Raphael Gleitsmann.	Syracuse Museum of Fine Arts, Syracuse, N. Y.
128. Harbor, by Xavier González	Seattle Art Museum, Seattle, Wash.
129. Four Houses, by Antonio P. Martini, N. A.	Randolph-Macon College, Lynchburg, Va.
130. Night, by Albert John Pucci	Museum of Art, University of Kansas, Lawrence, Kans.
131. Paris, by William A. Smith, A. N. A.	Florida Southern College, Lakeland, Fla.
132. Farm in Essex, by Gifford Beal, N. A.	Isaac Delgado Museum of Art, New Orleans, La.
133. Nine men, by Joseph Hirsch	Dallas Art Association, Dallas Museum of Fine Arts, Dallas, Tex.
134. Rabbit Island, Hawaii, by Millard Sheets, N. A.	Lehigh University, Bethlehem, Pa.
135. Blacksmith Shop, by John Alonzo Williams, N. A.	The Brick Store Museum, Kennebunk, Maine.
136. Chimney Beams, by Andrew Wyeth, N. A.	Corcoran Gallery of Art, Washington, D. C.

REFERENCE LIBRARY

In all, 230 publications (158 volumes and 72 pamphlets) were accessioned during the year; 527 parts of periodicals were entered in the periodical record, and 17 volumes and 18 pamphlets (serials) were entered in the catalog. The total accessions in the National Collection of Fine Arts library now number 12,252.

On April 23, 1952, Anna Moore Link, librarian since 1942, was reassigned to duty in the reference and circulation section of the Smithsonian Library.

INFORMATION SERVICE

In addition to the many requests for information received by mail and telephone, inquiries made in person at the office numbered 1,856. Examination was made of 878 works of art submitted for identification.

Members of the staff performed numerous services for local and national art or civic organizations by giving talks on various art subjects and by judging current exhibitions of art and craft work.

SPECIAL EXHIBITIONS

Ten special exhibitions were held during the year:

August 30 through September 23, 1951.—The Second Annual Exhibition of Ceramic Art by the Kiln Club of Washington, D. C., consisting of 145 pieces by local ceramic artists and 40 pieces by outstanding artists in this and other countries, lent by the artists themselves or by embassies and collectors. Demonstrations of pottery-making using the potter's wheel were given several times each week by club members. A catalog was privately printed.

August 30 through September 23, 1951.—The Fourth Annual Exhibition of Sculpture by the Washington Sculptors Group, consisting of 21 pieces of sculpture. Gallery talks on sculptural methods and techniques were periodically given by members of the group.

November 4 through 25, 1951.—The Fourteenth Metropolitan State Art Contest, held under the auspices of the District of Columbia Chapter, American Artists Professional League, assisted by the Entre Nous Club, consisting of 396 paintings, sculpture, prints, ceramics, and metalcraft. A catalog was privately printed.

January 10 through February 27, 1952.—An exhibition of Art and Magic of Arnhem Land, Australia, consisting of 212 specimens obtained by the National Geographic Society, Smithsonian Institution, and Commonwealth of Australia Expedition in 1948.

March 7 through 28, 1952.—The Sixtieth Annual Exhibition of the Society of Washington Artists, consisting of 86 paintings and 21 pieces of sculpture. A catalog was privately printed.

April 5 through 27, 1952.—Biennial Art Exhibition of the National League of American Pen Women, consisting of 222 paintings, sculpture, prints, ceramics, and metalcraft. A catalog was privately printed.

May 4 through 30, 1952.—The Nineteenth Annual Exhibition of the Miniature Painters, Sculptors and Gravers Society of Washington, D. C., consisting of 209 examples. A catalog was privately printed.

May 15 through 30, 1952.—The Fifty-fifth Annual Exhibition of the Washington Water Color Club, consisting of 156 water colors, etchings, and drawings. A catalog was privately printed.

June 5 through 26, 1952.—Exhibition of Finnish Arts and Crafts held under the patronage of His Excellency, the Finnish Envoy to Washington, Minister Johan Nykopp, and the Finnish-American Society of Helsinki, consisting of

208 paintings, prints, sculpture, ceramics, and rugs. A catalog was privately printed.

June 5 through 26, 1952.—Under the same patronage, and concurrent with the above, an exhibition was shown of 10 portrait busts and figure sculpture, by Kalervo Kallio, a Washington resident from Finland. A catalog was privately printed.

Respectfully submitted.

THOMAS M. BEGGS, *Director.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 4

Report on the Freer Gallery of Art

SIR: I have the honor to submit the thirty-second annual report on the Freer Gallery of Art for the year ended June 30, 1952.

THE COLLECTIONS

Additions to the collections by purchase were as follows:

BRONZE

51.18. Chinese, Shang dynasty (ca. 1766–1122 B. C.). A ceremonial vessel of the type *ku*. Design cast in high and low relief. Inside the base is cast a one-character inscription. 0.326 x 0.191.

51.19. Chinese, Shang dynasty (ca. 1766–1122 B. C.). A ceremonial vessel of the type *tsun*, round with widely flaring lip, bulging belly, and high flaring foot. Decoration cast in high and low relief. Two-character inscription cast inside base. 0.366 x 0.374.

52.1. Egyptian, Copto-Arabic, A. D. 8th–9th century. Incense burner in form of a square, five-domed structure resting on four feet, with *à jour* decoration and handle. 0.315 x 0.212 x 0.408

METALWORK

51.8. Persian (Ṭabaristān), Seljuk period, A. D. 11th century. Silver candlestick decorated with repoussé and engraved designs and Arabic inscriptions in *kūfī* script. 0.571 x 0.570.

51.17. Persian (Khurāsān), Seljuk period, A. D. 12th century, late. Brass candlestick decorated with repoussé and engraved designs, also inlaid with silver, copper, and pitch. 0.403 x 0.477. (Illustrated.)

PAINTING

52.2. Indian, Mughal, about A. D. 1600. A Mongol chieftain with attendants; color and gold on paper; Persian verse in *nasta'līq*, orange paper border with gold animal and colored bird drawings; on reverse, four *nasta'līq* panels and border with tinted figures. 0.423 x 0.265 over all.

52.7. Chinese, Ming dynasty (A. D. 1368–1644). Scroll painting by Wang Fu dated in correspondence with 15 June 1410. Bamboos in ink on paper; 43 seals and 1 inscription on painting, 32 seals and 11 inscriptions on mounting. 0.261 x 8.470.

POTTERY

51.9. Chinese, Ming dynasty (A. D. 1368–1644). Jar of the type *cha-tou;* white porcelain decorated with dragons and floral scrolls in underglaze blue. Four-character mark of the Chêng-tê period (1506–1521) on base. 0.125 x 0.154.

51.10. Chinese, Ming dynasty (A. D. 1368–1644). Pair of dishes with plain
51.11. flaring rims; white porcelain decorated in underglaze blue with "the three friends" inside and garden scenes with figures outside. Six-character marks of the Ch'êng-hua period (1465–1487) on both bases. 0.043 x 0.201.

51.12. Chinese, Ming dynasty (A. D. 1368–1644), second half of the 15th century. Jar of the type *cha-tou;* white porcelain decorated with fruiting and flowering branches in underglaze blue. 0.108 x 0.149. (Illustrated.)

51.13. Chinese, Ming dynasty (A. D. 1368–1644). Dish with foliate sides and flaring rim; white porcelain decorated with 1 large dragon inside and 10 small dragons outside. Six-character mark of the Hsüan-tê period (1425–1436) on base. 0.048 x 0.213.

51.14. Chinese, Ming dynasty (A. D. 1368–1644), early 15th century. Bowl with plain straight rim; white porcelain decorated in underglaze blue with flowers and fruit inside and plain dark petals outside. 0.100 x 0.210.

51.15. Chinese, Ming dynasty (A. D. 1368–1644), 15th century. Tankard with bulbous body, 16-sided neck and attached handle; white porcelain decorated with floral scrolls in underglaze blue. 0.140 x 0.128.

51.16. Chinese, Ming dynasty (A. D. 1368–1644). Stem cup with plain straight rim; white porcelain decorated in underglaze blue and overglaze *tou-ts'ai* enamels. Six-character mark of the Ch'êng-hua period (1465–1487) in horizontal line on base. 0.080 x 0.063.

51.20. Chinese, Sung dynasty (A. D. 960–1279). *Lung-ch'üan* tripod of the type *hakamagoshi koro;* gray porcelain with even, sea-green, celadon glaze. 0.104 x 0.140.

52.3. Chinese, Ming dynasty (A. D. 1368–1644). Dish with plain flaring rim; white porcelain decorated with dragons incised in the paste under a solid deep blue glaze. Six-character mark of the Chia-ching period (1522–1566) in underglaze blue on base. 0.045 x 0.250.

52.4. Chinese, Ming dynasty (A. D. 1368–1644), second half of the 15th century. Bowl with plain, slightly flaring rim; white porcelain decorated with "the three friends" inside and landscape with figures outside, all in underglaze blue. 0.095 x 0.204.

52.5. Chinese, Ming dynasty (A. D. 1368–1644), early 15th century. Vase of the type *mei-p'ing;* white porcelain decorated with floral scrolls in underglaze cobalt blue. 0.248 x 0.152.

52.6. Chinese, Ming dynasty (A. D. 1368–1644). Bowl with plain rim and thick sides; white porcelain decorated with underglaze cobalt blue; inside plain, outside with six sprays of fruits and flowers; six-character mark of the Hsüan-tê period (1426–1435) in a single horizontal line below the rim. 0.096 x 0.261.

52.8. Chinese, Sung dynasty (A. D. 960–1279). Cup of southern *kuan* ware with horizontal foliate flange on one side above a small loop handle; even, light grayish-brown glaze with deep irregular crackle. 0.045 x 0.109 over all.

52.9. Chinese, Sung dynasty (A. D. 960–1279). Tea bowl of *chien* type with metal rim; coarse, dark reddish-brown stoneware with thick, black glaze closely streaked with silvery iridescence, rusty brown near rim. 0.071 x 0.124.

52.10. Chinese, Han dynasty (207 B. C.–A. D. 220). Large jar with wide belly and small mouth of the hard, dark-gray ware called "proto-porcelain"; decorated with incised designs under a thin, transparent, olive-green glaze, animal-mask handles and horizontal bands in relief; remains of an inscription in red on a gesso-like ground over the glaze. 0.329 x 0.382.

SCULPTURE

51.21. Japanese, Suiko period, A. D. 7th century, middle. Gilt bronze figure of a *Bodhisattva* standing on a lotus pedestal. 0.338 x 0.113. (Illustrated.)

REPAIRS TO THE COLLECTION

Cleaning and restoration of 12 American paintings were completed by John and Richard Finlayson of Boston.

CHANGES IN EXHIBITIONS

Changes in exhibitions totaled 198 as follows:

American art:	
Oil paintings	70
Pastels	30
Silverpoints	2
Water colors	28
Chinese art:	
Paintings	50
Pottery	2
Egyptian art:	
Crystal	1
Persian art:	
Metalwork	14
Veneto-Islamic art:	
Metalwork	1

LIBRARY

Accession of books, pamphlets, periodicals, rubbings, and photographs totaled 775 pieces; and additional study materials included a stone implement and several hundred pottery shards. Cataloging of all kinds, including cards typed and filed, covered 4,688 items, while 9 bibliographies were prepared in reply to letters and 140 bibliographic entries were made on Gallery folder sheets. A total of 567 items were bound, labeled, repaired, or mounted. The card catalog was revised to facilitate reference to analytical material shelved in the Periodical Room. Work on the indexing of both the English and Japanese editions of the Japanese periodical Kokka continued. The establishment of the technical research laboratory with its specialized library and new field of subject headings and bibliography problems has increased and broadened the work of the library.

PUBLICATIONS

One publication of the Gallery was issued during the year:

Title page and contents, Occasional Papers, vol. I, 1951. (Smithsonian Publication 4049.)

Papers by staff members in outside publications were as follows:

Ettinghausen, Richard: Islamic art and archaeology. *In* "Near Eastern Culture and Society," edited by T. Cuyler Young; pp. 17–47, figs. 1–25. Princeton University Press, 1951.

———. The "beveled style" in the post-Samarra period. *In* "Archaeologica Orientalia in Memoriam Ernst Herzfeld," edited by George C. Miles; pp. 72–83, pls. 9–16. Locust Valley, N. Y., 1952.

———. [Contributor to] Bibliography of periodical literature on the Near and Middle East, vols. 19–22. The Middle East Journal, 1951–52.

———. Ars Islamica–Ars Orientalis. Ars Islamica, vols. 15–16, pp. vii–viii, 1951.

———. In memoriam: Ernst Herzfeld, with supplementary bibliography. Ars Islamica, vols. 15–16, pp. 261–267, 1951.

———. In memoriam: Ananda Kentish Coomaraswamy. Ars Islamica, vols. 15–16, p. 259, 1951.

———. Islamic metalwork in the British Museum, by D. Barrett (review). Ars Islamica, vols. 15–16, pp. 255–257, 1951.

Gettens, R. J.: Principles in the conservation of mural paintings. *In* "Essays on Archaeological Methods," edited by James B. Griffin; pp. 59–72. University of Michigan Press, 1951.

———. The bleaching of stained and discoloured pictures on paper with sodium chloride and chlorine dioxide. Museum, vol. 5, No. 2, 1952.

Pope, John A.: Archaeological research in Indo-China, vol. 2: The district of Chiu-Chên during the Han dynasty. Description and comparative study of the finds, by Olov R. T. Janse (review). Harvard Journal of Asiatic Studies, vol. 14, Nos. 3, 4, pp. 637–644, Dec. 1951.

———. The Princessehof Museum in Leeuwarden. Archives of the Chinese Art Society of America, vol. 5, pp. 23–37, 8 pls., 1951.

———. A potter's portfolio, a selection of fine pots, by Bernard Leach (review). New Republic, Apr. 21, 1952.

REPRODUCTIONS

During the year the photographic laboratory made 4,547 prints, 506 glass negatives, and 144 lantern slides.

BUILDING

The general condition of the building is good, both inside and out, and the maintenance and operation continue satisfactory; the mechanical equipment, though inadequate, continues in working order. A temporary painter again helped out with the most urgent work, but the lack of a full-time painter is reflected in the gradual deterioration of the appearance of the exhibition galleries and other interior areas.

The major project of the cabinet shop was the completion and furnishing of the technical research laboratory begun last year. Both conventional and special equipment was installed to provide the necessary plumbing, ventilating, light, and power requirements; and

closet, bookcases, specimen cases, instrument cases, microscope table, and examining table were built and installed to meet the specifications of the associate in technical research.

Eight new exhibition cases are under construction, and miscellaneous odd jobs in care of office and Gallery equipment, crating, etc., continue as usual.

ATTENDANCE

The Gallery was open to the public from 9 to 4:30 every day except Christmas Day. The total number of visitors to come in the main entrance was 74,940. The highest monthly attendance was in August, 10,714, and the lowest was in December, 2,507. There were 1,498 visitors to the office during the year.

HERZFELD ARCHIVE

Mrs. Charlotte Bradford, sister of the late Ernst Herzfeld, presented to the Herzfeld Archive further manuscripts and notes prepared by Professor Herzfeld. The Herzfeld material continues to be used by experts in Near Eastern archeology throughout the world.

STAFF ACTIVITIES

The work of the staff members has been devoted to the study of new accessions, of objects contemplated for purchase, and of objects submitted for examination, as well as to individual research projects in the fields represented by the collections of Chinese, Japanese, Persian, Arabic, and Indian materials. Reports, oral or written, and exclusive of those made by the laboratory which are listed below, were made upon 4,385 objects as follows: belonging to private individuals, 1,749; belonging to dealers, 485; belonging to other museums, 2,151. In all, 654 photographs of objects were examined and 504 oriental language inscriptions were translated for outside individuals and institutions. By request 10 groups totaling 357 persons met in the exhibition galleries for docent service by staff members; and 2 groups totaling 24 persons were given docent service in the study-storage rooms.

With the completion of the technical research laboratory and the appointment of Rutherford J. Gettens as associate in technical research, a new phase of Gallery activity was inaugurated. Its purpose is to carry on a continuing investigation of the methods and materials used by the artists and craftsmen in the ancient civilizations represented by objects in the Gallery collections. The laboratory was ready for occupancy in March, and Mr. Gettens carried out the installation of new equipment and materials, including a large

binocular microscope on extendable arm, a chemical microscope, a metalographic microscope with vertical illuminator, and a photomicrographic camera. Also included is a wide selection of standard chemical apparatus, reagents, and supplies, including ovens, furnaces, and equipment for glassworking and electrolysis. Reference files, technical library, and the collection of specimens of pigments, minerals, polished metals, and microscopic slide mounts were put in order. Certain research projects were undertaken while the settlement was still in progress, and by the end of the fiscal year work had begun on the Gallery collections and 40 reports had been made on objects submitted for technical examination by outside individuals and institutions.

Dr. Ettinghausen continued his work abroad. Leaving Afghanistan early in July, he spent 3 weeks in Pakistan and India and then returned to Iran for 5 weeks, during which time Mrs. Ettinghausen completed her photographic work on the Ardebil Chinese porcelains for Mr. Pope's publication of the material he studied there in 1950. Continuing westward Dr. Ettinghausen spent 6 weeks in Turkey and 2 weeks each in Morocco and Spain, with shorter visits to Lebanon, Syria, Jordan, Greece, Tunisia, and Algeria on the way. He returned to the Gallery in December after an absence of 14 months during which he studied most of the important monuments of Islamic culture.

By invitation the following lectures were given outside the Gallery by staff members:

1951

June 28. Dr. Ettinghausen addressed a group from the press department of the Afghan Government and the Kabul Museum, Kabul, Afghanistan, on "Muslim Art in Western Eyes." Attendance, 80.

Aug. 22. Dr. Ettinghausen addressed the Iran-America Society in the Cultural Center, Tehran, on "Persian Miniature Paintings." (Illustrated.) Attendance, 78.

Sept. 18. Dr. Ettinghausen, as chairman of the first meeting of the section "General Islamic Art," addressed the XXIId International Congress of Orientalists (Islamic section) at Istanbul, Turkey, on "Early Turkish Art from the Court of the Ghaznevids." (Illustrated.) Attendance, 35.

Oct. 4. Mr. Pope addressed members of the Arts Club, Washington, D. C., on "Chinese Porcelain." (Illustrated.) Attendance, 75.

Nov. 19. Mr. Stern addressed the wives of members of the Officers' Club, Andrews Air Force Base, Washington, D. C., on "A Survey of Japanese Art." (Illustrated.) Attendance, 16.

1952

Jan. 17. Dr. Ettinghausen addressed members of the Board of Regents at the annual dinner, held at the Smithsonian Institution, on "Research in Art of the Moslem World." (Illustrated.) Attendance, 25.

1952

Feb. 4. Mr. Gettens addressed members of the Cosmos Club on "Some Observations on the Patina and Corrosion Products of Ancient Bronzes." (Illustrated.) Attendance, 50.

Mar. 12. Mr. Pope addressed members of the Questers at luncheon in the Arts Club, Washington, D. C., on "Mr. Freer and His Collections." Attendance, 25.

Apr. 15. Dr. Ettinghausen addressed members of the Oriental Institute in Chicago on "Islamic Manuscripts and Miniatures." (Illustrated.) Attendance, 90.

Apr. 17. Dr. Ettinghausen addressed members of the Department of Near Eastern Studies, University of Michigan, Ann Arbor, Mich., on "Islamic Art; The Book." (Illustrated.) Attendance, 90.

Apr. 21. Dr. Ettinghausen addressed members of the Department of Near Eastern Studies, University of Michigan, Ann Arbor, Mich., on "Islamic Art; The Mosque." (Illustrated.) Attendance, 30.

May 20. Mr. Stern addressed members of the Takoma Park Women's Club on "Survey of Japanese Art." (Illustrated.) Attendance, 25.

May 21. Dr. Ettinghausen addressed members and guests of the Middle East Institute and Oriental Club, Washington, D. C., on "Travels in Afghanistan and India." (Illustrated.) Attendance, 120.

May 29. Dr. Ettinghausen addressed members and guests of the Middle East Institute and Oriental Club, Washington, D. C., on "Travels in Afghanistan and India." (Illustrated.) Attendance, 90.

During the year five members of the staff made a total of 14 trips outside of Washington on official business.

Members of the staff held honorary posts and undertook additional duties outside the Gallery as follows:

Mr. Wenley: Member, visiting committee, Dumbarton Oaks Research Library and Collection.

Research professor of oriental art, University of Michigan.

Trustee, Hermitage Foundation, Norfolk, Va.

Chairman of the Louise Wallace Hackney scholarship committee of the American Oriental Society.

Member, Smithsonian Art Commission.

Trustee, Textile Museum of the District of Columbia.

Member of the Board of United States Civil Service Examiners at Washington, D. C., for the Smithsonian Institution.

Mr. Pope: President, Far Eastern Ceramic Group.

Art editor, Far Eastern Quarterly.

President, Washington Society, Archaeological Institute of America.

Member, two advisory selection committees for Fulbright awards in fine arts and architecture, under the Conference Board of Associated Research Councils.

Served as one of the judges at the Second Annual Exhibition of Ceramic Art, Kiln Club of Washington, D. C., held at the Smithsonian Institution, National Collection of Fine Arts, on August 28, 1951.

51.21

RECENT ADDITION TO THE COLLECTION OF THE FREER GALLERY OF ART

51.12

51.17

RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART

Dr. Ettinghausen: Research professor of Islamic art, University of Michigan.
Editor, Ars Islamica.
Editor, A Selected and Annotated Bibliography of Books and Periodicals in Western Languages Dealing with the Near and Middle East with Special Emphasis on Medieval and Modern Times; to be published under the auspices of the American Council of Learned Societies.
Member, editorial board, the Art Bulletin.
Trustee, American research center in Egypt.
Member, Comitato Internazionale di Patronato, Museo Internazionale delle Ceramiche, Faenza, Italy.
Chairman, Persian and Islamic section Twenty-second International Congress of Orientalists, Istanbul, Sept. 15–22, 1951.
Chairman, Islamic Session, Twenty-second International Congress of Orientalists, Istanbul, Sept. 18, 1951.
Member, editorial advisory committee, Archaeologica Orientalia in Memoriam Ernst Herzfeld.
Member, editorial advisory committee, Studies in Art and Literature in Honor of Belle DaCosta Greene.

Mr. Gettens: Associate editor, Studies in Conservation; new journal being published for the International Institute for the Conservation of Museum Objects.
Abstractor for Chemical Abstracts, American Chemical Society.

Respectfully submitted.

JOHN A. POPE, *Acting Director.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 5

Report on the Bureau of American Ethnology

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1952, conducted in accordance with the act of Congress of April 10, 1928, as amended August 22, 1949, which provides for continuing "independently or in cooperation anthropological researches among the American Indians and the natives of lands under the jurisdiction or protection of the United States and the excavation and preservation of archeologic remains."

Information was furnished during the year by members of the Bureau staff in reply to numerous inquiries concerning the American Indians, past and present, of both continents. The increased number of requests from teachers of primary and secondary grades and from Scout organizations indicates a rapidly growing interest in the American Indian. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

SYSTEMATIC RESEARCHES

Dr. M. W. Stirling, Director of the Bureau, devoted most of his time during the fiscal year to administrative affairs and to the preparation of manuscript on previous field studies in Panamá and southern México. During the year he prepared three reports for publication: "Stone Monuments of the Río Chiquito, México," "The Use of Jade in Aboriginal America," and "An Archeological Survey of Southern Veracruz, Tabasco, and Northern Campeche."

Dr. Frank H. H. Roberts, Jr., Associate Director of the Bureau and Director of the River Basin Surveys, devoted most of his time during the year to the management and direction of the River Basin Surveys. In August he went to Lincoln, Nebr., to inspect the Missouri Basin headquarters. From Lincoln, accompanied by Paul L. Cooper, field director, he proceeded to the Fort Randall Reservoir area near Chamberlain, S. Dak., and visited a number of archeological sites that were being excavated by field parties of the River Basin Surveys and also the excavations being conducted by the Nebraska State Historical Society. He also took part in a conference on local archeological problems held at the field camp of the University of Kansas party

which was excavating an Indian village site as part of the cooperative program of the National Park Service. From the Fort Randall area he proceeded to the Oahe Reservoir area north of Pierre, S. Dak., where he visited two River Basin Surveys excavating parties. From Pierre he proceeded to Cody, Wyo., in company with Dr. Waldo R. Wedel, curator of archeology, United States National Museum, to inspect an archeological site on Sage Creek where remains of early man had been found. The purpose of that trip was to assist in planning a series of investigations to be carried on there during the field season of 1952 as a cooperative project between the Smithsonian Institution and Princeton University. Returning to Pierre, Dr. Roberts held a number of conferences with staff members to discuss the plans and operations of the salvage program in that area. During the fall and winter months he made several trips to the Missouri Basin headquarters at Lincoln. In March he went to Columbus, Ohio, and delivered a lecture on "Early Man in the New World" before the Ohio State Historical Society at the State museum. He returned to Columbus in May to attend the annual meeting of the Society for American Archaeology and to take part in a symposium dealing with the carbon-14 method for dating archeological remains. During the year Dr. Roberts completed two manuscripts: "River Basin Surveys: The First Five Years of the Inter-Agency Archeological and Paleontological Salvage Program" and "The Carbon-14 Method of Age Determination," both of which were published in the 1951 Smithsonian Annual Report. During the year Dr. Roberts received the Viking Fund Medal and Award of the Wenner-Gren Foundation for Anthropological Research for his work in American archeology.

Dr. Henry B. Collins, anthropologist, continued his research on the Eskimo and other Arctic activities. Through arrangements with the National Museum of Canada, his assistant of 1950, William E. Taylor, returned to Cornwallis Island in the Canadian Arctic for further excavations. Mr. Taylor's collections, including Thule and Dorset culture materials, with notes and photographs, were received by Dr. Collins for inclusion in the final report on the Cornwallis Island work. Preliminary reports on the first two seasons' excavations on Cornwallis Island were published in the annual reports of the National Museum of Canada for the fiscal years 1949–50 and 1950–51. A general article, "The Origin and Antiquity of the Eskimo," summarizing the present evidence of archeology, physical anthropology, and linguistics, was published in the 1950 Smithsonian Annual Report. A paper on the present status of the Dorset culture, with special emphasis on new evidence from Greenland and Alaska, which was presented at the December 1951 meeting of the American Association for the Advancement of Science, will be included in a volume on American archeology

being published by the Wenner-Gren Foundation for Anthropological Research. At the meeting of the Society for American Archaeology in May 1952 Dr. Collins presented a paper summarizing and evaluating the results of radiocarbon dating in the Arctic in the light of the archeological evidence, and including an interpretation of the ancient Denbigh Flint Complex of Alaska, its Old World connections and age, and its relationships to Folsom, Yuma, and Eskimo. The paper will appear in the January issue of American Antiquity. An article on the progress of anthropology in 1951 was prepared for the Encyclopaedia Britannica and another on the Races of Asia for the Encyclopaedia Hebraica. He also edited Science in Alaska, a volume of selected papers presented at the First Alaskan Science Conference held in Washington in November 1950 under the auspices of the National Academy of Sciences–National Research Council. The volume was published by the Arctic Institute of North America and contains papers on Alaskan anthropology, agriculture, botany, geology and geography, geophysics, meteorology, public health, and zoology. Dr. Collins continued to serve as chairman of the directing committee supervising preparation of Arctic Bibliography, a comprehensive, annotated, and indexed bibliography of English and foreign-language publications in all fields of science relating to the Arctic and sub-Arctic regions of America, Siberia, and Europe. The bibliography is being assembled by the Arctic Institute of North America under contract with the Office of Naval Research with funds from the Departments of the Army and the Navy, and the Defense Research Board of Canada. At the end of the fiscal year material for a supplemental volume of about 900 pages was completed and ready for the printer. Proofreading continues on the initial six volumes of similar size now at the Government Printing Office.

At the beginning of the fiscal year Dr. John P. Harrington was in México engaged in studying the Maya language. On his return to Washington he completed the preparation of a grammar and dictionary of the Maya language, with the assistance of a Maya informant, Domingo Canton Aguilar, whom he brought to Washington for that purpose. He also completed a monograph on the numeration system of the Valladolid Maya Indians of Yucatán. Another paper he completed during the fiscal year was on the first vocabulary of the Virginia Indians, compiled by William Strachey in 1612. The original of this vocabulary is in the Bodleian Library at Oxford, England.

At the beginning of the fiscal year and until after Labor Day, Dr. William N. Fenton was visiting professor of anthropology at the University of Michigan. During his stay in Ann Arbor he examined important historical papers relating to the political history of the

Six Nations, or Iroquois, in the William L. Clements Library of the University of Michigan. Returning to Washington in September, Dr. Fenton resumed his research at the Bureau of American Ethnology. He organized and conducted the Seventh Conference on Iroquois Research held at Red House, N. Y., October 5–7. In November he participated in a symposium on the training of professional anthropologists, which was held on the occasion of the annual meetings of the American Anthropological Association. Late in November Dr. Fenton was called to the National Research Council to organize a national conference on disaster studies, in which he participated on December 6. He resigned his position with the Bureau to accept an appointment as executive secretary of the Division of Anthropology and Psychology at the National Research Council and began his duties on January 1, 1952.

Dr. Philip Drucker reported for duty as general anthropologist on January 3, 1952, immediately following his release to inactive duty by the United States Navy. On February 15 he proceeded to México D. F., for a period of 6 weeks, which he spent studying the large offering of artifacts of jade and similar materials excavated in 1941 at Cerro de las Mesas by the National Geographic-Smithsonian Institution archeological project. This collection is housed in the National Museum of Mexico. On his return to Washington he prepared a descriptive monograph on the collection, which was ready to be submitted to the Director of the Bureau at the end of the fiscal year. In addition, Dr. Drucker continued his studies of Meso-American archeology in general.

RIVER BASIN SURVEYS

(Report prepared by FRANK H. H. ROBERTS, JR.)

The River Basin Surveys, organized in the autumn of 1945 as a unit of the Bureau of American Ethnology to carry into effect a memorandum of understanding between the Smithsonian Institution and the National Park Service, continued its operations throughout the year. The memorandum provides for the salvage of archeological and paleontological materials that would otherwise be lost as a result of numerous projects for flood control and irrigation, hydroelectric installations, and navigation improvements in the river basins of the United States. As in the past, the investigations were conducted in cooperation with the National Park Service and the Bureau of Reclamation of the Department of the Interior, the Corps of Engineers of the Department of the Army, and a number of nongovernmental local institutions. The operations as a whole are called the Inter-Agency Archeological and Paleontological Salvage Program.

The work of the River Basin Surveys in the past fiscal year was financed by a transfer of $156,403 to the Smithsonian Institution by the National Park Service. Of that amount $120,783 was for investigations in the Missouri Basin and $35,620 was for all other areas where projects were under way. The money comprising those funds was derived in part from the Bureau of Reclamation and in part from the National Park Service. Carry-over of previous funds provided an additional $77,576 for the Missouri Basin and $350 for other areas. The total of all funds available for the year was $234,329. Because of a delay in the passage of the appropriation bill it was necessary to suspend operations outside the Missouri Basin during July and August.

Activities in the field consisted of reconnaissance or surveys for the purpose of locating archeological sites and paleontological deposits that will be involved in construction work or are so situated that they will be flooded, and in the excavation of sites observed and recorded by previous surveys. In contrast to former years there was greater emphasis on excavation. This was because of the fact that the survey parties were finally catching up with the over-all program and there were fewer proposed reservoir areas needing attention. Archeological survey parties visited 10 new reservoir basins located in 6 States and a paleontological party made preliminary investigations at 6 reservoirs in 3 States. In addition a number of reservoirs where previous preliminary surveys had been made were revisited for further checking. At the end of the fiscal year excavations were completed or under way in 13 reservoir areas in 11 States. There were 22 excavating parties in the field during the course of the year. Six of the excavating projects were in areas where there had been no previous digging, but the remainder were a continuation of investigations at reservoir projects where there had been other operations. At the close of the fiscal year the total of the reservoir areas where archeological surveys had been made or excavations carried on since the start of the actual field work in the summer of 1946 was 235 located in 25 States. The survey parties have located and reported 3,105 archeological sites, and of that number 578 have been recommended for excavation or limited testing. Preliminary appraisal reports were completed for all the reservoirs surveyed. Some, together with others finished near the end of the previous fiscal year, were mimeographed for limited distribution to the cooperating agencies. During the year 15 such reports were distributed, bringing to 149 the total issued since the start of the program. The discrepancy between the latter figure and the total number of reservoirs is due to the fact that in some cases a series of reservoirs is included in a single report covering a subbasin, while in others the

completed manuscripts had not yet been mimeographed at the close of the year. Excavations made during the year brought the total for reservoir basins where such work has been done to 38, located in 17 States. Reports on some of that work have been published in various scientific journals, and eight such papers are now in press as a Bulletin of the Bureau of American Ethnology. The technical reports on two other excavation projects have been finished. Paleontological surveys have been made in 121 reservoir areas, 86 of them being those where archeological work has also been done. Eventually the other 35 will be visited by archeological parties. The total of all reservoir basins surveyed, including those where archeological work still remains to be done, is 270.

As of June 30, 1952, the reservoir projects which had been surveyed for archeological remains were distributed by States as follows: California, 20; Colorado, 24; Georgia, 4; Idaho, 11; Illinois, 2; Iowa, 3; Kansas, 7; Kentucky, 1; Louisiana, 1; Minnesota, 1; Montana, 15; Nebraska, 28; New Mexico, 1; North Dakota, 13; Ohio, 2; Oklahoma, 7; Oregon, 27; Pennsylvania, 2; South Dakota, 9; Tennessee, 1; Texas, 19; Virginia, 2; Washington, 11; West Virginia, 2; Wyoming, 21. Excavations have been made or were being made in reservoir areas in: California, 5; Colorado, 1; Georgia, 3; Kansas, 1; Montana, 1; Nebraska, 1; New Mexico, 1; North Dakota, 3; Oklahoma, 2; Oregon, 2; South Carolina, 1; South Dakota, 3; Texas, 7; Virginia, 1; Washington, 3; West Virginia, 1; Wyoming, 2. The foregoing figures refer only to the work of the River Basin Surveys or that which was done in direct cooperation with local institutions. Projects carried on by local institutions alone or in direct cooperation with the National Park Service are not included because complete information about them was not available.

Throughout the year the River Basin Surveys continued to receive helpful cooperation from the National Park Service, the Bureau of Reclamation, the Corps of Engineers, and numerous State and local institutions. At a number of projects guides and transportation were furnished to staff members in the field. Temporary office and laboratory space was provided at others, and on several occasions labor and mechanical equipment were made available by the construction agency. Such assistance speeded up the work of the field men and made possible greater accomplishment than would otherwise have been the case. The National Park Service continued to serve as the liaison between the various agencies both in Washington and through its several regional offices and provided the Smithsonian Institution with necessary information about the locations for proposed dams and reservoirs and construction priorities. Furthermore, the National Park Service primarily was responsible for obtaining the funds which

made the operations possible. The progress of the program as a whole was greatly furthered by the enthusiastic help of Park Service personnel.

General direction and supervision of the work in California, Georgia, and Virginia were from the main office in Washington. In the Columbia Basin the program was directed from a field office and laboratory at Eugene, Oreg.; that in the Missouri Basin was under the supervision of a field office and laboratory at Lincoln, Nebr.; and that in Texas was under a field office and laboratory at Austin. The materials collected by the survey and excavating parties in those three areas were processed at the respective field laboratories. The collections made in Georgia were processed at a laboratory in Athens.

At the end of the fiscal year a change was made in the plan of operations for the Inter-Agency Salvage Program. The work of the River Basin Surveys was terminated in the Columbia Basin and Pacific coast areas, in the Southwest including Texas, and in Georgia and other portions of the Southeast. With the beginning of the new fiscal year the direction and supervision of the investigations in those areas were to be under the National Park Service with its respective regional offices in direct charge. At the close of the year arrangements were being made to transfer certain of the River Basin Surveys' personnel to the National Park Service and for the latter agency to take over the various field headquarters.

Washington office.—Throughout the fiscal year the main headquarters of the River Basin Surveys continued under the direction of Dr. Frank H. H. Roberts, Jr. Carl F. Miller, Joseph R. Caldwell, and Ralph S. Solecki, archeologists, were based on that office. Because of lack of funds for work outside the Missouri Basin, however, Miller was assigned to the Missouri Basin project during July, August, and September, and Caldwell was on leave without pay until September 10, 1952. Solecki was on leave of absence with an expedition to Iraq for most of the year, returning to duty with the surveys in May.

Mr. Miller's activities in the Missouri Basin are discussed in that section of this report. During the fall and winter months at the Washington office he completed his technical paper on the excavations he supervised at the Allatoona Reservoir in Georgia during an earlier fiscal year and processed specimens from sites which he dug at the John H. Kerr (formerly called Buggs Island) Reservoir the latter part of the previous fiscal year. In May he returned to the John H. Kerr Reservoir area on the Roanoke River in southern Virginia and carried on test excavations at a number of sites. That work was completed on June 30 and Mr. Miller returned to Washington. The gates of the dam were scheduled to be closed early in July, and no further investigations are planned for that area.

Early in August Mr. Caldwell received word that an important site located a short distance above the Clark Hill Dam on the Savannah River, Ga., would be inundated well in advance of the date originally indicated by the engineers. With funds provided by the Smithsonian Institution and the University of Georgia and with the help of the resident engineer of the Corps of Engineers, he started excavations on the 18th of the month and continued to dig until he and his party were driven out by water at the end of October. When Federal funds became available in September the River Basin Surveys took over the financing of the project. During January and February Mr. Caldwell carried on test excavations at the remains of Fort Charlotte at the upper end of the Clark Hill Reservoir in South Carolina. While at his headquarters at Athens, Mr. Caldwell completed five preliminary reports and made considerable progress on the final technical report of his part of the excavations at the Allatoona Reservoir. The report on Fort Charlotte was mimeographed and ready for distribution at the close of the fiscal year. An article on work completed a previous fiscal year, "The Booger Bottom Mound: A Forsyth Period Site in Hall County, Ga.," was published in American Antiquity, volume 17, No. 4, April 1952. Mr. Caldwell's employment by the River Basin Surveys was terminated as of June 30, 1952, by his transfer to the National Park Service.

Dr. Theodore E. White, geologist, divided his time between the Washington office and the Missouri Basin. He spent the winter and early spring months in Washington cleaning, identifying, and cataloging specimens he had collected during the field season. He also identified four lots of mammal bones from archeological excavations along the Columbia River, and four lots of bones from the Missouri Basin which were sent to Washington for that purpose. He completed a manuscript, "Preliminary Analysis of the Vertebrate Fossil Fauna of the Canyon Ferry Reservoir Area," which was accepted for publication in the Proceedings of the United States National Museum, and two papers on observations on the butchering techniques of aboriginal peoples as indicated by the bones from the refuse deposits at archeological sites. One paper, "Preliminary Analysis of the Vertebrate Fossil Fauna of the Boysen Reservoir Area," was published in the Proceedings of the United States National Museum, volume 102, No. 3296, April 1952. Another, "Observations on the Butchering Technique of Some Aboriginal Peoples, I," appeared in American Antiquity, volume 17, No. 4, April 1952. A third, "Suggestions for Facilitating Identification of Animal Bone from Archeological Sites," was printed in the Plains Archeological Conference News Letter, volume 5, No. 1, May 1952. In May Dr. White left Washington to continue his field investigations in the Missouri Basin.

After his return to active duty Mr. Solecki spent the time until June 30 working on manuscripts and reports. He also made preparations for an aerial survey of certain reservoir areas in the Missouri Basin and was to proceed to the latter area at the beginning of the new fiscal year.

California.—The only work in California during the fiscal year was at the Cachuma Reservoir on the Santa Ynez River in Santa Barbara County. From April 28 to June 30 Albert D. Mohr, field assistant, supervised excavations at two sites. At one of them a cemetery belonging to what is called the Hunting Culture, the middle stage of a three-culture sequence, was dug, and in addition the remains of a house belonging to the same horizon were uncovered. The latter are of particular interest because only two such structures were known previously and the one discovered this year has added considerable information with respect to construction methods. Opening of graves in the cemetery produced skeletal material useful in determining the physical characteristics of the people and also good data on burial customs. The other site, also mainly a burial ground, belongs to a later horizon probably attributable to the Chumash.

A report by Martin A. Baumhoff, field assistant the previous year, on the investigations at the Cachuma Reservoir in late fiscal 1951 was completed early in June 1952 and the manuscript is now available for publication. A summary report on the results of the excavations made at the Terminus Reservoir on the Kaweah River in Tulare County was completed by Franklin Fenenga, archeologist, during the autumn months and was published in American Antiquity, volume 17, No. 4, April 1952.

As indicated in the preliminary section of this report, the River Basin Surveys will have no further projects in California, as the operations there are to be under the direction and supervision of the Region Four office of the National Park Service.

Columbia Basin.—The field office at Eugene, Oreg., was closed from July 1 to September 10 because of lack of funds, and during that period there were no activities in the region. After the office was reopened and until the close of the fiscal year the operations for the Columbia Basin were, as in the previous year, under the supervision of Joel L. Shiner. Office and laboratory work during the fall and winter months was mainly concerned with the processing, study, and cataloging of materials from the surveys and excavations of the previous year. Most of the materials and data were from a habitation site in the McNary Reservoir area which had been buried beneath a thick mantle of volcanic ash which is estimated to be several thousand years old. A summary report on the results of that excavation was finished, mimeographed, and distributed to the operating agencies. Study of the materials from another site in the McNary area, a village

of late prehistoric and early historic times, was also completed and a summary report finished. The latter was mimeographed and distributed in June.

Late in October Mr. Shiner made a brief investigation at the site of The Dalles Dam on the Columbia River and in March made an exhaustive survey of the area to be flooded. A brief preliminary report was issued after the first visit, while a second and more detailed one was written and mimeographed following the investigations in March. The survey showed that there were 10 sites and that 3 were worthy of further investigation. One of them is a very large mound with stratified deposits some 15 feet in depth. It offers one of the best opportunities along the Columbia River for obtaining evidence on the sequence of cultural development. This mound, the Wakemap, is in danger from two sources, flooding and looting by private collectors. The situation with respect to unauthorized digging was so critical that plans were being made to start excavations there shortly after the beginning of the new fiscal year. Two other sites in the area were tested later in the spring and one of them proved to be much deeper and richer in artifacts than had been anticipated. One test pit, 5 feet square, yielded large numbers of flaked-stone tools and "fetish" stones and reached a depth of 13 feet. More extended excavations at that location are indicated.

From April 7 to 19 Mr. Shiner carried on test excavations at three sites in the McNary area. One of them consisted of an occupation level underlying the same layer of volcanic ash as that covering the site worked the previous year. The findings corroborated those of the previous year and in addition the digging produced several new artifact types. At another it appeared that the Indians who had occupied it moved in shortly after the fall of the ash. The interval represented by the ash layer will help to explain certain differences in the artifacts and provides a good basis for establishing relative dating in the district. Excavations at the third site proved fruitless. The latter part of April Mr. Shiner moved his field party to the Albeni Falls Reservoir project on the Pend Oreille River in Idaho for the purpose of testing a number of sites in that basin. The occupational debris at the various locations was found to be so shallow, however, that extensive digging was not warranted. Consequently the party spent several days making surface collections. A good series of specimens was obtained which will be useful in extending the known distribution of types. The data collected indicate that the area never had a permanent population. It apparently was a place where various groups of Indians spent their summers hunting, fishing, and gathering food.

After returning to the office Mr. Shiner devoted most of his time to processing the artifacts collected in the field. Over 1,500 were

cleaned and cataloged. A report on the investigations at Albeni Falls was completed and one on the test digging at The Dalles was practically finished by the end of the year. A collection of specimens from a previous year's digging in the McNary Reservoir was packed and shipped to Washington.

Four articles pertaining to the results of previous work in the Columbia Basin were published in American Antiquity, volume 17, No. 4, April 1952. They were: "The 1950 Excavations at Site 45BN6 McNary Reservoir, Wash.," by Joel L. Shiner; "Material Culture of an Upper Coulee Rock-shelter," by John E. Mills and Carolyn Osborne; "Archeological Investigations in the Chief Joseph Reservoir," by Douglas Osborne, Robert Crabtree, and Alan Bryan; and "Archeological Investigations in O'Sullivan Reservoir, Grant County, Wash.," by Richard D. Daugherty.

Mr. Shiner's affiliation with the River Basin Surveys terminated on June 30 by transfer to the National Park Service. The River Basin Surveys office at Eugene was to be kept open, however, by the National Park Service, and Mr. Shiner was to be permitted to complete his reports on the work he did for the Smithsonian Institution. The River Basin Surveys will have no further operations in that area.

Georgia.—As in the case of the Columbia Basin, field work in the Georgia area was handicapped by the delay in obtaining funds and the limited amount of money available for the project. During the period from August 18 until the end of October an emergency cooperative excavation project, as described in an earlier section of this report, was carried on at the Lake Springs site on the Savannah River just above the Clark Hill Dam. A large sample of archaic material representing a prepottery horizon called the Savannah River Focus of the Stalling's Island Culture was obtained there together with a small series of contemporary crania showing a population of both round- and long-headed individuals. The most important discovery at the site, however, was a new early culture deep below the archaic levels. This new manifestation, which has been designated the Old Quartz Culture, showed an artifact assemblage similar to those which had been found at a large number of open stations in Piedmont Georgia and South Carolina. They have been regarded as probably early but could not be so proven until the discovery of the stratigraphy at Lake Springs. Unfortunately, the rising waters of the Clark Hill Reservoir flooded the excavation pits before as much work had been done as was desired, but the results obtained are a definite contribution to the archeology of the region.

In late January and February test excavations were carried on in the remains of Fort Charlotte at the upper end of the Clark Hill Reservoir in South Carolina. Although located in the latter State

the investigations were considered as part of the over-all Georgia project. The outline of the fort was traced and a few minor artifacts were recovered. The fort had been a masonry structure erected in 1765 as a defense against the Creek and Cherokee Indians who were prone to raid the Scotch-Irish, French Huguenot, and German settlements in the Long Canes region of upper Carolina. Its seizure by patriot forces in 1775 was the first overt act of revolution in the southern colonies. American possession of the fort throughout the struggle was of considerable importance in holding the loyalties of the inhabitants of upper Carolina during the troubled times that followed. The recent excavations there give information about the physical nature of the fort and its location which was not available in documentary records. Underlying the occupation level of the fort were Indian materials indicating that the location had also been a place where the aborigines held forth. Pottery fragments suggest that the Creeks were the tribe involved. There is no question but what the Indian material is some years, possibly a good many, older than the fort and that the site was deserted at the time it was chosen for the location of Fort Charlotte.

There will be no further work in Georgia under the direction and supervisions of the River Basin Surveys, unless there are further changes in present plans. As indicated earlier in this report Mr. Caldwell's employment terminated on June 30 and he was transferred to the National Park Service. He will be permitted, however, to complete his technical reports on work done under the Smithsonian Institution and the manuscripts will be turned over to the River Basin Surveys.

Missouri Basin.—The Missouri Basin project as in previous years continued to operate from the field headquarters at Lincoln, Nebr. Paul L. Cooper served as director for the program in that area from July 1 until February 28 when, in accordance with his request to be relieved of administrative duties, Ralph D. Brown took charge. Certain changes were made in the organization at that time and Mr. Brown was designated as chief of the Missouri Basin project, the old title of field director being dropped. Mr. Cooper remained with the organization and was assigned to the position of consulting archeologist. The trend toward more excavation and less reconnaissance or survey work, started the previous year, continued and increased in fiscal 1952. This is attributable to the fact that much has been accomplished in the survey portion of the program and there is less need for that kind of activity than in previous years. Furthermore, the available funds were sufficient to provide for extensive excavations. During the course of the year the staff was able to devote a greater proportion of its time to the study of data and specimens and in the preparation of technical reports.

During the year archeological surveys were conducted in five new reservoir areas of which three were in Wyoming, one was in Montana, and one in Nebraska–South Dakota. Others where the preliminary reconnaissance had not been completed were revisited and a total of 115 new sites was recorded. In the 1951 field season archeological excavations were made in four reservoir areas by seven different units. By the end of June 1952 there again were seven archeological excavation parties working in four reservoir areas, three of them the same as in the previous year. Digging at the Keyhole Reservoir in Wyoming was completed in 1951 and excavations in the Jamestown Reservoir in North Dakota were started in 1952. The other three are Fort Randall and Oahe in South Dakota, and Garrision in North Dakota. During the year there were paleontological investigations in 12 reservoir areas. An archeological survey party was scheduled to start for the field in late June but because of an emergency was delayed and its departure rescheduled for the first week in July.

At the Fort Randall Reservoir in South Dakota the 1951 excavations were at an Indian site and at a historic trading-post site. The Indian site is of particular interest because it represents three occupational periods. One was a fortified earth-lodge village, one an unfortified earth-lodge village, and the third an occupational area underlying both of the others. In the fortified area 7 earth lodges, a smaller structure, 450 feet of stockade trench, 11 cache pits, and 22 refuse areas were exposed and excavated. In the unfortified earth-lodge area, one circular earth lodge, one cache pit, and four refuse pits were unearthed. In May 1952 excavations were resumed in the unfortified area and before the end of June had exposed 2 earth lodges, a refuse midden, and 19 exterior pits. The date of the fortified village was earlier and the occupational area beneath much older still. Completion of the work at that location will provide an excellent sequence of materials leading up to the development of fortified villages in that district.

The historic work in the Fort Randall Reservoir in 1951 was at the location of the Fort Lookout trading post. The occupational level of the post was established. Charred beams used in construction, sections of vertical posts still in place, and other architectural features were uncovered, along with numerous specimens of trade goods. Two Indian occupational levels antedating the establishment of the trading post and the nearby fort were found beneath the ruins of the post. They are of interest because they produced materials not previously known in that part of South Dakota. In May 1952 historic investigations were resumed, but they were at the site of the Whetstone agency which was established for the Brule and Ogallala bands of Sioux from the Fort Laramie region by a treaty drawn in April

1868. By 1869 about 1,000 Indians were living there, and by 1870 the number had increased to about 2,250. One year later the Indians were moved to a new location but the agency buildings continued in use through the later 1870's as a steamboat landing for supplies to be conveyed overland to Indian agencies in the interior. Little is known about the physical characteristics of the agency or of the Indian camp, and digging there should provide interesting data to augment the documentary records. By the end of June floor areas had been uncovered and cedar post butts in palisade trenches were exposed. Work at that site is scheduled to continue until it is completed, which probably will be at about the end of the current field season.

In the Oahe Reservoir area during the 1951 field season excavations were carried on at two Indian sites. One of them is located just below the dam in an area which will ultimately be destroyed by construction activities, while the other is several miles upstream on the west bank just below the point where the Cheyenne River empties into the Missouri. At the first location, known as the Phillips Ranch site, 5 earth lodges and 47 cache pits were uncovered, 2 trenches were dug across the fortification ditch which surrounded the village, and the refuse-bearing overburden was stripped from approximately one-eighth of the village area. During the previous year 5 lodges and 46 cache pits had been dug, so the total for the village was 10 houses and 96 cache pits. A large collection of specimens was obtained there, the most outstanding probably being a few small fragments of coiled basketry. The latter is extremely rare in archeological sites in the Plains area. The data obtained from the site provided the basis for establishing a previously unrecognized cultural complex for the district. It appears to date from the early part of the eighteenth century and almost certainly represents the protohistoric Arikara occupation of the area. Excavations at the Phillips Ranch site have been completed.

The other site, known as the Cheyenne River village, was only partially dug and will be completed at a later date. The work there consisted of the excavation and mapping of four house sites (a fifth was nearly finished when heavy storms flooded it so badly that it had to be abandoned) and the digging of cache pits. Cultural materials from house sites and cache pits were recovered in large quantities and preliminary studies indicate that they will provide much new information about the arts and industries of their makers.

The 1952 excavations in the Oahe Reservoir were started at new sites. One of them, which had been partly destroyed by construction activities, is on the east bank of the Missouri River opposite the Phillips Ranch site, while the other, which represents a large village, is located not far downstream from the Cheyenne River village.

Work had not progressed sufficiently at either location by the end of the fiscal year to indicate what results might be expected.

At the Garrison Reservoir in North Dakota two excavating parties spent the 1951 field season digging in Indian and historic sites. At one Indian village location the remains of 8 circular houses, 4 sweat lodges, 48 cache pits, and numerous other miscellaneous features were uncovered. The artifact yield was good, including uncommon steatite fragments from bowls made from that material. The bowls probably reached the area by trade from the west. They may have come up the Columbia and down the Missouri as that was a main aboriginal trade route. During the 1950 field season at that location five houses were excavated and the palisade and moat were traced. The combined data for the two seasons give a satisfactory story of the village and its material culture. The village was reputedly occupied in the late eighteenth century by the Hidatsa Indians and is particularly interesting because it presumably was the most northerly of the fortified earth-lodge communities belonging to the period preceding the replacement of aboriginal material culture by trade goods obtained from the white man. The other site investigated had also been a fortified village. Five houses and parts of a sixth were excavated there, and a ceremonial structure 72 feet in diameter, a large village gateway, and several other features were found. Cross sections were taken of the surrounding defensive ditch. This site, believed to have been occupied chiefly by the Arikara Indians, produced relatively few artifacts but it throws valuable light on the architecture and community plan of the period. In June 1952 an excavating party proceeded to the Night Walker's Butte to begin digging the remains of one of the few known Indian villages located on top of a butte.

The historic-sites party spent the period from July 1 to October 7, 1951, in the excavation of Fort Stevenson, a mile above the Garrison Reservoir dam site. The foundations of five of the more important military buildings and of several minor ones were traced and a considerable quantity of materials was obtained. Fort Stevenson was a typical Missouri River frontier post and was built to keep the river open for navigation and to protect the Fort Berthold Indians from the Sioux. In addition the post served as one of the main points on the overland mail route which ran from St. Paul to Montana. Although the fort was started in 1867 and was completed late in 1868 and there are considerable documentary data about it, useful new information pertinent to the actual character of the post and certain Indian relationships was obtained during the course of the work. Before stopping for the season the Fort Stevenson party made tests in a trading-post site at the mouth of the White Earth River and obtained some trade goods. The historic-sites party returned to the Garrison area in June 1952 and began work at a site in the Fort Berthold district.

From July 1 to September 25, 1951, six key sites were excavated in the Keyhole Reservoir on the Belle Fourche River in Crook County, Wyo. The excavated sites include one large protohistoric camp with pottery remains, three prehistoric camp sites, and two stratified rock shelters. The lowest levels in both rock shelters are manifestations of a new early-man complex. The data indicate that the aboriginal occupation of the Keyhole area may have started about 5,000 years ago. Much more recent materials were found in the upper levels and in a few cases there were potsherds from vessels of the so-called Woodland types. The latter are significant because they extend considerably westward the known range of that kind of Indian pottery. The investigations at the Keyhole Reservoir have been completed.

The Jamestown Reservoir on the river of the same name in North Dakota was listed for investigation for the first time since the start of the program. A survey party was supposed to make a reconnaissance there in the fall of 1951 but because of bad weather was unable to do so. As a consequence a combined survey and excavating party went there in May 1952. After 3 weeks' preliminary examination of the area and 18 sites had been located, excavations were started in a mound 75 feet in diameter and 10 feet in height located on a bluff, and in some house remains on the bottom lands. The mounds in that portion of North Dakota show considerable similarity to those in northern Minnesota and southern Manitoba and all probably belong to the same cultural complex. The actual people involved have not been identified as yet, and as little is known about the character of the remains the results of the investigations there should add materially to knowledge about the Indians. The work there had not progressed sufficiently by June 30 to permit a statement about the findings.

During the 1951 field season the paleontological party visited and collected in five reservoir areas, two in Montana, one in North Dakota, and two in South Dakota. In exploring the Oligocene and Miocene deposits in the Canyon Ferry Reservoir basin in Montana the party added two genera of small mammals to the known fauna of the Oligocene and six genera of those of the Miocene. While the sediments of the Montana group of the the Upper Cretaceous were being studied near the dam for the Oahe Reservoir, S. Dak., the first nearly complete skeleton of one of the pygmy species of mosasaur, genus *Clidastes*, ever obtained was found. The 1952 field season's work started with a preliminary reconnaissance of the Tuttle Creek and Lovewell Reservoir basins in the Kansas River drainage, Kansas, and was followed by surveys of three reservoir areas in the Platte Drainage. They were the Narrows in Colorado, and the Ashton and Trenton in Nebraska. Preliminary prospecting was also carried on at the Gavins

Point Reservoir on the Missouri River in Nebraska and South Dakota. The first of June found the party at the Keyhole Reservoir in Wyoming exploring Cretaceous sediments and the latest report is that most of the skeleton of a small plesiosaur was found in the Newcastle member of the Granerose shale, the first record of vertebrate remains from that formation. On June 25 the party moved to the Canyon Ferry Reservoir in Montana and was just starting work there at the end of the fiscal year.

During the course of the year seven preliminary appraisal reports were completed, mimeographed, and distributed to the cooperating agencies; four were completed and are ready for mimeographing; and two supplements to previous reports were finished and are awaiting mimeographing. Four short articles on specific subjects in Plains archeology were prepared by members of the staff and published in the Plains Archeological Conference News Letter. Two articles were published in American Antiquity and one report appeared in the Proceedings of the U. S. National Museum. One technical report on excavations in the Oahe area was completed and the first drafts of those on two others have been finished.

The laboratory at Lincoln processed 87,935 specimens from 170 sites in 18 reservoir areas and 2 sites not in reservoir areas. The work in the laboratory also included: reflex copies of record sheets, 21,444; contact prints made, 8,826; negatives, 2,036; enlargements, 1,326; specimens drawn for illustrations, 872; color transparencies cataloged, 321; drawings, tracings, maps made, 112.

Robert B. Cumming, Jr., archeologist, was in charge of the survey and excavation of aboriginal archeological sites at the Fort Randall Reservoir in South Dakota from July 1 to November 6 and from May 19 to the end of the fiscal year. During the winter months at the Lincoln headquarters Mr. Cumming worked on the technical report on the Oldham site, the scene of most of his activities during the 1951 summer field season.

Paul L. Cooper, archeologist, served as field director for the Missouri Basin activities during the period from July 1 to February 28. On the latter date he became consulting archeologist for the project. During the spring months Mr. Cooper devoted considerable time to discussing the project with Mr. Brown, the new chief, and in consultation with other members of the staff on archeological procedures in the laboratory. He completed a report of progress for the period from the beginning of the project in 1946 through April 1952 for the Interior Missouri Basin Field Committee. He also worked on a more detailed report covering the calendar years 1950 and 1951. He met with the Interior Missouri Basin Field Committee at its April session where he evaluated the progress made to that date by the

River Basin Surveys of the Smithsonian Institution and took part in a discussion of the future needs of the salvage program. Mr. Cooper served as the chairman of the Ninth Conference for Plains Archeology, which met at Lincoln in April. On June 6 he left Lincoln for the Oahe Reservoir in South Dakota and at the end of the fiscal year was directing a party excavating aboriginal sites along the Missouri below the mouth of the Cheyenne River.

Franklin Fenenga, archeologist, was in charge of a reconnaissance party from the beginning of the fiscal year until September when he returned to the Lincoln office. During the field season his party visited 15 proposed reservoir areas. Probably the most interesting part of the season was that devoted to a boat trip down the Bighorn River Canyon in Wyoming-Montana to examine the area of the proposed Yellowtail Reservoir. On June 8 he went to the Oahe Reservoir and started a series of excavations near the dam site a few miles above Pierre, S. Dak. Those activities were well under way by June 30. During the months spent at the headquarters in Lincoln Mr. Fenenga prepared preliminary appraisal reports for seven reservoir projects. He presented two papers before the Ninth Conference for Plains Archeology, and served as editor of the News Letter for that conference. He was reelected to that office for the year 1952–53. He also read a paper before the 62d annual meeting of the Nebraska Academy of Sciences. During the 1952 meeting of the Academy he served as acting chairman of the anthropological section and was elected its chairman for 1953. Mr. Fenenga had two papers published during the year: "The Archeology of Slick Rock Village, Tulare County, California," American Antiquity, volume 17, No. 4, April 1922, and "The Wabino, a One-time Rival of the Midewiwin," Proceedings of the Nebraska Academy of Sciences, 62d Annual Meeting, 1952.

Donald D. Hartle, archeologist, was in charge of an excavating party at the Rock Village site in the Garrison Reservoir area of North Dakota from July 1 to August 20. From August 20 to October 27 he directed the excavations at the Star site in the same reservoir basin. The latter part of October, in collaboration with James H. Howard of the North Dakota State Historical Society, he recorded 12 Indian songs, including several of those known as "Custer" songs. Two Arikara Indians, Jonie Fox and Davis Paint, did the singing for Hartle and Howard. From November 1 to June 1, Hartle spent his time at the Lincoln headquarters studying his materials from the Rock Village and preparing a technical report on the results of his investigations. Further work was contemplated at Rock Village and the manuscript could not be finished until that was done. Hartle left Lincoln on June 2 with a party to continue his studies at Rock Village and by the end of the month had completed the additional excavations.

Mr. Hartle presented a paper on the investigations at Rock Village before the Ninth Conference for Plains Archeology at Lincoln in April.

Donald J. Lehmer, archeologist, conducted excavations from July 1 to September 10 at the Phillips Ranch site in the Oahe Reservoir near Pierre, S. Dak. Returning to Lincoln from South Dakota Mr. Lehmer devoted the period to December 31, when his appointment with the River Basin Surveys terminated, to completing a technical report on the results of two seasons' work in the Oahe area. This report, consisting of 250 manuscript pages, presents in detail the information obtained from the Dodd and Phillips Ranch sites. Publication of the report is planned for the next fiscal year. In addition Mr. Lehmer completed two shorter articles which were published in American Antiquity for April 1952. One was "The Fort Pierre Branch, Central South Dakota." The other was on an Oklahoma project and is referred to in a later section of this report.

George Metcalf, field and laboratory assistant, worked with the Hartle party in the Garrison Reservoir during July and August. In addition to taking an active part in the excavations he made a series of surveys in the area and located a number of new sites. In September he joined the Smith party in the investigations at Fort Stevenson and in October participated in a reconnaissance of the region adjacent to Fort Stevenson. During the winter months he checked the survey records and prepared a supplemental report on the archeological resources of the Garrison Reservoir. He assisted in the analysis of artifacts from the Rock Village and collaborated in the preparation of the section of a technical report dealing with trade materials and pottery. In May Mr. Metcalf made a survey of the Big Sandy Reservoir in the Eden Valley, western Wyoming. In June, during an emergency, he took charge of one of the parties in the Oahe area for a 2-week period. On June 30 he was en route to join the party under G. H. Smith in the Garrison Reservoir, N. Dak.

Carl F. Miller, archeologist, transferred to the Missouri Basin for the season, spent the latter part of July, August, and until September 13 digging in a historic site in the Fort Randall Reservoir near Chamberlain, S. Dak. When the excavations were completed Mr. Miller proceeded to Lincoln where he spent two weeks completing field records and other data. From Lincoln he returned to his base at the Washington office where he finished his report on the summer's activities.

John E. Mills joined the staff of the Missouri Basin project as an archeologist on April 10, 1952. During April and May he examined and studied all the records and artifacts pertaining to historic-site research in the Fort Randall Reservoir area and in May made a brief survey trip through the reservoir basin with National Park Service representatives of Region Two to determine what historic

sites merited excavation. In early June he started excavations at the site of the Whetstone Agency and was continuing operations there at the end of the fiscal year.

James M. Shippee, field and laboratory assistant, spent the early part of July with the Wheeler party at the Keyhole Reservoir in Wyoming. The last 2 weeks of the month he joined the Fenenga party for the boat trip through the Bighorn Canyon. He returned to the Keyhole area in August and remained with the Wheeler party until it returned to Lincoln in September. During the fall and winter months he was occupied with various duties at the field headquarters. In March he spoke before the Great Bend chapter of the Missouri Archeological Society and in May read a paper at the annual meeting of the Nebraska Academy of Sciences on salvage work at an archeological site destroyed by flood prevention work near Kansas City, Mo.

G. H. Smith, archeologist, spent the period from July 1 to October 1, 1951, excavating in the remains of Fort Stevenson. During that period five of the more important building sites were completely or largely excavated and there was some digging in a few lesser ones. In October Mr. Smith, accompanied by George Metcalf, made a reconnaissance in a previously unsurveyed part of the Garrison Reservoir. Some test excavations were made at that time at the supposed site of the fur-trading post of James Kipp. From October 28 to June 2, Mr. Smith was at the Lincoln headquarters where he prepared a report on the results of the Fort Stevenson investigations. The first draft was completed and referred to the Chief for review. In May Mr. Smith accompanied a party of National Park Service historians on a visit to historic sites in the Gavins Point, Fort Randall, Oahe, and Garrison Reservoirs. In June he returned to the Garrison Reservoir and started excavations at the supposed site of the original Fort Berthold, and at Fort Atkinson, its successor, which is also known as Fort Berthold II. By June 30 a section of the site of the latter had been opened and considerable information was being obtained concerning the post and Indian trade in general.

Dr. Waldo R. Wedel, curator of the division of archeology, U. S. National Museum, was detailed to the River Basin Surveys for the field season of 1951. He directed excavations at the Cheyenne River village site in the Oahe Reservoir area from June 21 to September 14. During the winter months at his regular station in Washington Dr. Wedel worked on the materials and data from the site. As there is considerable more digging to be done there, however, it will not be possible to write the detailed technical report until that has been accomplished.

Richard Page Wheeler, archeologist, spent the period from the start of the fiscal year through September 25 excavating at sites in the Key-

hole Reservoir area in Crook County, Wyo. Returning to Lincoln, Wheeler spent the autumn and winter months analyzing field data and preparing a number of reports. He published a paper, "A Note on the 'McKean Lanceolate Point'" in the Plains Archeological Conference News Letter, volume 4, No. 4, based on materials from sites in the Keyhole Reservoir area. He presented a report on the Keyhole investigations before the Ninth Conference for Plains Archeology in April. Before starting for the field in June he completed two manuscripts: "Excavations and Survey in the Boysen Reservoir Area, Central Wyoming" and "Plains Ceramic Analysis: A check-list of Features and Descriptive Terms." From the middle of June until the end of the year Mr. Wheeler was in charge of a survey and excavation party at the Jamestown Reservoir in North Dakota.

Dr. Theodore E. White, geologist, spent the period from July 1 to 8 exploring the Oligocene and Miocene deposits in the Canyon Ferry Reservoir area in Montana. From July 10 to 21 he was at the Tiber Reservoir in the same State studying the Colorado group of the Upper Cretaceous. From July 22 to August 13 he examined the exposures of the Paleocene Fort Union formation on the south side of the Missouri River in the Garrison Reservoir in North Dakota. The period from August 15 to September 8 was spent exploring the sediments of the Montana group of the Upper Cretaceous near the dam in the Oahe Reservoir area. He then moved on to the Fort Randall Reservoir and spent September 8 to 16 in the area near the dam. That completed Dr. White's field investigations for the 1951 season. His activities during the winter months have already been discussed in connection with the section on the Washington office. From May 15 to 21, 1952, he made a preliminary survey of the Tuttle Creek and Lovewell Reservoirs in the Kansas River drainage, the Narrows, Trenton and Ashton Reservoirs in the Platte drainage, and Gavins Point on the Missouri River. From June 2 to 25 Dr. White examined the Cretaceous sediments in the Keyhole Reservoir and then moved on to the Canyon Ferry Reservoir for further explorations in that area.

Oklahoma.—No field work was done in Oklahoma during the last fiscal year. The technical report on the excavations of the previous year at the Tenkiller Ferry Reservoir on the Illinois River, 15 miles south of Tahlequah, was completed by Donald J. Lehmer. The report, "The Turkey Bluff Focus of the Fulton Aspect," was published in American Antiquity, volume 17, No. 4, April 1952. No further work will be done in Oklahoma by the River Basin Surveys of the Smithsonian Institution since it falls within one of the areas where the investigations will be under the direction and supervision of the National Park Service after July 1, 1952.

Texas.—The River Basin Surveys in Texas continued to operate from the headquarters at Austin. The office, which was closed tempo-

rarily at the beginning of the fiscal year because of lack of funds, was reopened on September 10 and functioned until June 30, 1952. Edward B. Jelks, acting field director, was in charge during that period.

Field work in Texas consisted of surveys and excavations. Preliminary surveys and appraisals were made at the Colorado City Reservoir on the Colorado River in Borden and Scurry Counties, at the Oak Creek Reservoir in the same drainage in Coke County, at the Paint Creek Reservoir on the Clear Fork of the Brazos River in Haskell County, and at the Cooper Reservoir on the South Sulphur River in Delta County. A total of 62 sites was found. In the Colorado City, Oak Creek, and Paint Creek areas none of them appeared to be of sufficient importance to warrant further investigations. At the Cooper Reservoir, however, are a number of small mounds and several village sites which give surface evidence of occupation by two cultural phases. Six of the sites have been recommended for excavation.

Excavations were carried on in three sites at the Belton Reservoir on the Leon River in Coryell County. Some work had been done there in a previous year, but the current digging added much new information. Artifacts from the Caddoan area to the east were found in association with material from the Central Texas and Edwards Plateau cultural aspects. Analysis of the specimens makes it possible, by cross-dating, to place the Central Texas aspect in its proper place in the relative chronology for Texas.

In April, May, and June an excavating party investigated three sites at the Texarkana Reservoir on the Sulphur River in Cass and Bowie Counties. Adequate data were obtained to reconstruct the cultural history of each. Twelve burials were found at one of the sites, nine at another, and five at the third. The skeletal material will provide good information on the physical characteristics and possible relationships of the people. When all the data from the excavations have been studied and the report is completed a gap in the knowledge of that Texas-Arkansas area will be filled. The results should have an important bearing on the problem of Caddoan influences in the eastern Texas region.

Four survey reports were completed for mimeographing during the year. A technical report, "Archeological Excavations at the Belton Reservoir, Coryell County, Texas," by Edward B. Jelks and E. O. Miller, has been completed and will be published this fall in the Bulletin of the Texas Archeological and Paleontological Society. A general paper, "The River Basin Surveys Archeological Salvage Program in Texas," was prepared by Edward B. Jelks for the Texas Journal of Science. One technical report, completed the previous year, "The Hogge Bridge Site and the Wylie Focus," by Robert L. Stephenson, was published in American Antiquity, volume 17, No. 4, April 1952.

The River Basin Surveys will do no further work in Texas since that is one of the projects being taken over by the National Park Service on July 1. Arrangements have been made, however, for the completion of the reports on the investigations made under the direction and supervision of the River Basin Surveys and when the manuscripts are received they will be published in accordance with previous plans.

Virginia.—All the work in Virginia during the past year was concerned with the John H. Kerr Reservoir (formerly called Buggs Island) on the Roanoke River. During the period from May 19 to June 30, 1952, test excavations were made in seven sites. One had been partially dug the previous year but a stratigraphic test as a countercheck against the earlier results was deemed advisable. Data obtained during the current activities augment those from other seasons, filling in certain gaps and clarifying some obscure features. From all the information now available a complete sequence of cultural developments from a relatively early prepottery stage to the late pre-Colonial period can be described. No further work will be possible at the John H. Kerr Reservoir as the gates of the dam will be closed in July and the various sites will soon be flooded.

Sections of the technical report pertaining to sites that were excavated in previous years have been completed. The writing of the report on the current investigations and the summary and conclusions should be completed before the end of the present calendar year.

Future work in Virginia depends upon the program of the Corps of Engineers. There are proposed projects for the James and Shenandoah Valleys and when they are authorized investigations will be needed in both. Indications are that two small reservoirs in the upper James drainage may be started within the next year or two.

Cooperating institutions.—Various State and local institutions cooperated with the River Basin Surveys as in previous years. The University of Washington and State College of Washington cooperated in excavations in the Columbia Basin. Space for field offices and laboratories for units of the surveys was provided by the Universities of Nebraska, Oregon, Texas, and Georgia.

The program developed by the National Park Service whereby various scientific agencies carried on salvage operations on the basis of agreements between those agencies and the Service was continued throughout the year. In some cases the agreements were signed in the preceding year and in others the work provided for did not start until after the close of the fiscal year. However, during fiscal 1952 such agreements were in force with the University of California, University of Washington, University of Oregon, State College of Washington, Montana State University, University of Missouri, University of South Dakota, Nebraska State Historical Society, University of Kansas, University of Wyoming, State Historical Society of North

Dakota, University of Nebraska State Museum, University of Nebraska Laboratory of Anthropology, University of Oklahoma, University of Texas, the Museum of New Mexico, and the University of Mississippi.

INSTITUTE OF SOCIAL ANTHROPOLOGY

(Report prepared by George M. Foster)

During the period under review one phase in the history of the Institute of Social Anthropology drew to a close, and a new one began. The Department of State informed the Smithsonian Institution on September 28, 1951, that it would terminate its support on December 31, 1951. Following the abolition of the Inter-Departmental Committee on Scientific and Cultural Cooperation in 1949, under whose auspices the Institute of Social Anthropology was established and its work carried out, the Institute was placed under the Division of International Exchange of Persons. Since the Institute did not form an organic part of this program, the Department of State's decision to terminate support was not entirely unforeseen. During the period July 1–December 31, 1951, operations were financed with a grant of $42,000 from Public Law 402.

For some time there had been a growing feeling on the part of the Institute personnel that the general factual knowledge it had accumulated since 1944 should be put to some practical use. Therefore, in the spring of 1951 anthropological analyses of health centers sponsored by the Institute of Inter-American Affairs and the Ministries of Health in México, Colombia, Perú, and Brazil were carried out. The results of this investigation were made available in mimeographed form in July in a paper entitled "A Cross-Cultural Anthropological Analysis of a Technical Aid Program," which demonstrated to the satisfaction of the IIAA that the anthropological knowledge and technical methods used by anthropologists would be useful in carrying out United States Government technical aid programs in Latin America. Accordingly, in a letter dated September 28, 1951, Dr. Henry G. Bennett, Administrator, Technical Cooperation Administration, asked the Institute of Social Anthropology to integrate its activities with those of the IIAA, effective January 1, 1952. In response to this request the IIAA made a grant of $45,705 to enable the ISA to continue its activities in all four countries, with the understanding that Smithsonian anthropologists would be available for program analyses of technical aid projects.

Individual activities of staff members are described in the separate country sections. The largest single enterprise consisted of participation in a general survey of IIAA public-health programs in Latin America. During the spring of 1952 the IIAA decided to utilize

anthropologists on a permanent basis and requested that plans be made to incorporate ISA personnel directly into that organization. This, of course, signaled the termination of ISA activities as such. Accordingly, the Department of State was requested to notify the Ministers of Foreign Relations of the cooperating countries that the United States would make use of the escape clauses in its memorandum agreements, bringing to a close as of June 30 the agreements that have governed ISA operations during past years. Late in June 1952, the IIAA asked to extend its grant to the Smithsonian Institution for an additional 3 months, to give time for an orderly transfer of personnel. An additional $15,725 was included in the amended grant, which was to terminate September 30, 1952.

Operations during the period July 1, 1951, to June 30, 1952, were as follows:

Washington.—Dr. George M. Foster continued as Director of the Institute. In September he concluded arrangements with the United States Public Health Service and the IIAA whereby certain Institute of Social Anthropology staff members, as indicated below, would be detailed for varying periods to participate in health-program analyses. He spent most of October in El Salvador as a member of the team that was initiating this work, and gathered data from a country little known anthropologically. During January and February 1952, he visited field personnel in Brazil, Perú, Colombia, and México and participated in the health survey in Chile. In May he went to Geneva, Switzerland, as an adviser on cultural problems to the American Delegation to the Fifth Assembly of the World Health Organization. In June he undertook the editorship of the full USPHS-IIAA report on the Latin-American health survey.

Early in October the Smithsonian Institution brought Dr. Julio Caro Baroja, director of the Museo del Pueblo Español in Madrid, to Washington for a 3 months' stay. During this period he and Dr. Foster were engaged in the preliminary steps of writing a major monograph on Spanish ethnography, designed to make available Hispanic background data to make more intelligible the modern cultures of Hispanic America. Dr. Caro's passage was taken care of by the Smithsonian Institution; his stay in the United States was made possible by a grant from the Wenner-Gren Foundation for Anthropological Research.

Miss Lois Northcott, administrative assistant to the Director since 1947, resigned to take a position with the Technical Cooperation Administration in Egypt, and her place was taken by Mrs. Virginia Clark, formerly with the Bureau of American Ethnology.

Brazil.—Both Dr. Donald Pierson and Dr. Kalervo Oberg continued their teaching activities at the Escola de Sociologia e Politica in São Paulo. Dr. Pierson, as in former years, served as dean of grad-

uate work, as co-editor of the quarterly Sociologia, and as editor of the book series Biblioteca de Ciencias Sociais. In addition, he was occupied in developing long-range plans for an elaborate cultural research program in the São Francisco Valley. The sum of 500,000 cruzeiros was made available to the Escola by the Brazilian Government to carry out this work, and Dr. Pierson was asked to plan and direct the research. In the spring of 1952 he made several short trips to this area to organize field teams and initiate work. The services of Dr. Oberg were requested by the IIAA for analyses of some of their health and health-education programs in Chonin, Minas Gerais, during the months of July and August 1951. After concluding formal teaching obligations in December he again returned to Chonin, remaining until April 1952. His assignment in São Paulo being concluded, Dr. Oberg was brought to Washington in June, preparatory to reassignment to Rio de Janeiro by the IIAA. Dr. Pierson elected not to transfer to the IIAA, and on June 30, 1952, his connection with the ISA was severed.

Colombia.—Charles Erasmus continued his collaboration with the Colombian Government's Instituto Etnológico in Bogotá. In August he initiated a community analysis of the mestizo village of Tota in the Province of Boyacá. In this work he was aided by Dr. Silva Celis, director of the anthropological museum in Sogamosa, and Sr. Silvio Yepes, member of the staff of the Instituto Etnológico. In November he was detailed to the United States Public Health Service and sent to Ecuador where he remained until January 1952. In this capacity he participated with the health survey group which at that time was working in Ecuador. He was detailed to the IIAA in May 1952, and sent to Haiti for 6 weeks to participate, with a team of experts, in surveying the Artibonite Valley for planning of agricultural programs.

México.—Dr. Isabel Kelly taught two courses during the fall semester at the Escuela Nacional de Antropología, in Mexico City. During October she made a brief visit to El Salvador to consult with the director of the Institute regarding analyses of IIAA projects (see Washington), and to make comparative observations in that country. In November she initiated additional research on health problems in the Federal District, in which work she was assisted by students from the Escuela Nacional. This research continued until March 1952. In May and June of that year Dr. Kelly carried out research in applied anthropology in the village of Cadereyta, Querétaro, where the IIAA desired information on the sociological effects of a new water-supply system.

Dr. William Wonderly continued teaching activities through August, at which time he asked to be placed on leave status for the remainder of the year. In December the decision was made not to

continue linguistic training as a part of the Institute of Social Anthropology program, and he left the staff to accept a position at the University of Oklahoma.

Both Drs. Kelly and Wonderly represented the Smithsonian Institution at the Mexican Government's "Round Table" anthropological conference in Jalapa, Veracruz, in August.

Perú.—Ozzie Simmons continued his teaching activities at the Instituto de Estudios Etnológicos in Lima, and continued to direct research in the mestizo village of Lunahuaná in the Cañete Valley south of Lima. In December Mr. Simmons was detailed to the United States Public Health Service and sent to Chile to participate in the evaluation of IIAA health projects in that country. This work continued until late January 1952. Mr. Simmons was brought to Washington in April 1952, following which he took leave to defend his dissertation at Harvard University, where he was awarded his doctorate. He returned to Lima in May to conclude his study in the Lunahuaná Valley.

EDITORIAL WORK AND PUBLICATIONS

There were issued during the year one Annual Report, four Bulletins, and one Publication of the Institute of Social Anthropology, as listed below:

Sixty-eighth Annual Report of the Bureau of American Ethnology, 1950–1951. ii+40 pp. 1952.

Bulletin 146. Chippewa child life and its cultural background, by Sister M. Inez Hilger. xiv+204 pp., 31 pls., 1 fig. 1951.

Bulletin 147. Journal of an expedition to the Mauvaises Terres and the Upper Missouri in 1850, by Thaddeus A. Culbertson. Edited by John Francis McDermott. viii+164 pp., 2 maps. 1952.

Bulletin 148. Arapaho child life and its cultural background, by Sister M. Inez Hilger. xv+253 pp., 40 pls., 1 fig. 1952.

Bulletin 149. Symposium on local diversity in Iroquois culture. Edited by William N. Fenton. v+187 pp., 21 figs. 1951.

- No. 1. Introduction: The concept of locality and the program of Iroquois research, by William N. Fenton.
- No. 2. Concepts of land ownership among the Iroquois and their neighbors, by George S. Snyderman.
- No. 3. Locality as a basic factor in the development of Iroquois social structure, by William N. Fenton.
- No. 4. Some psychological determinants of culture change in an Iroquoian community, by Anthony F. C. Wallace.
- No. 5. The religion of Handsome Lake; Its origin and development, by Merle H. Deardorff.
- No. 6. Local diversity in Iroquois music and dance, by Gertrude P. Kurath.
- No. 7. The Feast of the Dead, or Ghost Dance at Six Nations Reserve, Canada, by William N. Fenton and Gertrude P. Kurath.
- No. 8. Iroquois women, then and now, by Martha Champion Randle.

Institute of Social Anthropology Publication No. 14. The Indian caste of Peru, 1795–1940. A population study based upon tax records and census reports, by George Kubler. vi+71 pp., 2 pls., 1 fig., 20 maps. 1952.

The following publications were in press at the close of the fiscal year:

Bulletin 145. The Indian tribes of North America, by John R. Swanton.

Bulletin 150. The modal personality of the Tuscarora Indians, as revealed by the Rorschach test, by Anthony F. C. Wallace.

Bulletin 151. Anthropological Papers, Nos. 33–42.

No. 33. "Of the Crow Nation," by Edwin Thompson Denig. With biographical sketch and footnotes by John C. Ewers.

No. 34. The water lily in Maya art: A complex of alleged Asiatic origin, by Robert L. Rands.

No. 35. The Medicine Bundles of the Florida Seminole and the Green Corn Dance, by Louis Capron.

No. 36. Technique in the music of the American Indian, by Frances Densmore.

No. 37. The belief of the Indians in a connection between song and the supernatural, by Frances Densmore.

No. 38. Aboriginal fish poisons, by Robert F. Heizer.

No. 39. Aboriginal navigation off the coast of Upper and Baja California, by Robert F. Heizer and William C. Massey.

No. 40. Exploration of the Adena Mound at Natrium, W. Va., by Ralph S. Solecki.

No. 41. The Wind River Shoshone Sun Dance, by D. B. Shimkin.

No. 42. Current trends in the Wind River Shoshone Sun Dance, by Fred Voget.

Bulletin 152. Index to Schoolcraft's "Indian Tribes of the United States," compiled by Frances S. Nichols.

Bulletin 153. La Venta, Tabasco: A study of Olmec ceramics and art, by Philip Drucker.

Bulletin 154. River Basin Surveys Papers: Inter-Agency Archeological Salvage Program. Nos. 1–6.

No. 1. Prehistory and the Missouri Valley Development Program: Summary report on the Missouri River Basin Archeological Survey in 1948, by Waldo R. Wedel.

No. 2. Prehistory and the Missouri Valley Development Program: Summary report on the Missouri River Basin Archeological Survey in 1949, by Waldo R. Wedel.

No. 3. The Woodruff Ossuary, a prehistoric burial site in Phillips County, Kans., by Marvin F. Kivett.

No. 4. The Addicks Dam site:

I. An archeological survey of the Addicks Dam basin, Southeast Texas by Joe Ben Wheat.

II. Indian skeletal remains from the Doering and Kobs sites, Addicks Reservoir, Texas, by Marshall T. Newman.

No. 5. The Hodges site:

I. Two rock shelters near Tucumcari, N. Mex., by Herbert W. Dick.

II. Geology of the Hodges site, Quay County, N. Mex., by Sheldon Judson.

No. 6. The Rembert mounds, Elbert County, Ga., by Joseph R. Caldwell.

Appendix. List of River Basin Surveys reports published in other series.

Bulletin 155. Settlement patterns in the Virú Valley, Perú, by Gordon R. Willey

Bulletin 156. The Iroquois Eagle Dance, an offshoot of the Calumet Dance, by William N. Fenton, with an analysis of the Iroquois Eagle Dance and songs, by Gertrude Prokosch Kurath.

Institute of Social Anthropology Publication No. 13. The Tajin Totonac: Part 1. History, subsistence, shelter, and technology, by Isabel Kelly and Angel Palerm.

Institute of Social Anthropology Publication No. 15. Indian tribes of Northern Mato Grosso, Brazil, by Kalervo Oberg. With appendix by Marshall Newman, entitled "Anthropometry of the Umotina, Nambicuara, and Iranxe, with comparative data from other northern Mato Grosso tribes."

Institute of Social Anthropology Publication No. 16. Penny capitalism: A Guatemalan Indian economy, by Sol Tax.

Publications distributed totaled 21,505, as compared with 22,377 for the fiscal year 1951.

ARCHIVES

Miss Mae W. Tucker, archivist for the Bureau of American Ethnology, retired at the end of February 1952 after nearly 27 years' service with the Institution.

Notable additions to the collections during the fiscal year were the diaries of John K. Hillers, who accompanied Maj. J. W. Powell on his famous voyage through the Grand Canyon of the Colorado in 1871 and 1872. Mr. Hillers, who became photographer for the expedition, kept a full daily record of the expedition, which constitutes a most valuable addition to our knowledge of this famous adventure. The diaries were presented to the Bureau by Mrs. J. K. Hillers of Washington, D. C., daughter-in-law of the author.

Mrs. Alice Norvell Hunt, of Washington, D. C., presented to the Bureau an interesting collection of early photographs of western Indians collected by her father while an army officer in the West and Southwest. Comprising photographs made by Baker and Johnston; Addison of Fort Sill, Oklahoma Territory; O. S. Goff, Dickinson, N. Dak.; A. S. Goff, Fort Custer, Mont.; Chr. Barthelmess, Fort Keogh, Mont.; and Chase Thorne, El Paso, the 46 prints, including a number of famous Indians, are all new to the collections.

William H. Myer, of Washington, D. C., and Mrs. Annie Lee Myer Turner, of Carthage, Tenn., presented a book containing 75 drawings by Indians of the Southern Plains. The book was acquired about the year 1880 by Capt. David N. McDonald and was later purchased by W. E. Myer, father of the donors.

Mrs. J. C. Cardell, of Lenoir, N. C., presented a Mohawk dictionary of 973 pages with French equivalents. It is in the dialect spoken at Lake of Two Mountains, Caughnawaga and St. Regis in the Province of Quebec, Canada, and is the work of Rev. J. A. Cuoc. It was obtained later by Jeremiah Curtain, father of the donor.

Henry Lookout, of Pawhuska, Okla., son of the late Fred Lookout, last principal chief of the Osage Nation, sent to the Bureau on indefinite loan a group of papers relating to the history of the Osage Nation, passed down from father to son for generations. Among the

documents is a treaty of peace between the United States, the Osage Nations, and the Missouri and Arkansas Tribes, signed in 1815 at Portage des Sioux in what is now St. Charles County, Mo. In addition to the many Indian seals and signatures, it carries the signatures of William Clark, of Lewis and Clark expedition fame, Ninian Edwards, governor of the Territory of Illinois, and Auguste Chouteau, principal figure of the early fur trade in the West. Also included in the material from Mr. Lookout is a Jefferson medal of 1801, made for presentation to Indian leaders. These are extremely rare since they were usually buried with their recipient.

COLLECTIONS

Acc. No.

191398. Mold and finished face mask of Frances Densmore, made by Mička in 1912.

192829. Cornhusk ceremonial mask, Grand River Iroquois, Ontario, Canada, probably collected by J. N. B. Hewitt.
(Through Dr. M. W. Stirling) Ceremonial and historical wampum of the Iroquois, collected in 1928–29 by J. N. B. Hewitt at the Six Nations Reserve, Ontario, Canada.

192830. Shell necklace used in the Tutelo adoption ceremony, collected in 1941 by W. N. Fenton.

FROM RIVER BASIN SURVEYS

193461. Skeletal and archeological material from sites Mc44 and Ha6, Buggs Island Reservoir, Roanoke River, near Clarksville, Va.

191031. (Through Dr. F. H. H. Roberts, Jr.) Vertebrate material collected by Dr. Theodore E. White, May 1951, Garza-Little Elm Dam, north fork of Trinity River, Denton County, Tex.

191587. Fossil vertebrate material from Oligocene and Miocene deposits in the Canyon Ferry Reservoir area, Montana, collected by Dr. Theodore E. White, July 1951.

192062. 5 fossil vertebrates including mammals, reptiles, and fishes, from Garrison Reservoir area near Williston, N. Dak., collected by Dr. Theodore E. White, August 1951.

192063. 1 mosasaur skeleton and shark teeth from Pierre formation, Upper Cretaceous, in Oahe Reservoir area near Pierre, S. Dak., collected by Dr. Theodore E. White, August 1951.

193460. Tympanic bullae of kangaroo rat from near Pierre, S. Dak.

193835. (Through R. L. Stephenson) Approximately 120 land mollusks from Texas.

Respectfully submitted.

M. W. Stirling, *Director.*

Dr. A. Wetmore,
Secretary, Smithsonian Institution.

APPENDIX 6

Report on the International Exchange Service

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1952:

The Smithsonian Institution is the official United States agency for the exchange with other nations of governmental, scientific, and literary publications. The International Exchange Service, initiated by the Smithsonian Institution in the early years of its existence for the interchange of scientific publications between learned societies and individuals in the United States and those of foreign countries, serves as a means of developing and executing in part the broad and comprehensive objective, "the diffusion of knowledge." It was later designated by the United States Government as the agency for the transmission of official documents to selected depositories throughout the world, and it continues to execute the exchanges pursuant to conventions, treaties, and other international agreements.

Although the number of packages received for transmission during the year decreased by 9,386 to the yearly total of 1,001,614, the total weight of the packages increased by 36,854 pounds to the total of 825,627 pounds. The average weight of the individual package increased to 13.18 ounces as compared to the 12.46-ounce average for the fiscal year of 1951. The publications received from both the foreign and domestic sources for shipment are classified as shown in the following table:

Classification	Packages		Weight	
	Number	*Number*	*Pounds*	*Pounds*
United States parliamentary documents sent abroad	591,147		267,339	
Publications received in return for parliamentary documents		10,987		19,678
United States departmental documents sent abroad	173,747		182,096	
Publications received in return for departmental documents		5,201		20,591
Miscellaneous scientific and literary publications sent abroad	171,220		245,773	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		49,312		90,150
Total	936,114	65,500	695,208	130,419
Grand total	1,001,614		825,627	

The packages of publications are forwarded to the exchange bureaus of foreign countries by freight, or where shipment by such means is impractical, to the addressees by direct mail. The number of boxes shipped to the foreign exchange bureaus was 3,058, or 174 more than for the previous year. Of these boxes 867 were for depositories of full sets of United States Government documents, these publications being furnished in exchange for the official publications of foreign governments which are received for deposit in the Library of Congress. The number of packages forwarded by mail and by means other than freight was 205,666.

Transportation rates continue to increase and are primarily responsible for the 148,014 pounds of publications that remained unshipped at the end of the fiscal year.

No shipments are being made to either China or Rumania. Publications intended for addresses in Formosa and formerly sent through the Chinese Exchange Bureau at Nanking are now forwarded by direct mail.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The number of sets of United States official publications received by the Exchange Service for transmission abroad in return for the official publications sent by foreign governments for deposit in the Library of Congress is now 104 (62 full and 42 partial sets), listed below. Changes that occurred during the year are shown in the footnotes.

DEPOSITORIES OF FULL SETS

ARGENTINA: División Biblioteca, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.

AUSTRALIA: Commonwealth Parliament and National Library, Canberra.
- NEW SOUTH WALES: Public Library of New South Wales, Sydney.
- QUEENSLAND: Parliamentary Library, Brisbane.
- SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
- TASMANIA: Parliamentary Library, Hobart.
- VICTORIA: Public Library of Victoria, Melbourne.
- WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

AUSTRIA: Administrative Library, Federal Chancellery, Vienna.

BELGIUM: Bibliothèque Royale, Bruxelles.

BRAZIL: Biblioteca Nacional, Rio de Janeiro.

BULGARIA: Bulgarian Bibliographical Institute, Sofia.

BURMA: Government Book Depot, Rangoon.

CANADA: Library of Parliament, Ottawa.
- MANITOBA: Provincial Library, Winnipeg.
- ONTARIO: Legislative Library, Toronto.
- QUEBEC: Library of the Legislature of the Province of Quebec.

CEYLON: Department of Information, Government of Ceylon, Colombo.

CHILE: Biblioteca Nacional, Santiago.

CHINA: Ministry of Education, National Library, Nanking, China.[1]
PEIPING: National Library of Peiping.[1]
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Biblioteca Nacional, San José.
CUBA: Ministerio de Estado, Canje Internacional, Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Institut Danois des Échanges Internationaux, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Offentliche Wissenschaftliche Bibliothek, Berlin.
Parliamentary Library, Bonn.
GREAT BRITAIN:
ENGLAND: British Museum, London.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
HUNGARY: Library of Parliament, Budapest.
INDIA: National Library, Calcutta.
Central Secretariat Library, New Delhi.
INDONESIA: Ministry for Foreign Affairs, Djakarta.
IRELAND: National Library of Ireland, Dublin.
ISRAEL: Government Archives and Library, Hakirya.
ITALY: Ministerio della Publica Istruzione, Rome.
JAPAN: National Diet Library, Tokyo.[2]
MÉXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, México, D. F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Utenriksdepartmentets Bibliothek, Oslo.
PAKISTAN: Central Secretariat Library, Karachi.[3]
PERÚ: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.
POLAND: Bibliothèque Nacionale, Warsaw.
PORTUGAL: Biblioteca Nacional, Lisbon.
SPAIN: Biblioteca Nacional, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.
UNITED NATIONS: Library of the United Nations, Geneva, Switzerland.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Bibliografski Institut, Belgrade.[3]

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.
ANGLO-EGYPTIAN SUDAN: Gordon Memorial College, Khartoum.

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[1] Shipment suspended.
[2] Receives two sets.
[3] Added during year.

BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.
BRAZIL:
MINAS GERAIS: Directoria Geral de Estatistica em Minas, Belo Horizonte.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
CANADA:
ALBERTA: Provincial Library, Edmonton.
BRITISH COLUMBIA: Provincial Library, Victoria.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Department of Provincial Affairs, St. John's.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
SASKATCHEWAN: Legislative Library, Regina.
DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Ciudad Trujillo.
ECUADOR: Biblioteca Nacional, Quito.
EL SALVADOR:
Biblioteca Nacional, San Salvador.
Ministerio de Relaciones Exteriores, San Salvador.
GREECE: National Library, Athens.
GUATEMALA: Biblioteca Nacional, Guatemala.
HAITI: Bibliothèque Nationale, Port-au-Prince.
HONDURAS:
Biblioteca y Archivo Nacionales, Tegucigalpa.
Ministerio de Relaciones Exteriores, Tegucigalpa.
ICELAND: National Library, Reykjavik.
INDIA:
BIHAR AND ORISSA: Revenue Department, Patna.
BOMBAY: Undersecretary to the Government of Bombay, General Department Bombay.
UNITED PROVINCES OF AGRA AND OUDH:
University of Allahabad, Allahabad.
Secretariat Library, Uttar Pradesh, Lucknow.[4]
WEST BENGAL: Library, West Bengal Legislative Secretariat, Assembly House, Calcutta.
IRAN: Imperial Ministry of Education, Tehran.
IRAQ: Public Library, Baghdad.
JAMAICA: Colonial Secretary, Kingston.
University College of the West Indies, St. Andrew.
LEBANON: American University of Beirut, Beirut.[3]
LIBERIA: Department of State, Monrovia.
MALAYA: Federal Secretariat, Federation of Malaya, Kuala Lumpur.
MALTA: Minister for the Treasury, Valleta.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
PAKISTAN: Chief Secretary to the Government of Punjab, Lahore.
PANAMÁ: Ministerio de Relaciones Exteriores, Panamá.
PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.
SCOTLAND: National Library of Scotland, Edinburgh.
SIAM: National Library, Bangkok.
SINGAPORE: Chief Secretary, Government Offices, Singapore.
VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

[4] Changed from Civil Secretariat, Council House, Lucknow.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 87 copies of the Federal Register and 94 copies of the Congressional Record. This is an increase over the preceding year of 2 copies of the Federal Register and 2 of the Congressional Record. The countries to which these journals are being forwarded are given in the following list:

DEPOSITORIES OF CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:
- Biblioteca del Congreso Nacional, Buenos Aires.
- Biblioteca del Poder Judicial, Mendoza.[5]
- Boletín Oficial de la República Argentina, Ministerio de Justica e Instrucción Pública, Buenos Aires.
- Cámara de Diputados Oficina de Información Parlamentaria, Buenos Aires.

AUSTRALIA:
- Commonwealth Parliament and National Library, Canberra.
- NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.
- QUEENSLAND: Chief Secretary's Office, Brisbane.
- VICTORIA: Public Library of Victoria, Melbourne.[5] [6]
- WESTERN AUSTRALIA: Library of Parliament of Western Australia.

BRAZIL:
- Biblioteca da Camera dos Deputados, Rio de Janeiro.
- Secretaria de Presidencia, Rio de Janeiro.[6]
- AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manáos.
- BAHIA: Governador do Estado da Bahia, São Salvador.
- ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.
- RIO GRANDE DO SUL: Imprensa Oficial do Estado, Porto Alegre.
- SERGIPE: Biblioteca Pública do Estado de Sergipe, Aracajú.
- SÃO PAULO: Imprensa Oficial do Estada, São Paulo.

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:
- Library of Parliament, Ottawa.
- Clerk of the Senate, Houses of Parliament, Ottawa.

CEYLON: Ceylon Ministry of Defense and External Affairs, Colombo.[6]

CUBA:
- Biblioteca del Capitolio, Habana.
- Biblioteca Publica Panamericana, Habana.[5]
- House of Representatives, Habana.

CZECHOSLOVAKIA: Library of the Czechoslovak National Assembly, Prague.[6]

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.[6]

EL SALVADOR: Library, National Assembly, San Salvador.

FRANCE:
- Bibliothèque Assemblée Nationale, Paris.
- Bibliothèque Conseil de la République, Paris.
- Library, Organization for European Economic Cooperation, Paris.[6]
- Publiques de l'Institut de Droit Comparé, Université de Paris, Paris.[5]
- Research Department, Council of Europe, Strasbourg.[6]
- Service de la Documentation Étrangère, Assemblée Nationale, Paris.[6]

[5] Federal Register only.
[6] Congressional Record only.

GERMANY:
- Amerika-Institut der Universität, München, München.[2] [3]
- Archiv, Deutscher Bundesrat, Bonn.
- Bibliotek der Instituts für Weltwirtschaft an der Universität Kiel, Kiel-Wik.
- Der Bayrische Landtag, Munich.[2] [7]
- Deutscher Bundesrat, Bonn.[3]
- Deutscher Bundestag, Bonn.[3]

GREAT BRITAIN:
- Department of Printed Books, British Museum, London.[2] [3]
- House of Commons Library, London.[3]
- Printed Library of the Foreign Office, London.
- Royal Institut of International Affairs, London.[3]

GREECE: Bibliothèque, Chambre des Députés Hellénique, Athens.

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

INDIA:
- Civil Secretariat Library, Lucknow, United Provinces.[2]
- Indian Council of World Affairs, New Delhi.[3]
- Legislative Assembly Library, Lucknow, United Provinces.
- Legislative Department, Simla.
- Parliament Library, New Delhi.[3]

IRELAND: Dail Eireann, Dublin.

ITALY:
- Biblioteca Camera dei Deputati, Rome.
- Biblioteca del Senato della Republica, Rome.
- European Office, Food and Agriculture Organization of the United Nations, Rome.[3]
- International Institute for the Unification of Private Law, Rome.[3]

JAPAN: Library of the National Diet, Tokyo.

KOREA: Secretary General, National Assembly, Pusan.[2]

MÉXICO:
- Dirección General Información, Secretaría de Gobernación, México, D. F.
- Biblioteca Benjamin Frankin, México, D. F.
- AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.
- BAJA CALIFORNIA: Gobernador del Distrito Norte, Mexicali.
- CAMPECHE: Gobernador del Estado de Campeche, Campeche.
- CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutiérrez.
- CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.
- COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.
- COLIMA: Gobernador del Estado de Colima, Colima.
- DURANGO: Gobernador Constitucional del Estado de Durango, Durango.
- GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.
- GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.
- JALISCO: Biblioteca del Estado, Guadalajara.
- MÉXICO: Gaceta del Gobierno, Toluca.
- MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.
- MORELOS: Palacio de Gobierno, Cuernavaca.

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[7] Three copies.

MÉXICO—Continued

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periódico Oficial, Palacia de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.

SINALOA: Gobernador del Estado de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TABASCO: Secretaría de Gobierno, Sessión 3a, Ramo de Prensa, Villahermosa.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NETHERLANDS: Koninklijke Bibliotheek, The Hague.[2]

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Library of the Norwegian Parliament, Oslo.

PAKISTAN: Punjab Legislative Assembly Department, Lahore.

PERÚ: Cámara de Diputados, Lima.

POLAND: Ministry of Justice, Warsaw.[2]

PORTUGAL: Secretaria de Assembla National, Lisbon.[2]

PORTUGUESE TIMOR: Repartição Central de Administração Civil, Dili.[1 2]

SWITZERLAND: Bibliothèque, Bureau International du Travail, Geneva.[2]

International Labor Office, Geneva.[1 2]

Library, United Nations, Geneva.

UNION OF SOUTH AFRICA:

CAPE OF GOOD HOPE: Library of Parliament, Cape Town.

TRANSVAAL: State Library, Pretoria.

UNION OF SOVIET SOCIALIST REPUBLICS: Fundamental'niia Biblioteka, Obshchestvennykh Nauk, Moscow.[2]

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE SERVICES

Exchange publications for addresses in the countries listed below are forwarded by freight to the exchange services of those countries. Exchange publications for addresses in other countries are forwarded directly to the addresses by mail.

LIST OF EXCHANGE SERVICES

AUSTRIA: Austrian National Library, Vienna.

BELGIUM: Service des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

CHINA: Bureau of International Exchange, National Central Library, Nanking.[1]

CZECHOSLOVAKIA: Bureau of International Exchanges, National and University Library, Prague.

DENMARK: Institut Danois des Échanges Internationaux, Bibliothèque Royale, Copenhagen K.

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[2] Two copies.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Delegation of the Scientific Societies, Snellmaninkatu 9–11, Helsinki.

FRANCE: Service des Échanges Internationaux, Bibliothèque Nationale, 58 Rue de Richelieu, Paris.

GERMANY: Notgemeinschaft der Deutschen Wissenschaft, Bad Godesberg.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 83/84 Berwick Street, London, W. 1.[a]

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

INDIA: Superintendent of Government Printing and Stationary, Bombay.

INDONESIA: Department of Cultural Affairs and Education, Djakarta.

ISRAEL: Jewish National and University Library, Jerusalem.

ITALY: Ufficio degli Scambi Internazionali, Ministero della Publica Istruzione, Rome.

JAPAN: Division of International Affairs, National Diet Library, Tokyo.

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

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

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.

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

RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.[a]

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationary Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Palais Fédéral, Berne.

TASMANIA: Secretary of the Premier, Hobart.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationary Office, Cape Town, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: Bureau of Book Exchange, State Lenin Library, Moscow 19.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Bibliografski Institut FNRJ, Belgrade.

Respectfully submitted.

D. G. WILLIAMS, *Chief*.

DR. A. WETMORE,
Secretary, Smithsonian Institution.

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[a] Between the United States and England only.

APPENDIX 7

Report on the National Zoological Park

SIR: Transmitted herewith is a report on the operations of the National Zoological Park for the fiscal year ended June 30, 1952.

There were 590 accessions, comprising 1,575 individual animals, added to the collection during the year by gifts, deposits, purchases, exchanges, births, and hatchings. Among these were many rare specimens never before shown in this Zoo. The addition of new kinds of animals enhances the value of the collection, which is maintained not only for exhibition, but for research and education, thus fostering the Smithsonian's established purpose of "the increase and diffusion of knowledge." Valuable opportunities for research are afforded students of biology, particularly vertebrate zoology, as well as artists, photographers, and writers. Only methods of study that do not endanger the welfare of animals or the safety of the public are permitted.

Services of the staff included answering in person or by phone, mail, or telegraph questions regarding animals and their care and transportation; furnishing to other zoos and other agencies, public and private, information regarding structures for housing animals; cooperating with other agencies of Federal, State, and municipal governments in research work; and preparing articles for publication.

The stone restaurant building, which was constructed in the Park in 1940, is leased at $23,052 a year. This money is deposited in the general fund of the United States Treasury. The concessionaire serves meals and light refreshments and sells souvenirs.

THE EXHIBITS

Animals for exhibition are acquired by gift, deposit, purchase, exchanges, births, and hatchings, and are removed by death, exchange, or return of those on deposit. Although depositors are at liberty to remove their specimens, many leave them permanently.

As in any colony of living things, there is a steady turn-over, and so the exhibits are constantly changing. Thus, the inventory list of specimens in the collection on June 30 of each year does not show all the kinds of animals that were exhibited during the year; sometimes creatures of outstanding interest at the time they were shown are no longer in the collection at the time the list is prepared.

The United States National Museum is given first choice of all specimens that die in the Zoo. If they are not desired for the Museum they are then made available to other scientific institutions or scientific workers. Thus the value of the specimen continues long after it is dead.

Professional workers of the National Institutes of Health frequently perform autopsies on animals for the information thus obtained that might be of use in the study of human diseases. They frequently diagnose causes of death and make suggestions for treatment of living animals. In particular, acknowledgment is made for the excellent assistance and advice given the Zoo from time to time by Dr. W. H. Eyestone, of the National Cancer Institute, and by Miss Frances Dobell, biologist in his laboratory.

Zoos are constantly striving to take such good care of their animals that they may live out their maximum life spans. Therefore when fair success is attained and animals live in captivity longer than they usually do or when they appear to have established outstanding longevity records, it is gratifying. In the National Zoological Park there are many animals that continue to thrive after relatively long periods in captivity. A few of these are listed below. Though none of them has established a maximum longevity record, all are noteworthy.

Mammals.—A ringtail, or cacomistle (*Bassariscus astutus*), received as an adult in August 1941, is still living and in good condition.

A digger pine pocket gopher (*Thomomys bottae mewa*), received on May 19, 1949, lived until June 27, 1952. Pocket gophers do not ordinarily survive so long in captivity.

Birds.—The bird that has been in the zoo collection the longest is a Siberian crane (*Grus leucogeranus*), which was received in 1906. It is still thriving and appears to be in good condition.

A white-naped crane (*Grus leucauchen*) received in 1916 appears to be in good health.

A wood ibis (*Mycteria americana*) and a lesser adjutant stork (*Leptoptilus javanicus*) were both received in 1928 and are still doing well.

East African crowned cranes (*Balearica regulorum gibbericeps*) received in 1926 and West African cranes (*Balearica pavonina*) received in 1931 are thriving.

A single-wattled cassowary (*Casuarius unappendiculatus*), received in 1928, and other cassowaries received in 1937 are still alive.

Small birds that are still thriving are white-cheeked bulbuls (*Pycnonotus leucogenys*) and mourning finches (*Phrygilus fruticeti*) received in 1940.

Reptiles.—The oldest animal in the collection is a Galápagos turtle (*Testudo vicina*), which was collected by the Lord Rothschild Expedi-

tion to the Galápagos Islands in 1898, the first scientific exploration of these islands. Since its receipt it has continued to thrive and grow.

An African water turtle (*Pelomedusa galeata*), obtained in 1926 by the Smithsonian-Chrysler Expedition, is still alive.

Other reptiles with interesting records are: A soft-shelled turtle (*Amyda ferox*) received in 1930; flat-headed turtles (*Platemys platycephala*) received in 1931; two African crocodiles (*Crocodylus niloticus*) received in 1929; four spectacled caimans (*Caiman sclerops*) received in 1931; and a pike-head snake (*Oxybelis acuminatus*) received in 1943.

Among the amphibians are Argentine horned frogs (*Ceratophrys ornata*) received in 1939 and giant toads (*Bufo marinus*) received in 1931.

Two South American lungfishes (*Lepidosiren paradoxa*), received in 1931, are still living.

The most serious loss of the year from both a financial and sentimental standpoint was the death on June 30, 1952, of the African elephant "Jumbina," which had been with the Zoo since August 8, 1913. She was never the docile soul that endears some elephants to children, but she was admired by many for her active, alert ways as well as for her stature and remarkable form. When she was obtained from the Government Zoological Garden at Giza, Egypt, she was 4 feet 3 inches high at the shoulders and weighted 875 pounds. An arthritic-like condition apparently caused her decline.

ACCESSIONS

By extensive correspondence with persons in foreign lands the Zoo is frequently able to acquire by gift, exchange, or purchase highly desirable animals that are not ordinarily available through animal dealers or other zoos.

OUTSTANDING ACQUISITIONS

The Commonwealth of Australia presented to the President of the United States an albino kangaroo and a pair of the beautiful Crown Prince Rudolph's blue birds-of-paradise. These are quartered in the Zoo and are most interesting additions to the exhibits, as the kangaroo is believed to be the only one of its kind in captivity, and the birds are the first of this species that this Zoo has ever had.

In exchange with E. J. L. Hallstrom, president of the Taronga Zoological Park Trust, Sydney, N. S. W., an outstanding collection was received from Australia, consisting of gang-gang cockatoos (*Callocephalon fimbriatum*), Barraband's parakeets (*Polytelis swainsoni*), Leadbeater's cockatoos (*Kakatoe leadbeateri*), bare-eyed cockatoos (*Kakatoe sanguineus*), sulphur-crested cockatoos (*Kakatoe galerita*), emus (*Dromiceius novachollandiae*), bowerbirds (*Ptilonorhynchus*

violaceus), Cape Barren geese (*Cereopsis novaehollandiae*), black swans (*Chenopis atrata*), 4 long-eared opossums (*Trichosurus vulpecula*), 6 phalangers (*Petaurus norfolcensis*), 2 wallabies (*Wallabia agilis*), 2 wallaroos (*Macropus robustus*), 2 red kangaroos (*Macropus rufus*), 2 great gray kangaroos (*Macropus giganteus*), 7 White's skinks (*Egernia whitii*), 4 carpet pythons (*Python variegatus*), 5 black snakes (*Pseudechis porphyriacus*), 2 green snakes (*Dendrophis punctulatus*), and 4 tiger snakes (*Spilotes pullatus pullatus*). Other specimens are still to be received in this exchange. In return, a young giraffe, 2 pygmy hippopotamuses, and 1 grizzly bear were sent to Australia.

The United States Fish and Wildlife Service, through various members of its staff, has continued to assist us in maintaining an interesting collection during the year. A pair of MacQueen's bustards (*Chlamydotis undulata macqueenii*) was presented through Gardner Bump and the State of New Mexico. The first Ross's snow geese (*Chen rossi*) received since 1915 were sent by Vernon Ekedahl, superintendent of the Sacramento National Wildlife Refuge, from Willows, Calif. He also sent other North American waterfowl, which are enumerated in the list of donors. Other members of the Fish and Wildlife Service who assisted are given in the list of donors.

W. W. Dornin, of Phoenix, Ariz., continued from time to time to send choice specimens of reptiles of the southwestern United States.

Valuable specimens were received during the year from J. D. Handman, Nyasaland Railways Ltd., Monkey Bay, Nyasaland, Africa. As this is a region little known zoologically, all the specimens are unusual in collections. Outstanding among these was a file snake (*Simocephalus capensis*).

The United States Army Medical Unit in Malaya, under the leadership of Lt. Col. Robert Traub, again brought to the United States particularly interesting animals that were made available to the National Zoological Park after they had served their purpose with the Medical Unit. Although the collection was not large, all the specimens were very desirable. They included 2 baby orangutans (*Pongo pygmaeus abelii*); 2 young small-toothed civets (*Arctogalidia trivirgata*); 4 ferret-badgers (*Helictis everetti*); 2 tree shrews (*Tupai montana baluensis*); 4 choice specimens of the big black rat of Mount Kinabalu, North Borneo (*Rattus infraluteus*); 1 Bornean porcupine (*Trichys lipura*); and 1 remarkable tiny spineless hedgehog (*Hylomys suillus dorsalis*). On the long trip from Asia the animals were cared for by Charles Wharton, a zoologist who had been with the Medical Unit.

The Johns Hopkins Research Center deposited in the Zoo a group of young chimpanzees that have proved to be a fascinating exhibit.

The National Institutes of Health, through Samuel Poiley, presented 13 minks and a number of ferrets.

Fourteen species of animals were received that had not previously been exhibited in the National Zoological Park, and some of them probably had not previously been on exhibition in the United States. Among these were:

Scientific name	Common name
Arctogalidia trivirgata stigmatica	Small-toothed civet.
Helictis everetti	Ferret-badger.
Tupai montana baluensis	Kinabalu tree shrew.
Rattus infraluteus	Kinabalu giant rat.
Hylomys suillus dorsalis	Spineless hedgehog.
Trichys lipura	Bornean porcupine.
Presbytis phayrei	Phayre's langur.
Macropus giganteus	Albino great gray kangaroo.
Anas luzonica	Philippine mallard.
Crax alberti	Blue-cered curassow.
Cephalopterus ornatus	Umbrellabird.
Chlamydotis undulata macqueenii	MacQueen's bustard.
Denisonia superba	Australian copperhead.
Simocephalus capensis	File snake.

Other acquisitions of outstanding interest, although not the first of their kind to be exhibited by the Zoo, were:

Pongo pygmaeus abelii	Orangutan.
Pan troglodytes	Chimpanzee.
Hylobates lar	White-handed gibbon.
Speothos venaticus	Bush dog.
Diceros bicornis	Black rhinoceros.
Rupicola sanguinolenta	Scarlet cock-of-the-rock.
Rupicola rupicola	Orange cock-of-the-rock.
Polytelis swainsoni	Barraband's parakeet.
Callocephalon fimbriatum	Gang-gang cockatoo.
Psittacus erithacus	African gray parrot.
Kakatoe leadbeateri	Leadbeater's cockatoo.
Chen rossi	Ross's goose.
Bucorvus abyssinicus	Abyssinian ground hornbill.
Pharomachus mocino	Quetzal.
Kakatoe haematuropygia	Red-vented cockatoo.
Kakatoe sanguineus	Bare-eyed cockatoo.
Dromiceus novaehollandiae	Emu.
Ptilonorhynchus violaceus	Bowerbird.
Paradisornis rudophi	Prince Rudolph's bird-of-paradise.
Kinixys erosa	Hinged-back turtle.
Bombyx mori	Silkworm.

DEPOSITORS AND DONORS AND THEIR GIFTS

(Deposits are marked *)

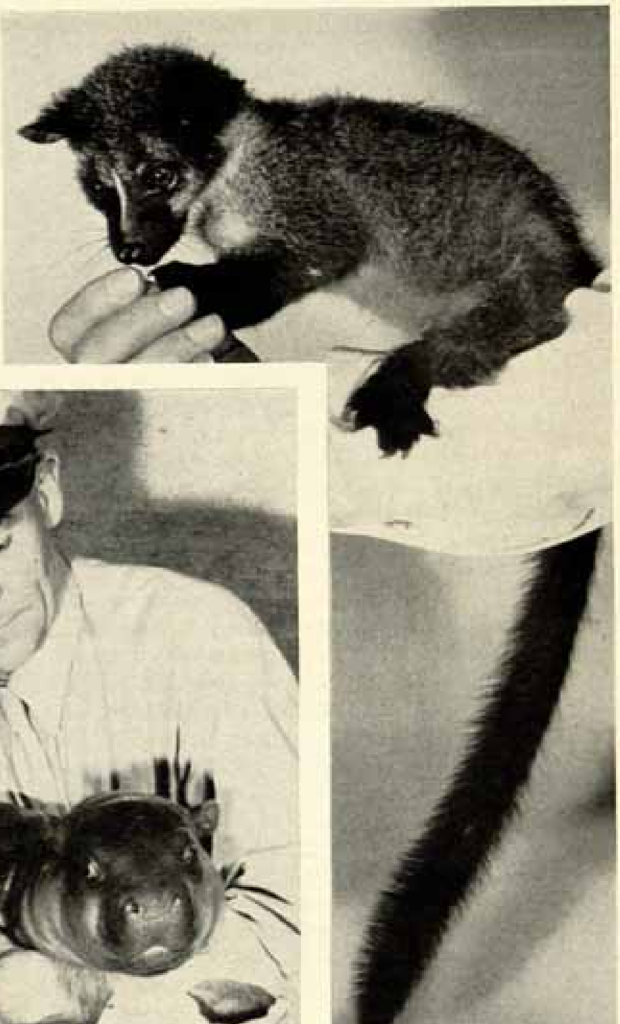
Adelle's Pet Shop, Washington, D. C., skunk.
Airline Pilots' Association, Washington, D. C., boa constrictor.
Amos, John T., Mount Rainier, Md., red fox.

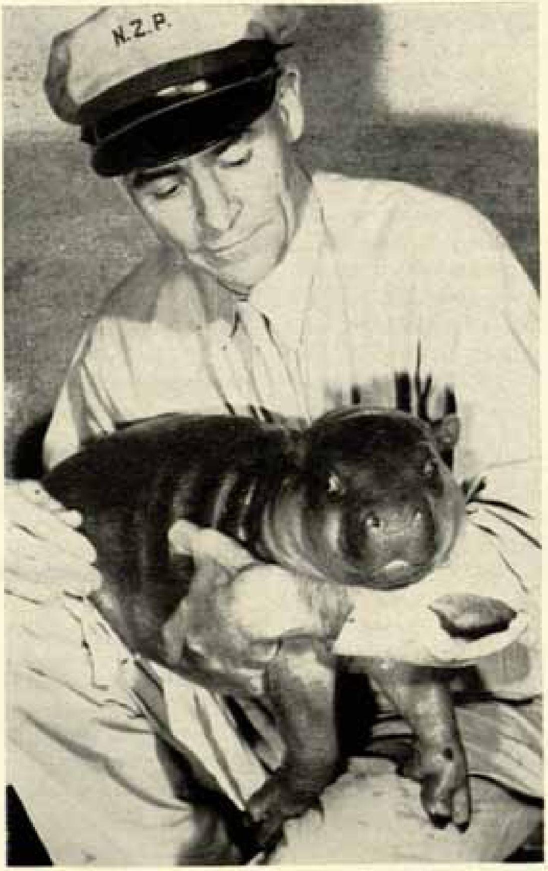
Animal Rescue League, Washington, D. C., squirrel monkey.
Armbruster, David, Washington, D. C., 9 opossums.
Australia, Commonwealth of, through E. J. L. Hallstrom, Sydney, N. S. W., albino kangaroo, 2 Crown Prince Rudolph's birds-of-paradise.
Ayer, Bruce, Washington, D. C., Pekin duck.
Ayers, Mrs. John K., Mount Rainier, Md., red-vented cockatoo.
Baeckel, Mrs. R. M., Washington, D. C., goldfish.
Backauer, Ben, Washington, D. C., rabbit.
Baker, Bobby, Washington, D. C., Pekin duck.
Baldwin, J. W., Alexandria, Va., gray fox.
Banister, Mrs. A. B., Chevy Chase, Md., salamander.
Barker, B., and Norris, R., Washington, D. C., gray fox.
Barnes, Roger L., Washington, D. C., Pekin duck.
Bartlett, Mrs. Hallie B., Washington, D. C., robin.
Bartley, Master Sgt. Frank E., Washington, D. C., skunk.
Barton, A. J., Pittsburgh, Pa., 6 timber rattlesnakes.
Bell, Curtis, Bethesda, Md., 3 Pekin ducks.
Bergen, W. P., Washington, D. C., Pekin duck.
Bernard, Mrs. H. J., Washington, D. C., canary.
Biessel, Barbara and Betty, Bethesda, Md., 2 Pekin ducks.
Birding, Mrs. Anne, Washington, D. C., red fox.
Blades, Lt. Charles P., Anacostia, D. C., red fox.
Blake, Lois, Bethesda, Md., 2 Pekin ducks.
Boges, E. H., Greenbelt, Md., 14 white rats.
Bole, Joe, 3d, Washington, D. C., 37 box turtles.
Bolton, E. S., Arlington, Va., horned lizard.
Bonsall, Mrs. E. S., College Park, Md., 2 Toulouse geese, Pekin duck.
Boy Scouts, Troop 443, Silver Spring, Md., pilot black snake.
Bradford, Mrs. D., Arlington, Va., 2 Pekin ducks.
Branitsch, Jay, Arlington, Va., 4 box turtles.
Breed, R. E., Washington, D. C., skunk.
Bretemps, F., Washington, D. C., Pekin duck.
Brinckerhoff, Wm. W., Washington, D. C., yellow-headed parrot.*
Brown, J. F., Hyattsville, Md., red-tailed hawk.
Brown, Russell L., Greenbelt, Md., crow.
Bruder, W. A., Washington, D. C., 2 Pekin ducks.
Bruer, John L., Alexandria, Va., keeled green snake.
Buck, Warren, Camden, N. J., pygmy hippopotamus,* 2 cotton-headed marmosets.*
Burke, Donald, Washington, D. C., snapping turtle.
Carson, James, Arlington, Va., 2 opossums.
Carter, Mrs. Hill, Washington, D. C., opossum.
Castle, Guy, Oxon Hill, Md., 5 Muscovy ducks.
Chambers, Bob, Rockville, Md., skunk.
Clutter, C. J., Washington, D. C., muskrat.
Coffield, Mrs. E., Washington, D. C., canary.
Collins, Elizabeth, Washington, D. C., screech owl.
Conlin, Thomas Byrd, Arlington, Va., 9 box turtles.
Cook, Elliott R., Arlington, Va., Pekin duck.
Cool, Mrs. Leon, Washington, D. C., cedar waxwing.
Cox, Ray E., Washington, D. C., rabbit.
Crn, Mrs. Re, Alexandria, Va., 2 Pekin ducks.
Curran, Sandra M., Washington, D. C., 2 newts.
Cutchfield, John, Washington, D. C., 3 hamsters.

Dade, Bob, Washington, D. C., long-eared owl.
Dahlgren, Danny, Alexandria, Va., horned lizard.
Davis, F. A., Silver Spring, Md., pilot snake.
Dawson, D. M., Mount Rainier, Md., scarlet tanager.
Dean, Carol A., Washington, D. C., Pekin duck.
Deck, J. C., Riverdale, Md., ring-necked snake.
Derrett, R. E., Washington, D. C., Pekin duck.
DeWind, Mrs. A. W., Chevy Chase, Md., 2 Pekin ducks.
Dickey, Mrs. Alexander M., Washington, D. C., 2 English sparrows.
District of Columbia Dog Pound, Washington, D. C., raccoon, barred owl.
Dornin, W. W., Phoenix, Ariz., 2 western bull snakes, garter snake, 6 glossy snakes, Sonoran burrowing snake, 7 diamondback rattlesnakes, prairie rattlesnake, 6 chuckwallas, 6 sidewinders, 2 desert rattlers, Boyle's king snake, leaf-nosed snake, desert snake, striped racer, red racer, lizard.
Douglas, J. E., Rockville, Md., worm snake, ring-necked snake.
Douse, Richard, Washington, D. C., pilot black snake.
Doutrich, Edward A., Silver Spring, Md., American crow.
Downs, Larry E., Arlington, Va., rhesus monkey.*
Dulerio, Mrs. L. F., Fort Foote, Md., robin.
Durham, Mrs. A. W., Bethesda, Md., canary.
Durham, B. G., Chevy Chase, Md., 3 horned lizards.
Dyke, Mrs. Grace, Washington, D. C., 2 grass parakeets.
Edwards, Mrs. Kenneth, Washington, D. C., 3 grass parakeets.
Edwards, Marion, Washington, D. C., skunk.
Egbert, Gordon R., Chevy Chase, Md., 6 Pekin ducks.
Espenshade, G. H., Arlington, Va., 3 Pekin ducks.
Fahey, A. J., Takoma Park, Md., opossum.
Feeney, Mrs. J., Chevy Chase, Md., Pekin duck.
Fine, J. L., Hyattsville, Md., hamster.
Fleischman, Mrs. Morgan, Washington, D. C., 2 Pekin ducks.
Floyd, Mrs. R., Silver Spring, Md., Pekin duck.
Ford, Bertelle E., Rockville, Md., ring-necked snake.
Fothergill, James, and Stockwell, Frank, Newburyport, Mass., snapping turtle.
Fox, Dr. C. Corbin, Harrisonburg, Va., black vulture.
Freeman, D. H., Washington, D. C., rabbit.
French, M. B., Chevy Chase, Md., Pekin duck.
Gault, Mrs. S. W., Alexandria, Va., Pekin duck.
Gaver, Gordon, Thurmont, Md., 9 rhesus monkeys,* Javan macaque,* 2 pilot black snakes,* king cobra,* 5 Siamese cobras,* Indian python,* regal python,* 2 common boas,* green tree boa,* rainbow boa,* ball python,* mangrove snake,* African python,* 2 Gila monsters,* 3 black tegus,* 5 Florida diamondback rattlers,* Texas diamondback rattler,* 2 hog-nosed snakes.*
Geib, Mrs. Pat, Brentwood, Md., rabbit.
Gilligan, George W., Washington, D. C., black snake.
Grady, Dallis M., West River, Md., bald eagle.
Grassgreen, Mrs. Anne, Mount Rainier, Md., rabbit.
Graus, Mrs. Matilda, Alexandria, Va., Pekin duck.
Graybill, Catherine, Cabin John, Md., 2 water snakes.
Grow, Mrs. Norman A., College Park, Md., gray fox.
Guim, J. M., Alexandria, Va., black-widow spider.
Guinn, Terry, Arlington, Va., king snake.
Hagenbeck, Lorenz, Hamburg, Germany, 15 yellow-bellied toads.
Hahl, Miss L., Falls Church, Va., grass parakeet.

Hall, Billy and Bobby, Arlington, Va., alligator.
Hallard, Mrs., Arlington, Va., Pekin duck.
Hambright, D., Washington, D. C., 2 Pekin ducks.
Hanson, Chuck, Crestview, Fla., diamondback rattlesnake, 2 pygmy rattlesnakes.
Harris, Carter E., Jr., Takoma Park, Md., red fox.*
Hartman, John, Silver Spring, Md., 2 Pekin ducks.
Hawkins, Sandra L., Lewisdale, Md., 2 Pekin ducks.
Haymes, W. E., Lynchburg, Va., rhesus monkey.*
Heeland, Mrs. W., Washington, D. C., bobwhite quail.
Henderson, Bill, Vienna, Va., snapping turtle.
Hensley, Mrs. Betty, Richmond, Va., lion cub.
Herndon, J. L., family, Washington, D. C., sooty mangabey.
Hingorani, D. K., Washington, D. C., Pekin duck.
Hoke, John, Washington, D. C., flying squirrel.
Holland, Charles W., Arlington, Va., 3 white rats.
Hough, Milton, Washington, D. C., sparrow hawk.
Howard, Jeff, Washington, D. C., Pekin duck.
Howe, Chester, Herndon, Va., 2 raccoons.*
Hughes, Gloria B., Alexandria, Va., 3 opossums.
Humphrey, Nancy, Chevy Chase, Md., black-widow spider.
Huntt, Mrs. Henry S., Silver Spring, Md., blue jay.
Hutchins, Miss, Bethesda, Md., Pekin duck.
Ingham, Rex, Ruffin, N. C., 4 Ariel toucans, 2 smooth-scaled green snakes, 2 corn snakes.
Jenkins, Mrs. Louise N. M., Arlington, Va., raccoon.
Jerome, Mrs. Wm., Alexandria, Va., Pekin duck.
Jessup, Gordon L., Washington, D. C., pilot black snake.
Johns Hopkins Research Center, Baltimore, Md., 13 chimpanzees.*
Jones, Mrs. G. E., Washington, D. C., guinea fowl.
Joy, Jack, Kansas City, Mo., copperhead.
Joyner, Harry S., Arlington, Va., snapping turtle.
Kefauver, Senator Estes, Washington, D. C., skunk.
Kent, W. W., Silver Spring, Md., 2 raccoons.
Kerschbaum, Matt, Washington, D. C., horned lizard.
Kidwell, James, Washington, D. C., snapping turtle.
Kitts, J. F., Washington, D. C., rhesus monkey.
Kitts, Jean and Buddy, Washington, D. C., woodchuck.
Knutson, Mrs. A. L., Chevy Chase, Md., Pekin duck.
Kundahl, Mary Flo, Chevy Chase, Md., Pekin duck.
Kuntz, Dr. Robert E., Cairo, Egypt, fennec fox, 3 sand skinks, 2 agamas, 5 sand vipers, 3 horned vipers, 2 black vipers.
Leas, Russell, Hoadly, Va., baby brown bat.
Lebella, Mrs. Harry, Arlington, Va., Pekin duck.
Lee, Mrs. Sally, Washington, D. C., giant land snail.
Leslie, Carol, Washington, D. C., Pekin duck.
Lewis, Patsy, Mount Rainier, Md., Pekin duck.
Lister, H. E., Washington, D. C., Pekin duck.
Lyon, L. P., Arlington, Va., 2 Pekin ducks.
Mackellar, G. W., Hyattsville, Md., Pekin duck.
Mackintosh, Hugh, Bethesda, Md., 3 water snakes.
Maguire, Mrs. John A., Herndon, Va., pigeon.
Manson, Mrs. P. R., Washington, D. C., raccoon.
Manyette, Mr. and Mrs. Paul, Washington, D. C., mustached monkey.

May, J. Q., Falls Church, Va., diamondback terrapin.
McCabe, Elaine, and Knox, Bobby, Washington, D. C., large snapping turtle.
McCabe, John, Arlington, Va., snowy owl.*
McCourtney, Bruce, Norge, Va., 4 narrow-nosed frogs.
McDonald, R., Chevy Chase, Md., rabbit.
McEvoy, Miss H., Washington, D. C., 2 Pekin ducks.
McKinley, Douglas, Washington, D. C., silkworm.
McKnight, R. E., Avondale, Md., opossum.
McMichael, B. F., Washington, D. C., weasel.
Memory, Mrs. Amrion, Takoma Park, Md., Pekin duck.
Mercarlo, Karen, Washington, D. C., 2 Pekin ducks.
Miller, Patricia Anna, Washington, D. C., Pekin duck.
Milner, James L., Takoma Park, Md., mole.
Miner, Ernest H., Jr., Washington, D. C., 2 speckled king snakes,* 2 ornate whipsnakes,* red racer.*
Mize, Mrs. A. M., Rockville, Md., 15 bantam fowl.*
Monagon, Cathleen, Washington, D. C., robin.
Monks, Tommy, Washington, D. C., American crow.
Montgomery, C. R., Ringling Brothers Barnum & Bailey Circus, Sarasota, Fla., Indian python,* African python.*
Mooney, Mrs. A., Arlington, Va., brown capuchin.
Moore, Mrs. Bessie, Washington, D. C. cardinal.
Moore, Laird C., Washington, D. C., Pekin duck.
Morgan, Harriett, Silver Spring, Md., Pekin duck.
Moriarity, Mrs. Wm. B., Chevy Chase, Md., rabbit.
Muller, Mrs. E. D., Washington, D. C., red fox.
Murray, M. L., Silver Spring, Md., 2 Pekin ducks.
Musser, George, Arlington, Va., copperhead, timber rattler.
Myers, Howard A., Silver Spring, Md., brown capuchin.
National Institutes of Health, Betheseda, Md., through Samuel Poiley, 13 minks, 13 ferrets.
Nelson, Thurman M., Washington, D. C., screech owl.
Nugent, Robert, Greenbelt, Md., skunk.
O'Donnell's Restaurant, through Mr. Burger, Washington, D. C., alligator.
Pahlow, Mrs. H., Washington, D. C., 2 Cumberland terrapins.
Paraous, Col. M. V., Bethesda, Md., cardinal.
Payne, Jack, Mount Rainier, Md., 2 Pekin ducks.
Payne, Marie, Washington, D. C., red fox.
Payton, Mary Lee, North Arlington, Va., chicken, Pekin duck.
Pearson, S. H., Greenbelt, Md., snapping turtle.
Peratino, Mrs. William, Silver Spring, Md., 2 Pekin ducks.
Pet House, Washington, D. C., 4 prairie dogs.
Petro, Mrs. Joseph, Washington, D. C., Pekin duck.
Pickett, Lamar, Vienna, Va., pigeon hawk.
Plavsky, Mrs. R. K., Washington, D. C., American crow.
Potter, Mrs. Vergie, Washington, D. C., 4 Pekin ducks.
Powell, Mr. and Mrs. J. H., Washington, D. C., horned lizard.
Preston, John, Mount Pleasant, Pa., platinum fox.
Pusey, George O., Falls Church, Va., titi monkey.
Randolph, Frank, Lanham, Md., 4 American crows.
Randolph, Susan, Washington, D. C., 2 Pekin ducks.
Ray, Mrs. Nan C., Washington, D. C., yellow-naped parrot.*
Reindel, John A., Alexandria, Va., mole snake.





RECENT ADDITIONS TO THE NATIONAL ZOOLOGICAL PARK COLLECTIONS

Left, Baby pygmy hippopotamus (*Choeropsis liberiensis*) held by Assistant Headkeeper Ralph Norris. The baby is known as "Gumdrop XII" as it is the twelfth pygmy hippopotamus to be born in the Zoo. *Right*, Young Bornean small-toothed civet (*Arctogalidia trivirgata*). Length of adults from tip of nose to base of tail, 17 to 21 inches. The three continuous black stripes on the back from neck to hips distinguish them from the palm civets (*Paradoxurus*), of somewhat similar appearance. (Photographs by Ernest P. Walker.)

Rinehart, Max, Arlington, Va., Florida gallinule.
Roberts, Burt, Washington, D. C., 2 barn owls.
Roberts, H., Washington, D. C., mole snake.
Robins, Martin, Silver Spring, Md., snapping turtle.
Rodban, Kathleene, Washington, D. C., 2 Pekin ducks.
Roger, J., Bethesda, Md., 6 black snakes.
Rogers, Mrs. Margarette, Landover, Md., 2 albino ferrets.*
Rollins, J. W., Mechanicsville, Md., bald eagle.
Royer, Scott, Bethesda, Md., 2 black-widow spiders.
Rubenstein, Stan, Washington, D. C., rabbit.
Russel, R. D., Washington, D. C., Nias wattled mynah.*
Ryan, Cathy, Washington, D. C., rabbit.
Sakil, Patsy, Washington, D. C., robin.
Sallwan, Walter C., Corona, Calif., tarantula.
Sanders, Mrs. V. L., Arlington, Va., 3 Pekin ducks.
Saunders, Jeannie, Washington, D. C., Pekin duck.
Schaide, F. P., Arlington, Va., common loon.
Scheid, Pat, and West, David, Chevy Chase, Md., 2 musk turtles.
Schultz, Theodore A., Washington, D. C., hog-nosed snake, desert rattler.*
Schwab, E. M., Richmond, Va., 4 Bengali finches.
Scruggs, William, Washington, D. C., cottontail rabbit.
Scurley, William, Bethesda, Md., 2 Pekin ducks.
Seegers, Scott, McLean, Va., 2 blue jays.*
Shepherd, Elsie M., Washington, D. C., 2 black-cheeked lovebirds,* canary.*
Sherwood, W. Cullen, and Murphy, A. Page, Fairfax, Va., timber rattlesnake.
Shomette, Petey, Landover Hills, Md., smooth-scaled green snake.
Sidwell Friends School, Washington, D. C., 5 rabbits.
Simonton, L. J., Washington, D. C., hamster.
Sims, J. W., Hyattsville, Md., 3 grass parakeets.
Singer, Mrs. Harold, Washington, D. C., 2 Pekin ducks.
Sloane, E. K., Norfolk, Va., least tern.
Smith, Mrs. B. H., Arlington, Va., 2 rabbits.
Smith, Mrs. C., Jr., Arlington, Va., 2 Pekin ducks.
Smith, Mrs. C. W., Washington, D. C., 2 Pekin ducks.
Spangenberg, Earl J. M., Takoma Park, Md., 2 opossums.
Sparks, P. W., Bladensburg, Md., banded krait, 2 Russell's vipers, 150 Indian finches.*
Spikes, R. A., Alexandria, Va., 3 horned lizards.
Stanley, A. C., Washington, D. C., 2 horned lizards.
Steinbraker, Mrs. Louis, Alexandria, Va., margay cat.
Swaney, W. K., Falls Church, Va., pilot black snake.
Sweeney, J. M., Silver Spring, Md., Pekin duck, 4 mallard ducks.
Swift, Joseph M., Washington, D. C., 2 Pekin ducks.
Tager, Paul, Rockville, Md., 2 barn owls, gray fox.
Taylor, Mary K., Washington, D. C., 2 hooded rats.
Thompson, Mrs. Francis B., Washington, D. C., double yellow-headed parrot.*
Thornton, Mrs. Allen F., Washington, D. C., 2 Pekin ducks.
Tumber, Bill, Charlotte, N. C., Hamadryas baboon.
Twentieth Century-Fox Studios, Washington, D. C., kangaroo.
Tyrrell, W. Bryant, Takoma Park, Md., 4 smooth-scaled green snakes.
United States Army Medical Unit in Malaya, through Lt. Col. Robert Traub, 2 orangutans, 2 small-toothed civets, 4 ferret-badgers, 2 tree shrews, 4 Mount Kinabalu black rats, 1 Bornean porcupine, 1 spineless hedgehog.

United States Customs, Washington, D. C., 2 grass parakeets.*
United States Fish and Wildlife Service:
Through John H. Buckalew, Cambridge, Md., Florida sandhill crane.
Through Gardner Bump and State of New Mexico, 2 MacQueen's bustards.
Through Vernon Ekedahl, Willows, Calif., 5 Hutchins's geese, 7 white-fronted geese, 10 snow geese, 17 cackling geese, 9 Ross's geese, 2 whistling swans.
Through Dr. H. S. Mosby, Blacksburg, Va., golden eagle.
Through Washington, D. C., office, wood rat.
United States Geological Survey, Washington, D. C., through I. G. Sohn, 2 horseshoe crabs.
University of Colorado Museum, Boulder, Colo., through Hugo G. Rodeck, 8 prairie rattlesnakes.
Van Dusen, Capt. E. R., Presidio of Monterey, Calif., Alexandrine parakeet.
Van Tassel, Ed, San Antonio, Tex., 2 ribbon snakes,* garter snake,* swift lizard.*
Van Tassel, Edward, Arlington, Va., copperhead snake.*
Vazquez, Albert, Arlington, Va., black snake.*
Vernon, J., Washington, D. C., sparrow hawk.
Virgin, Elizabeth, Washington, D. C., skunk.
Voigt, Paul, Washington, D. C., Pekin duck.
Walkup, Joe, Landover, Md., tree frog.
Walmsley, Alan, Arlington, Va., gopher tortoise.
Walsh, Mrs. Katie, Washington, D. C., red fox.
Walton, Mrs. A. I., Takoma Park, Md., blue jay.
Warren, Mrs. Arthur L., Falls Church, Va., rabbit.
Watkins, Jerry, Washington, D. C., hamster.
Weaver, Mrs. G., East Riverdale, Md., raccoon.
Weir, Mrs. R. H., Silver Spring, Md., worm snake.
Wells, Dr. R. Loma, Washington, D. C., sparrow hawk.
Whitaker, William J., Washington, D. C., Australian black swan.
White, Mr., Richmond, Va., lion cub.*
White, Melvin, Jefferson Heights, Md., barn owl.
Whitman, Phily H., Laurel, Md., pilot black snake.
Wicker, Nell, Chevy Chase, Md., 2 Pekin ducks.
Wightman, F. E., Green Meadows, Md., timber rattler.
Williams, Arthur, Washington, D. C., Muscovy duck.
Williams, Sylvester, Washington, D. C., black racer, 2 mole snakes.
Wilson, Steve and Tommy, Arlington, Va., 3 box turtles, 2 Pekin ducks.
Winkle, Mrs. Barbara, Chevy Chase, Md., pied-billed grebe.
Witt, Bill, Arlington, Va., fox snake, king snake, box turtle, Holbrook king snake,* fox snake,* 2 blue racers,* pilot black snake,* ribbon snake,* fence lizard,* 2 worm snakes,* green snake.*
Wolf, J., Bellmead, Md., 2 mallard ducks.
Xanten, Bill, Washington, D. C., snapping turtle, alligator.
Young, Oliver B., Arlington, Va., snapping turtle.
Zust, Ralph and James, Washington, D. C., opossum.

BIRTHS AND HATCHINGS

Animals that are kept on exhibition are usually not under conditions that are most favorable for breeding and raising young. However, occasionally young are born or hatched that are outstanding in their interest. The following were produced in the Zoo during the fiscal year:

MAMMALS

Scientific name	Common name	Number
Ammotragus lervia	Aoudad	4
Bos taurus	British Park cattle	2
	West Highland cattle	1
Cephalophus nigrifrons	Black-fronted duiker	1
Cercopithecus aethiops sabaeus × *C. a. pygerythrus.*	Green guenon × vervet guenon	1
Cervus nippon	Japanese deer	1
Choeropsis liberiensis	Pygmy hippopotamus	1
Comopithecus hamadryas	Hamadryas baboon	1
Dama dama	Brown fallow deer	4
	White fallow deer	3
Dasyprocta prymnolopha	Agouti	2
Erythrocebus patas	Patas monkey	1
Felis concolor	Puma	3
Felis leo	Lion	5
Giraffa camelopardalis	Nubian giraffe	1
Hippopotamus amphibius	Hippopotamus	1
Hydropotes inermis	Chinese water deer	5
Leontocebus rosalia	Silky marmoset	2
Llama glama	Llama	2
Macaca mulatta	Rhesus monkey	2
Mustela eversmanni	Ferret	13
Myocastor coypus	Coypu	4
Odocoileus virginianus	Virginia deer	1
Poephagus grunniens	Yak	1
Taurotragus oryx	Eland	1
Thalarctos maritimus × *Ursus middendorffi.*	Hybrid bear	4
Trichosurus vulpecula	Australian long-eared opossum	3
Wallabia agilis	Agile wallaby	2

BIRDS

Scientific name	Common name	Number
Anas platyrhynchos	Mallard duck	5
	White mallard duck	13
Branta canadensis	Canada goose	19
Cygnus cygnus	Whooper swan	2
Gallus gallus	Red junglefowl	1
Gennaeus leucomelanus	Nepal kaleege	2
Haliaeetus leucocephalus	Bald eagle	1
Larus novaehollandiae	Silver gull	1
Streptopelia tranquebarica	Blue-headed ring dove	2
Taeniopygia castanotis	Zebra finch	5
Tigrisoma lineatum	Tiger bittern	4

REPTILES

Scientific name	Common name	Number
Agkistrodon mokesen	Copperhead	3
Naja tripudians	Indian cobra	12

It is gratifying to note that the pair of mole rats (*Cryptomys lugardi*) from southeastern Africa raised two young that were born

last year. These are little-known burrowing creatures that somewhat resemble the pocket gophers of South America but are dark lead color with a large white blotch on the forehead. Their front teeth project even more than in most rodents and are used in burrowing.

MAINTENANCE AND IMPROVEMENTS

The work of rehabilitating the large-mammal house, which was begun in the previous fiscal year, was completed December 10, 1951.

Contract was let for the installation of zone heat regulators in the small-mammal and reptile houses. These should result in better control of the temperature than has heretofore been possible and should effect enough of a saving in heat to more than pay for the installation.

Every working day of the construction and maintenance department involves not only the routine work of cleaning the buildings and grounds, unstopping sewers and drains that have become clogged, repairing leaky faucets, broken windows, cages, cage doors, cage locks, and innumerable other small items, but also additional jobs of somewhat greater scope. The more important of these during the fiscal year were:

1. Remodeled bear cage, between monkey house and lion house.
2. Dismantled four old wooden animal shelters and replaced them with new brick-concrete shelters, in the line of cages above the reptile house.
3. Made extensive repairs to all outside cages attached to the bird house, and painted them.
4. Remodeled nine cages in the finch room at the bird house in new design, with plate glass covering upper half and electric-weld wire fabric covering lower half of cages.
5. Applied bituminous concrete to areas between road curbing and sidewalks along main roadway to prevent erosion, eliminate mud, and lessen danger of visitors' stumbling into traffic.
6. Installed new electric water heaters in annex No. 1 and in the lion house.
7. Made general repairs to 100 wooden park benches.
8. Cast new concrete bench legs and arms and concrete picnic-table tops.
9. Repaired iron work and placed new where needed, and applied three coats of paint on large outdoor eagle cage.
10. Dismantled old wooden shelters and replaced them with new brick-concrete shelters in large outdoor flight cage.
11. Made general repairs to boilers in the central heating plant, conduit system, and heating systems within the buildings. In the central heating plant this involved replacement of all fire-box tubing in the three boilers; cleaning and painting the interior and exterior of the boilers; renewal of parts in the blow-off valves; replacement of baffle walls, grates, and side bars. All steam and electric pumps and traps in the boiler room were overhauled, repaired and worn parts replaced, and the interior of the boiler room was painted. Throughout the heating system unserviceable steam lines were replaced. Worn parts in steam traps were repaired and steam traps that were beyond repair were replaced with new ones. Worn parts in the vacuum pumps were replaced where needed.

The fight to eradicate poison ivy in the Zoo grounds is being continued. This pest has been almost completely eliminated in those parts most frequented by the public, and control measures are being extended to more remote sections to keep it from spreading to areas used by the public. Otherwise the long-established policy of leaving the woodlands undisturbed is being followed.

Over a period of years there has been a gradual increase in the amount of trimming of trees along the roads, walks, and paths, and in the exhibition area. Because of their great age, some of the trees are dying and must be cut down. Others must be trimmed to remove dead or broken limbs which might fall and injure people or animals, or damage automobiles or structures within the grounds.

During the year a system was inaugurated of appointing temporary intermittent policemen to serve on Saturdays, Sundays, and holidays during the seasons of unusually heavy attendance or to relieve regular men when necessary. This plan is proving highly satisfactory, as it makes more men available for the few days of the year when they are most urgently needed without maintaining a large permanent force.

As in previous years the Zoo received gifts of various kinds of food that could not be sold for human consumption but was suitable for animals. This helps considerably to hold purchases to a minimum. Among the many kinds of such foods were 37,000 pounds of frozen skinned rabbits, frozen strawberries, frozen kale, and butter. Outstanding aid in supplying such material was given by W. Bruce Matthews, United States Marshal, who turned over food that was condemned through the courts. A considerable assortment came also from the Safeway Stores, Inc., which had suffered a fire at one of its establishments. From other sources there came 21 bags of English walnuts, 600 pounds of candy, 3,200 pounds of dog food, 25 cases of assorted baby food, 46 cases of egg noodles, 15 cases of macaroni, 100 cases of assorted dog and cat food, 450 pounds of turnips, and some avocados. The General Services Administration donated 36 cases of prunes no longer suitable for human consumption. The Fish and Wildlife Service sent the Zoo more than 200 four-week-old chicks that had been used in certain experiments but were still suitable for animal food. The National Institutes of Health, Navy Medical Center, and Army Medical Center gave mice, rats, guinea pigs, rabbits, and other animals no longer suitable for their purposes. The practice has been continued of picking up from grocery stores in the vicinity of the Zoo quantities of discarded green material such as cabbage, cauliflower, lettuce, beet tops, and celery stalks. This provides an abundance of greens for the animals and helps reduce purchases of such foods.

VISITORS

The estimated number of visitors to the Zoo was 3,294,569, or 165,831 less than for the year 1951, a decrease due mainly to inclement weather in the spring of 1952, particularly on week ends and holidays, which deterred persons from the District of Columbia, Maryland, and Virginia from visiting the Zoo. There was little change, however, in the record of automobile attendance and groups coming by bus.

Estimated number of visitors for fiscal year 1952

July (1951)	496,000	February	133,900
August	459,000	March	147,650
September	379,500	April	344,719
October	311,200	May	339,500
November	149,700	June	341,500
December	86,100		
January (1952)	105,800	Total	3,294,569

Groups came to the Zoo from schools in Canada and 32 States, some as far away as Maine, Florida, Oklahoma, Kansas, and South Dakota. This was an increase of 31 groups and 7,874 individuals in groups over last year.

Number of groups from schools

Locality	Number of groups	Number in groups	Locality	Number of groups	Number in groups
Alabama	11	407	Mississippi	2	126
Canada	1	54	Missouri	2	60
Connecticut	12	572	New Hampshire	1	34
Delaware	9	343	New Jersey	17	1,150
District of Columbia	149	6,596	New York	66	4,665
Florida	7	907	North Carolina	215	8,795
Georgia	46	3,876	Ohio	67	2,475
Illinois	4	351	Oklahoma	1	23
Indiana	9	795	Pennsylvania	266	18,904
Iowa	4	102	Rhode Island	2	75
Kansas	1	27	South Carolina	35	1,227
Kentucky	18	637	South Dakota	1	20
Louisiana	1	71	Tennessee	24	2,015
Maine	8	694	Virginia	498	26,967
Maryland	619	35,381	West Virginia	65	4,902
Massachusetts	10	356	Wisconsin	1	21
Michigan	16	1,159			
Minnesota	3	85	Total	2,191	123,872

About 2 p. m. each day the cars then parked in the Zoo are counted by the Zoo police and listed according to the State, Territory, or country from which they came. This is, of course, not a census of the cars coming to the Zoo but is valuable in showing the percentage of attendance, by States, of people in private automobiles. Many of the District of Columbia, Maryland, and Virginia cars come to the Zoo to bring

guests from other States. The tabulation for the fiscal year 1952 is as follows:

	Percent		Percent
Washington, D. C.	31.0	Ohio	1.7
Maryland	22.3	West Virginia	1.5
Virginia	19.0	New Jersey	1.4
Pennsylvania	4.3	Massachusetts	1.0
New York	2.6	Florida	.9
North Carolina	2.3	Illinois	.8

The cars that made up the remaining 11.2 percent came from every one of the remaining States, as well as from Africa, Alaska, Australia, Austria, Canal Zone, Cuba, El Salvador, England, Germany, Guam, Guatemala, Hawaii, Honduras, Japan, Mexico, Newfoundland, the Philippines, Puerto Rico, and the Virgin Islands.

On the days of small attendance there are cars parked in the Zoo from at least 15 States, Territories, the District, and foreign countries. On average days there are cars from about 22 States, Territories, the District, and foreign countries; and during the periods of greatest attendance the cars represent not less than 34 different regions.

NEEDS OF THE ZOO

Replacement of antiquated structures that have long since ceased to be suitable for the purposes for which they are used is still the principal need of the Zoo. The more urgently needed buildings are: (1) A new administration building to replace the 147-year-old historic landmark now in use as an office building but which is neither suitably located nor well adapted for the purpose; (2) a new building to house antelopes and other medium-sized hoofed animals that require a heated building; and (3) a fireproof service building for receiving shipments of animals, quarantining animals, and caring for animals in ill health or those that cannot be placed on exhibition.

It would be good economy in the long run to extend the steam conduit from the large-mammal house to the bird house, at an estimated cost of about $35,000. This would not only bring about a reduction in actual heating cost but would obviate boiler repairs and replacements that may be necessary very soon, as two of the boilers are 25 years old.

There is need for a veterinarian who can devote his entire time to assisting the animal department in selecting suitable foods, presenting foods to the animals in a satisfactory manner, practicing preventive medicine, and making autopsies to determine causes of death. The salary and operating cost for a veterinarian would be a good investment, for with professional care the lives of many animals in the Zoo would undoubtedly be lengthened.

The steadily increasing popularity of the Zoo, as a source of both entertainment and education, has developed such a volume of requests for information that there is now need for an additional scientist to share the load of answering queries and to assist in other administrative work so that the Director and Assistant Director can devote more time to general supervision of the Zoo and attention to visitors.

ANIMALS IN THE COLLECTION JUNE 30, 1952

MAMMALS

MONOTREMATA

Scientific name	*Common name*	*Number*
Tachyglossidae:		
Tachyglossus aculeatus	Echidna, or spiny anteater	2

MARSUPIALIA

Scientific name	*Common name*	*Number*
Didelphiidae:		
Caluromys laniger	Woolly opossum	1
Didelphis virginiana	Opossum	2
Marmosa mitis	Murine opossum	2
Marmosa sp	Murine opossum	1
Phalangeridae:		
Petaurus norfolcensis	Australian flying phalanger	9
Trichosurus vulpecula	Australian long-eared opossum	6
Macropodidae:		
Dendrolagus inustus	New Guinea tree kangaroo	1
Macropus giganteus	Great gray kangaroo	2
	Albino great gray kangaroo	1
Macropus robustus	Euro wallaroo	2
Macropus rufus	Great red kangaroo	3
Wallabia agilis	Agile wallaby	2

PRIMATES

Scientific name	*Common name*	*Number*
Tupaiidae:		
Tupai montana baluensis	Kinabalu tree shrew	2
Lemuridae:		
Lemur macaco	Acoumba lemur	2
Lemur mongoz	Mongoose lemur	2
Lorisidae:		
Nycticebus coucang	Slow loris	1
Cebidae:		
Aotus trivirgatus	Douroucouli, or night monkey	2
Ateles geoffroyi vellerosus	Spider monkey	2
Cebus apella	Pale capuchin	5
Cebus capucinus	White-throated capuchin	1
Cebus fatuellus	Weeping capuchin	2
Lagothrix lagotricha	Woolly monkey	1
Callithricidae:		
Leontocebus rosalia	Silky or lion-headed marmoset	4
Saimiri sciureus	Squirrel monkey	3

Scientific name	*Common name*	*Number*
Cercopithecidae:		
Cercocebus aterrimus	Black-crested mangabey	2
Cercocebus fuliginosus	Sooty mangabey	3
Cercopithecus aethiops pygerythrus	Velvet guenon	2
Cercopithecus aethiops sabaeus	Green guenon	7
Cercopithecus aethiops sabaeus × *C. a. pygerythrus.*	Hybrid, green guenon × vervet guenon.	2
Cercopithecus cephus	Moustached guenon	3
Cercopithecus diana	Diana monkey	3
Cercopithecus diana roloway	Roloway monkey	1
Cercopithecus neglectus	De Brazza's guenon	3
Cercopithecus nictitans petaurista	Lesser white-nosed guenon	1
Cercopithecus preussi	Preussi's guenon	1
Colobus polykomos	White-tailed colobus	1
Comopithecus hamadryas	Hamadryas baboon	3
Erythrocebus patas	Patas monkey	3
Macaca irus	Crab-eating macaque	1
Macaca irus mordax	Javan macaque	4
Macaca lasiotis	Chinese macaque	1
Macaca maurus	Moor macaque	1
Macaca mulatta	Rhesus monkey	14
Macaca nemestrina	Pig-tailed monkey	1
Macaca philippinensis	Philippine macaque	6
Macaca sinica	Toque, or bonnet monkey	1
Macaca speciosa	Red-faced macaque	1
Macaca sylvanus	Barbary ape	4
Mandrillus leucophaeus	Drill	2
Mandrillus sphinx	Mandrill	3
Papio comatus	Chacma baboon	2
Papio cynocephalus	Golden baboon	1
Presbytis phayrei	Phayre's langur	1
Pongidae:		
Hylobates agilis × *H. lar pileatus*	Hybrid gibbon	1
Hylobates hoolock	Hoolock gibbon	1
Hylobates lar	White-handed gibbon	1
Pan troglodytes	Chimpanzee	8
Pongo pygmaeus abelii	Orangutan	1

EDENTATA

Myrmecophagidae:		
Myrmecophaga tridactyla	Giant anteater	2
Bradypodidae:		
Choloepus didactylus	Two-toed sloth	5
Dasypodidae:		
Chaetophractus villosus	Hairy armadillo	2

LAGOMORPHA

Leporidae:		
Oryctolagus cuniculus	Domestic rabbit	9
Sylvilagus floridanus	Cottontail rabbit	2

RODENTIA

Scientific name	Common name	Number
Sciuridae:		
Callosciurus caniceps	Southern Asiatic squirrel	1
Callospermophilus lateralis	Albino golden-mantled ground squirrel.	1
Callospermophilus lateralis chrysodeirus.	Golden-mantled ground squirrel	1
Citellus beecheyi douglasii	Douglas's ground squirrel	2
Cynomys ludovicianus	Plains prairie dog	15
Marmota monax	Woodchuck, or ground hog	6
Tamias striatus	Eastern chipmunk	2
Heteromyidae:		
Dipodomys microps	Small-faced kangaroo rat	1
Cricetidae:		
Gerbillus pyramidum	Pyramid gerbil	1
Mesocricetus auratus	Golden hamster	10
Neotoma lepida	Pack rat	1
Ondatra zibethicus	Muskrat	1
Peromyscus maniculatus sonoriensis.	Sonoran white-footed mouse	1
Tatera schinzi shirensis	Nyasaland gerbil	1
Muridae:		
Acomys cahirinus	Egyptian spiny mouse	12
Cricetomys gambianus	Giant pouched rat	5
Mastomys coucha	Multimammate mouse	1
Mus musculus	White and other domestic mice	10
Phloeomys cumingi	Slender-tailed cloud rat	4
Rattus infraluteus	Kinabalu giant rat	1
Rattus norvegicus	Hooded rat	2
	White rat	2
Rattus sabanus	Large spiny-backed tree rat	1
Hystricidae:		
Acanthion brachyurum	Malay porcupine	3
Hystrix galeata	African porcupine	2
Trichys lipura	Bornean porcupine	1
Erethizontidae:		
Coendou sanctaemartae (or *rothschildi*).	Prehensile-tailed porcupine	1
Caviidae:		
Cavia porcellus	Guinea pig	15
Dasyproctidae:		
Cuniculus paca	Paca	4
Dasyprocta punctata	Speckled agouti	2
Dasyprocta sp	Agouti	7
Chinchillidae:		
Chinchilla chinchilla	Chinchilla	1
Lagidium viscaccia	Peruvian viscacha	1
Capromyidae:		
Myocastor coypus	Coypu	3
Ctenomyidae:		
Ctenomys sp	Tuco-tuco	1

Scientific name	Common name	Number
Echimyidae:		
Euryzygomatomys sp	Euryzygomatomys	1
Thryonomyidae:		
Thryonomys swinderianus	Cane rat	1
Bathyergidae:		
Cryptomys lugardi	Mole rat	4
CARNIVORA		
Canidae:		
Canis antarcticus	Dingo	1
Canis latrans	Coyote	3
Canis niger rufus	Texas red wolf	2
Fennecus zerda	Fennec fox	3
Nyctereutes procyonoides	Raccoon dog	5
Otocyon megalotis	Big-eared fox	4
Speothos venaticus	Bush dog	2
Urocyon cinereoargenteus	Gray fox	13
Vulpes fulva	Red fox	2
	Silver fox	5
Ursidae:		
Euarctos americanus	Black bear	3
Helarctos malayanus	Malay or sun bear	1
Selenarctos thibetanus	Himalayan bear	1
Thalarctos maritimus	Polar bear	1
Thalarctos maritimus × *Ursus middendorffi*.	Hybrid bear	4
	Hybrid bear, second generation	1
Tremarctos ornatus	Spectacled bear	1
Ursus arctos	European brown bear	1
Ursus arctos occidentalis	Syrian brown bear	2
Ursus gyas	Alaskan Peninsula bear	2
Ursus horribilis	Grizzly bear	2
Ursus middendorffi	Kodiak bear	1
Ursus sitkensis	Sitka brown bear	3
Ursus sp	Alaska brown bear	1
Procyonidae:		
Bassariscus astutus	Ringtail, or cacomistle	1
Nasua narica	Coatimundi	6
Nasua nelsoni	Nelson's coatimundi	1
Potos flavus	Kinkajou	6
Potos sp	Dwarf kinkajou	2
Procyon lotor	Raccoon	24
	Black raccoon	4
	Albino raccoon	1
Mustelidae:		
Lutra canadensis vaga	Florida otter	1
Meles meles leptorynchus	Chinese badger	1
Mephitis mephitis nigra	Skunk	11
Mustela eversmanni	Ferret	10
	Albino ferret	2
Mustela frenata noveboracensis	Weasel	2
Mustela vison	Mink	1
Spilogale phenax	California spotted skunk	1
Taxidea taxus	American badger	5

Scientific name	*Common name*	*Number*
Viverridae:		
Arctogalidia trivirgata stigmatica	Small-toothed civet	1
Civettictis civetta	African civet	1
Crossarchus obscurus	Kusimanse	1
Genetta tigrinus	Genet	3
Myonax sanguineus	Dwarf civet	1
Nandinia binotata	African palm civet	1
Viverra tangalunga	Ground civet	1
Hyaenidae:		
Crocuta crocuta germinans	East African spotted hyena	2
Felidae:		
Felis chaus	Jungle cat	1
Felis concolor	Puma	3
Felis concolor × *F. c. patagonica*	Hybrid, North American puma × South American puma.	9
Felis leo	Lion	6
Felis onca	Jaguar	3
Felis pardalis	Ocelot	1
Felis pardus	African leopard	4
Felis tigrina	Margay cat	1
Felis tigris	Bengal tiger	4
Felis tigris sumatrae	Sumatran tiger	1
Herpailurus yaguarundi	Yaguarundi	1
Oncifelis geoffroyi	Geoffroy's cat	2
Oncilla pardinoides	Lesser tiger cat	1
PINNIPEDIA		
Otariidae:		
Zalophus californianus	California sea-lion	3
Phocidae:		
Phoca vitulina	Harbor seal	1
TUBULIDENTATA		
Orycteropodidae:		
Orycteropus afer	Aardvark, or ant bear	1
PROBOSCIDEA		
Elephantidae:		
Elephas maximus	Asiatic elephant	3
Loxodonta africana oxyotis	African elephant	1
PERISSODACTYLA		
Equidae:		
Equus burchellii antiquorum	Chapman's zebra	1
Equus burchellii bohmi	Grant's zebra	3
Equus caballus	Horse	1
Equus kiang	Asiatic wild ass, or kiang	1
Equus onager	Onager	1
Equus przewalskii	Mongolian wild horse	2
Rhinocerotidae:		
Diceros bicornis	African rhinoceros	1
Rhinoceros unicornis	Great Indian one-horned rhinoceros.	1

ARTIODACTYLA

Scientific name	Common name	Number
Suidae:		
Phacochoerus aethiopicus aeliani	East African wart hog	2
Sus scrofa	European wild boar	1
Tayassuidae:		
Tayassu tajacu	Collared peccary	2
Hippopotamidae:		
Choeropsis liberiensis	Pygmy hippopotamus	9
Hippopotamus amphibius	Hippopotamus	2
Camelidae:		
Camelus bactrianus	Bactrian camel	2
Camelus dromedarius	Single-humped camel	2
Lama glama	Llama	4
Lama glama guanicoe	Guanaco	3
Lama pacos	Alpaca	4
Vicugna vicugna	Vicuña	1
Cervidae:		
Axis axis	Axis deer	1
Cervus canadensis	American elk	5
Cervus elaphus	Red deer	1
Cervus nippon	Japanese deer	4
Cervus nippon manchuricus	Dybowsky's deer	2
Dama dama	Fallow deer	15
	White fallow deer	18
Hydropotes inermis	Chinese water deer	6
Mazama sartorii	Mazama	2
Odocoileus virginianus	Virginia deer	5
Giraffidae:		
Giraffa camelopardalis	Nubian giraffe	5
Giraffa reticulata	Reticulated giraffe	1
Bovidae:		
Ammotragus lervia	Aoudad	21
Bibos gaurus	Gaur	5
Bison bison	American bison	9
Bos indicus	Zebu	2
Bos taurus	West Highland or Kyloe cattle	3
	British Park cattle	8
Bubalus bubalis	Water buffalo	2
Capra aegagrus cretensis	Agrimi goat	1
Cephalophus maxwellii	Maxwell's duiker	1
Cephalophus nigrifrons	Black-fronted duiker	2
Hemitragus jemlahicus	Tahr	2
Oryx leucoryx	Arabian oryx	1
Ovis aries	Woolless sheep	1
Ovis europaea	Mouflon	1
Poephagus grunniens	Yak	5
Pseudois nayaur	Bharal or blue sheep	1
Syncerus caffer	African buffalo	3
Taurotragus oryx	Eland	3

BIRDS

SPHENISCIFORMES

Scientific name	Common name	Number
Spheniscidae:		
Spheniscus demersus	Jackass penguin	3
Spheniscus humboldti	Humboldt's penguin	3

STRUTHIONIFORMES

Struthionidae:		
Struthio camelus	Ostrich	1

RHEIFORMES

Rheidae:		
Rhea americana	Common rhea	3

CASUARIIFORMES

Casuariidae:		
Casuarius casuarius aruensis	Aru cassowary	1
Casuarius unappendiculatus occipitalis.	Island cassowary	1
Casuarius unappendiculatus unappendiculatus.	One-wattled cassowary	1
Dromiceiidae:		
Dromiceius novaehollandiae	Common emu	4

TINAMIFORMES

Tinamidae:		
Crypturellus cinnamomeus	Salle's tinamou	7
Crypturellus idoneus	Santa Marta tinamou	8
Crypturellus soui	Little tinamou	1

PELECANIFORMES

Pelecanidae:		
Pelecanus erythrorhynchus	White pelican	2
Pelecanus occidentalis occidentalis	Brown pelican	2
Pelecanus onocrotalus	Old World white pelican	2
Sulidae:		
Sula dactylatra	Blue-faced booby	1
Phalacrocoracidae:		
Phalacrocorax auritus albociliatus	Farallon cormorant	1

CICONIIFORMES

Ardeidae:		
Ardea herodias	Great blue heron	2
Hydranassa tricolor ruficollis	Louisiana heron	1
Leucophoyx thula	Snowy egret	3
Notophoyx novaehollandiae	White-faced heron	1
Nyctanassa violacea	Yellow-crowned night heron	1
Nycticorax nycticorax hoactli	Black-crowned night heron	29
Tigrisoma lineatum	Tiger bittern	3

Scientific name	*Common name*	*Number*
Balaenicipitidae:		
Balaeniceps rex	Shoebill	1
Cochleariidae:		
Cochlearius cochlearius	Boat-billed heron	1
Ciconiidae:		
Ciconia alba	White stork	1
Dissoura episcopus	Woolly-necked stork	1
Ibis cinereus	Malayan painted stork	1
Jabiru mycteria	Jabiru	1
Leptoptilus crumeniferus	Marabou	1
Leptoptilus dubius	Indian adjutant	1
Leptoptilus javanicus	Lesser adjutant	2
Mycteria americana	Wood ibis	1
Threskiornithidae:		
Guara alba	White ibis	4
Guara alba × *G. rubra*	Hybrid, white ibis × scarlet ibis	1
Guara rubra	Scarlet ibis	3
Threskiornis melanocephala	Black-headed ibis	1
Threskiornis spinicollis	Straw-necked ibis	1
Phoenicopteridae:		
Phoenicopterus antiquorum	Old World flamingo	2
Phoenicopterus chilensis	Chilean flamingo	6
Phoenicopterus ruber	Cuban flamingo	2

ANSERIFORMES

Anhimidae:		
Chauna torquata	Crested screamer	3
Anatidae:		
Aix sponsa	Wood duck	3
Anas brasiliensis	Brazilian teal	1
Anas platyrhynchos	Mallard duck	52
	White mallard duck	3
Anas platyrhynchos × *Dafila acuta.*	Hybrid, mallard duck × pintail duck.	1
Anas platyrhynchos domestica	Pekin duck	60
Anas poecilorhyncha	Indian spotted-bill duck	2
Anas rubripes	Black duck	3
Anser albifrons	White-fronted goose	5
Anser albifrons subsp	Greenland white-fronted goose	1
Anser anser domestica	Toulouse goose	2
Anseranas semipalmata	Australian pied goose	1
Aythya affinis	Lesser scaup	1
Aythya fuligula	Tufted duck	1
Aythya valisineria	Canvasback duck	2
Branta canadensis	Canada goose	38
Branta canadensis occidentalis	White-cheeked goose	12
Branta canadensis × *Chen caerulescens.*	Hybrid, Canada goose × blue goose.	2
Branta hutchinsii	Hutchins's goose	4
Branta hutchinsii minima	Cackling goose	26
Branta ruficollis	Red-breasted goose	2
Cairina moschata	Muscovy duck	4
Cereopsis novaehollandiae	Cape Barren goose	4

Scientific name	*Common name*	*Number*
Anatidae—Continued		
Chen atlantica	Snow goose	11
Chen hyperborea	Lesser snow goose	2
Chen rossi	Ross's snow goose	12
Chenopis atrata	Black swan	7
Chloephaga leucoptera	Upland goose	2
Coscoroba coscoroba	Coscoroba	1
Cygnopsis cygnoides	Domestic swan-goose	2
Cygnus columbianus	Whistling swan	2
Cygnus cygnus	Whooper swan	4
Dafila acuta	Pintail	3
Dafila spinicauda	Chilean pintail	1
Dendrocygna autumnalis	Black-bellied tree duck	52
Eulabeia indica	Bar-headed goose	7
Mareca americana	Baldpate	1
Metopiana peposaca	Rosy-billed pochard	2
Netta rufina	Red-crested pochard	2
Nettion carolinense	Green-winged teal	1
Plectropterus gambiensis	Spur-winged goose	2
Querquedula cyanoptera	Cinnamon teal	1
Querquedula discors	Blue-winged teal	2
Tadorna tadorna	Shelldrake	2
FALCONIFORMES		
Cathartidae:		
Cathartes aura	Turkey vulture	1
Coragyps atratus	Black vulture	3
Gyps rueppelli	Rüppell's vulture	2
Sarcoramphus papa	King vulture	2
Vultur gryphus	Andean condor	2
Sagittariidae:		
Sagittarius serpentarius	Secretarybird	2
Accipitridae:		
Aquila chrysaetos canadensis	Golden eagle	1
Buteo fuscescens	Red-backed buzzard	2
Buteo jamaicensis	Red-tailed hawk	8
Buteo lineatus lineatus	Red-shouldered hawk	3
Buteo platypterus	Broad-winged hawk	1
Buteo poecilochrous	Buzzard eagle	1
Buteo swainsoni	Swainson's hawk	2
Haliaeetus leucocephalus	Bald eagle	5
Haliaeetus leucogaster	White-breasted sea eagle	2
Haliaeetus leucoryphus	Crowned sea eagle	1
Haliastur indus	Brahminy kite	3
Harpia harpya	Harpy eagle	1
Milvago chimango	Chimango	3
Milvus migrans parasitus	African yellow-billed kite	2
Spizaetus ornatus	Black-and-white hawk eagle	1
Falconidae:		
Falco mexicanus	Prairie falcon	1
Falco sparverius	Sparrow hawk	2
Polyborus plancus	South American caracara	3

GALLIFORMES

Scientific name	Common name	Number
Megapodiidae:		
Alectura lathami	Brush turkey	2
Cracidae:		
Crax alberti	Blue-cered curassow	5
Crax panamensis	Panama curassow	2
Crax rubra	Yellow-cered curassow	4
Ortalis motmot	Chachalaca	2
Penelope boliviana	Crested guan	3
Phasianidae:		
Argusianus argus	Argus pheasant	1
Colinus virginianus	Bobwhite	3
Crossoptilon auritum	Blue-eared pheasant	1
Gallus gallus	Bantam fowl	17
	Fighting fowl	6
	Red junglefowl	3
Gennaeus albocristatus	White-crested kaleege	1
Gennaeus leucomelanus	Nepal kaleege	2
Gennaeus nycthemerus	Silver pheasant	2
Hierophasis swinhoii	Swinhoe's pheasant	2
Odontophorus gujanensis marmoratus	Marbled Guiana quail	1
Pavo cristatus	Peafowl	12
Phasianus torquatus	Ring-necked pheasant	5
	White ring-necked pheasant	2
Numididae:		
Acryllium vulturinum	Vulturine guineafowl	1
Guttera plumifera schubotzi	Uele crested guineafowl	2
Numida meleagris	Guineafowl	2
	White guineafowl	2
Meleagrididae:		
Agriocharis ocellata	Ocellated turkey	3
Meleagris gallopavo	Wild turkey	1

GRUIFORMES

Scientific name	Common name	Number
Gruidae:		
Anthropoides virgo	Demoiselle crane	2
Balearica pavonina	West African crowned crane	2
Balearica regulorum gibbericeps	East African crowned crane	1
Grus canadensis	Sandhill crane	1
Grus leucauchen	White-naped crane	1
Grus leucogeranus	Siberian crane	1
Psophiidae:		
Psophia crepitans	Gray-backed trumpeter	1
Psophia viridis	Green-backed trumpeter	1
Rallidae:		
Aramides cajanea	Wood rail	2
Fulica americana	American coot	3
Gallinula chloropus cachinnans	Florida gallinule	3
Ionornis martinica	Purple gallinule	2
Laterallus leucopyrrhus	Black-white crake	2
Porphyrio poliocephalus	South Pacific swamp hen	2

Scientific name	Common name	Number
Eurypygidae:		
Eurypyga helias	Sun bittern	2
Cariamidae:		
Cariama cristata	Cariama or seriama	2
Otidae:		
Chlamydotis undulata macqueenii	MacQueen's bustard	2

CHARADRIIFORMES

Scientific name	Common name	Number
Recurvirostridae:		
Himantopus mexicanus	Black-necked stilt	1
Burhinidae:		
Burhinus bistriatus	South American thick-knee	1
Haematopodidae:		
Haematopus ostralegus	European oystercatcher	2
Charadriidae:		
Charadrius vociferus	Killdeer	1
Laridae:		
Larus argentatus	Herring gull	1
Larus delawarensis	Ring-billed gull	2
Larus dominicanus	Kelp gull	2
Larus novaehollandiae	Silver gull	4

COLUMBIFORMES

Scientific name	Common name	Number
Columbidae:		
Columba livia	Domestic pigeon	3
Columba nigrirostris	Short-billed pigeon	1
Gallicolumba luzonica	Bleeding-heart dove	2
Goura victoria	Victoria crowned pigeon	1
Streptopelia decaocto	Ring-necked dove	15
Streptopelia tranquebarica	Blue-headed ring dove	15
Zenaida asiatica	White-winged dove	6
Zenaidura macroura	Mourning dove	3

PSITTACIFORMES

Scientific name	Common name	Number
Psittacidae:		
Agapornis nigrigenis	Black-cheeked parakeet	1
Amazona aestiva	Blue-fronted parrot	3
Amazona auropalliata	Yellow-naped parrot	4
Amazona ochrocephala	Yellow-headed parrot	3
Amazona oratrix	Double yellow-headed parrot	6
Anodorhynchus hyacinthinus	Hyacinthine macaw	1
Ara ararauna	Yellow-and-blue macaw	5
Ara macao	Red, blue, and yellow macaw	6
Ara militaris	Green macaw	1
Aratinga pertinax	Rusty-cheeked parrot	3
Brotogerys jugularis	Tovi parakeet	2
Callocephalon fimbriatum	Gang-gang cockatoo	8
Calyptorhynchus magnificus	Banksian cockatoo	1
Domicella garrula	Red lory	1
Forpus cyanopygius	Little green parakeet	1
Kakatoe alba	White cockatoo	1
Kakatoe ducrops	Solomon Islands cockatoo	2

Scientific name	*Common name*	*Number*
Psittacidae—Continued		
Kakatoe galerita	Large sulphur-crested cockatoo	12
Kakatoe haematuropygia	Red-vented cockatoo	1
Kakatoe leadbeateri	Leadbeater's cockatoo	18
Kakatoe moluccensis	Great red-crested cockatoo	1
Kakatoe sanguineus	Bare-eyed cockatoo	7
Melopsittacus undulatus	Grass parakeet	6
Nestor notabilis	Kea	1
Nymphicus hollandicus	Cockatiel	1
Pionus menstruus	Blue-headed conure	1
Platycerus eximus	Rosella parakeet	2
Polytelis swainsoni	Barraband's parakeet	8
Psittacula eupatria	Red-shouldered parakeet	1
Psittacula krameri	Kramer's parakeet	1
Psittacus erithacus	African gray parrot	1
CUCULIFORMES		
Cuculidae:		
Eudynamys scolopacea	Koel	1
Musophagidae:		
Tauraco corythaix	South African turaco	1
Tauraco donaldsoni	Donaldson's turaco	1
Tauraco persa	Purple turaco	3
STRIGIFORMES		
Tytonidae:		
Tyto alba pratincola	Barn owl	7
Strigidae:		
Bubo virginianus	Great horned owl	7
Ketupa ketupu	Malay fishing owl	1
Nyctea nyctea	Snowy owl	1
Strix varia varia	Barred owl	11
TROGONIFORMES		
Trogonidae:		
Pharomachus mocino	Quetzal	2
CORACIIFORMES		
Alcedinidae:		
Dacelo gigas	Kookaburra	2
Coraciidae:		
Anthracoceros coronatus	Pied hornbill	2
Bucorvus abyssinicus	Abyssinian ground hornbill	1
Momotidae:		
Baryphthengus martii	Great rufous motmot	1
Momotus lessoni	Lesson's motmot	4
PICIFORMES		
Capitonidae:		
Megalaima asiatica	Blue-throated barbet	1
Megalaima zeylonica	Streaked barbet	1

Scientific name	Common name	Number
Ramphastidae:		
Pteroglossus torquatus	Ringed toucanet	9
Ramphastos ariel	Ariel toucan	2
Ramphastos carinatus	Sulphur-breasted toucan	3
Ramphastos culminatus	White-breasted toucan	1
Ramphastos innominatus	Todd's toucan	1
PASSERIFORMES		
Cotingidae:		
Cephalopterus ornatus	Umbrellabird	1
Chasmorhynchus nudicollis	Bellbird	1
Rupicola rupicola	Orange cock-of-the-rock	4
Rupicola sanguinolenta	Scarlet cock-of-the-rock	2
Corvidae:		
Corvus brachyrhynchos	American crow	6
Corvus corax principalis	Northern raven	1
Corvus insolens	Indian crow	2
Corvus monedula	Jackdaw	3
Cyanocitta cristata	Blue jay	1
Cyanocorax chrysops	Urraca jay	6
Gymnorhina hypoleuca	White-backed piping crow	1
Pica nuttalli	Yellow-billed magpie	1
Pica pica hudsonica	American magpie	3
Urocissa caerulea	Formosan red-billed pie	2
Ptilorhynchidae:		
Ptilonorhynchus violaceus	Bowerbird	8
Paradiseidae:		
Paradisa rubra	Red bird-of-paradise	2
Paradisornis rudophi	Prince Rudolph's bird-of-paradise	2
Timaliidae:		
Garrulax bicolor	White-headed laughing thrush	2
Pycnonotidae:		
Heterophasia capistratra	Black-headed sibia	1
Pycnonotus leucogenys	White-cheeked bulbul	1
Mimidae:		
Mimus polyglottos polyglottos	Eastern mockingbird	2
Mimus polyglottos leucopterus	Western mockingbird	1
Toxostoma rufum	Brown thrasher	1
Turdidae:		
Geokichla citrina	Orange-headed ground thrush	1
Hylocichla mustelina	Wood thrush	1
Platycichla flavipes	Yellow-footed thrush	1
Turdus migratorius	Eastern robin	5
Bombycillidae:		
Bombycilla cedrorum	Cedar waxwing	1
Sturnidae:		
Acridotheres tristis	Common mynah	1
Gracula religiosa	Wattled mynah	4
Gracula religiosa robusta	Nias wattled mynah	1
Gracupica melanoptera	White starling	1
Lamprocolius purpureus	Glossy starling	3
Spreo superbus	Superb starling	1
Sturnia malabarica	Gray-headed mynah	1

Scientific name	Common name	Number
Ploceidae:		
Aegintha temporalis	Sydney waxbill	8
Aidemosyne cantans	Tawny waxbill	3
Aidemosyne malabarica	Indian silverbill	2
Aidemosyne modesta	Plum-headed finch	2
Alisteranus cinctus	Parson finch	2
Amadina fasciata	Cut-throat weaver finch	5
Amandava amandava	Strawberry finch	14
Diatropura procne	Giant whydah	3
Estrilda astrild	Red-eared waxbill	6
Estrilda cinerea	Common waxbill	1
Euplectes franciscana	Bishop weaver	5
Euplectes oriz	Red bishop weaver	2
Hypochera ultramarina	Combasou or indigobird	1
Lonchura leucogastroides	Bengali finch	1
Munia maja	White-headed munia	1
Munia malacca	Black-throated munia	1
Munia punctulata	Spice finch	16
Padda oryzivora	Java sparrow	14
Passer domesticus	House sparrow	1
Ploceus baya	Baya weaver	2
Ploceus vitellinus	Vitelline masked weaver	5
Poephila acuticauda	Long-tailed finch	3
Quelea quelea	Red-billed weaver	1
Sporaeginthus melipodus	Orange-cheeked waxbill	12
Steganopleura bichenovii	Bicheno's finch	1
Steganura paradisea	Paradise whydah	4
Taeniopygia castanotis	Zebra finch	12
Uraeginthus bengalus	Cordon-bleu finch	4
Icteridae:		
Amblyrhamphus holosericeus	Scarlet-headed blackbird	1
Icterus giraudi	Giraud's oriole	3
Molothrus bonariensis	Shiny cowbird	1
Notiopsar curaeus	Chilean blackbird	2
Pezites defilippii	Military starling	1
Quiscalus quiscula	Purple grackle	1
Xanthocephalus xanthocephalus	Yellow-headed blackbird	1
Xanthornis angustifrons	Oropendula	1
Thraupidae:		
Calospiza ruficapilla	Brown-headed tanager	1
Piranga olivaceae	Scarlet tanager	1
Piranga rubra	Summer tanager	1
Ramphocelus carbo	Silver-beaked tanager	1
Ramphocelus dimidiatus	Crimson tanager	2
Ramphocelus flammigerus	Yellow tanager	2
Ramphocelus passerinii	Passerini's tanager	1
Thraupis cana	Blue tanager	8
Thraupis palmarum	Black-winged palm tanager	1
Fringillidae:		
Carpodacus mexicanus	Mexican house finch	2
Carpodacus purpureus californicus	California purple finch	1
Cyanocompsa argentina	Argentine blue grosbeak	1
Lophospingus pusillus	Black-crested finch	1

Scientific name	*Common name*	*Number*
Fringillidae—Continued		
Melopyrrha nigra	Cuban bullfinch	1
Melospiza melodia	Song sparrow	1
Paroaria cucullata	Brazilian cardinal	1
Paroaria gularis nigro-genis	Black-eared cardinal	1
Passerella iliaca	Fox sparrow	1
Passerina ciris	Painted bunting	1
Passerina cyanea	Indigo bunting	1
Pheucticus aureoventris	Black-and-yellow grosbeak	2
Phrygilus fruticeti	Mourning finch	2
Phrygilus gayi	Gay's gray-headed finch	1
Poospiza torquata	Ringed warbling finch	2
Richmondena cardinalis	Cardinal	2
Serinus canarius	Canary	10
Serinus icterus	Green singing finch	1
Sicalis luteola	Saffron finch	20
Sporophila aurita	Hicks's seedeater	1
Sporophila gutturalis	Yellow-billed seedeater	16
Sporophila melanocephala	Black-headed seedeater	2
Tiaris olivacea	Mexican grassquit	1
Volatinia jacarina	Blue-black grassquit	1
Zonotrichia albicollis	White-throated sparrow	3

REPTILES

LORICATA

Crocodylidae:		
Alligator mississipiensis	Alligator	30
Alligator sinensis	Chinese alligator	2
Caiman latirostris	Broad-snouted caiman	1
Caiman sclerops	Spectacled caiman	4
Crocodylus acutus	American crocodile	4
Crocodylus cataphractus	Narrow-nosed crocodile	1
Crocodylus niloticus	African crocodile	2
Crocodylus porosus	Salt-water crocodile	1
Osteolaemus tetraspis	Broad-nosed crocodile	3

SQUAMATA

Sauria

Gekkonidae:		
Tarentola cubana	Gecko	1
Thecadactylus rapicaudus	Gecko	4
Agamidae:		
Physignathus lesueuri	Lesueur's water dragon	2
Xenosauridae:		
Xenosaurus laticaudatus	Broad-tailed lizard	1
Gerrhosauridae:		
Gerrhosaurus flavigularis	Yellow-throated plated lizard	3
Gerrhosaurus major	Greater African plated lizard	9
Zonosaurus ornatus	Ornate lizard	1

Scientific name	Common name	Number
Iguanidae:		
Anolis carolinensis	American anolis, or false chameleon.	5
Anolis equestris	Giant anolis	5
Anolis porcatus	Lagartila verde	2
Anolis sp	Giant anolis	1
Basiliscus barbouri	Barbour's basilisk	1
Conolophus subcristatus	Galápagos iguana	2
Cyclura macleayi	Cuban iguana	3
Iguana iguana	Common iguana	1
Phrynosoma blainvillei	California horned lizard	6
Phrynosoma cornutum	Horned lizard	2
Sauromalus obesus	Chuckwalla lizard	4
Sceloporus undulatus	Pine or fence lizard	4
Zonuridae:		
Zonurus giganteus	African spiny lizard	1
Helodermatidae:		
Heloderma horridum	Mexican beaded lizard	3
Heloderma suspectum	Gila monster	2
Varanidae:		
Varanus niloticus	African monitor	1
Varanus sp	African monitor	1
Lacertidae:		
Eremias mucronata	Egyptian sand lizard	3
Lacerta ocellata	Eyed lizard	3
Scincidae:		
Chalcides ocellatus	Skink	2
Chalcides sp	Sand skink	2
Egernia cunninghami	Cunningham's skink	1
Egernia whitii	White's skink	13
Eumeces fasciatus	Blue-tailed skink	2
SERPENTES		
Boidae:		
Boa canina	Green tree boa	2
Boa enydris	Colombian boa	1
Constrictor imperator	Central American boa	32
Epicrates cenchria	Rainbow boa	5
Eunectes murinus	Anaconda	1
Python molurus	Indian rock python	1
Python regius	Ball python	1
Python sebae	African python	2
Colubridae:		
Acrochordus javanicus	Elephant trunk snake	1
Boaedon lineatum	Brown house snake	1
Boiga dendrophila	Mangrove snake	1
Coluber constrictor	Black snake	6
Diadophis punctatus	Ring-necked snake	2
Drymarchon corais couperi	Indigo snake	2
Elaphe obsoleta	Pilot snake	10
Elaphe obsoleta confinis	Southern pilot snake	1
Eryx thebaicus	Dassa's snake	3
Lampropeltis getulus boylii	Boyle's king snake	1

Scientific name	*Common name*	*Number*
Colubridae—Continued		
Lampropeltis getulus getulus	Chain or king snake	2
Lampropeltis getulus holbrooki	Holbrook's king snake	1
Lampropeltis getulus splendida	Sonoran king snake	1
Lampropeltis rhombomaculata	Mole snake	3
Natrix sp	Water snake	9
Opheodrys vernalis	Smooth-scaled green snake	1
Oxybelis acuminatus	Pike-head snake	1
Phrynonax sulphureus	False cobra	2
Pituophis catenifer	Western bull snake	1
Pituophis melanoleucus	Pine snake	5
Rhinocheilus lecontei	LeConte's snake	2
Storeria dekayi	DeKay's snake	2
Thamnophis elegans	Arizona garter snake	2
Thamnophis sirtalis	Garter snake	1
Zamenis florulentus	Egyptian racer	3
Elapidae:		
Dendroaspis viridis	Green mamba	1
Micrurus fulvius	Coral snake	2
Naja haje	Egyptian cobra	1
Naja hannah	King cobra	1
Naja tripudians	Indian cobra	3
Viperidae:		
Vipera russellii	Russell's viper	1
Crotalidae:		
Agkistrodon mokeson	Copperhead snake	2
Agkistrodon piscivorus	Cottonmouth moccasin	3
Crotalus atrox	Western diamondback rattlesnake	2
Crotalus cerastes	Sidewinder rattlesnake	2
Crotalus horridus	Timber rattlesnake	7
Crotalus mitchelli	Desert rattlesnake	2
Crotalus tigris	Tiger rattlesnake	1
Crotalus tortugensis	Tortuga rattlesnake	1
Crotalus viridis viridis	Prairie rattlesnake	1

TESTUDINATA

Chelydidae:		
Batrachemys nasuta	South American side-necked turtle.	2
Chelodina longicollis	Australian long-necked turtle	2
Chelys fimbriata	Matamata turtle	2
Hydraspis sp	Cagado or South American snake-necked turtle.	1
Hydromedusa tectifera	South American snake-necked turtle.	15
Platemys platycephala	Flat-headed turtle	1
Kinosternidae:		
Kinosternon subrubrum	Mud turtle	5
Sternotherus odoratus	Musk turtle	5
Chelydridae:		
Chelydra serpentina	Snapping turtle	8
Testudinidae:		
Batagur baska	Indian fresh-water turtle	1
Chrysemys picta	Painted turtle	8

Scientific name	*Common name*	*Number*
Testudinidae—Continued		
Clemmys guttata	Spotted turtle	6
Clemmys insculpta	Wood turtle	5
Cyclemys amboinensis	Kura kura box turtle	1
Emydura krefftii	Krefft's turtle	3
Emydura macquariae	Murray turtle	10
Emys orbicularis	European pond turtle	1
Gopherus polyphemus	Gopher turtle	2
Graptemys barbouri	Barbour's turtle	7
Graptemys geographica	Map turtle	3
Kinixys erosa	Hinged-back turtle	2
Malaclemys centrata	Diamond-back turtle	4
Pelomedusa galeata	African water turtle	1
Pelusios sinuatus	Yellow-bellied water turtle	4
Pseudemys concinna	Cooter	1
Pseudemys elegans	Mobile turtle	12
Pseudemys ornata subsp	Central American turtle	4
Pseudemys rubriventris	Red-bellied turtle	1
Pseudemys troostii	Cumberland turtle	2
Terrapene carolina	Box turtle	50
Terrapene major	Florida box turtle	3
Terrapene triunguis	Three-toed box turtle	2
Testudo ephippium	Duncan Island turtle	2
Testudo graeca	Grecian turtle	2
Testudo hoodensis	Hood Island turtle	2
Testudo tabulata	South American turtle	2
Testudo vicina	Albemarle Island turtle	5
Trionychidae:		
Amyda ferox	Soft-shelled turtle	9
Amyda triunguis	West African soft-shelled turtle	1

AMPHIBIANS

CAUDATA

Salamandridae:		
Triturus pyrrhogaster	Red Japanese salamander	17
Triturus torosus	Giant newt	2
Triturus viridescens	Common newt (of the United States).	1
Amphiumidae:		
Amphiuma means	Congo eel	1
Cryptobranchidae:		
Megalobatrachus japonicus	Giant Japanese salamander	4

SALIENTIA

Bufonidae:		
Bufo alvarius	Western green toad	3
Bufo americanus	Common toad	3
Bufo bufo	European toad	2
Bufo calamita	Natterjack toad	3
Bufo marinus	Marine toad	9
Bufo paracnemis	Rococo toad	2
Bufo viridis	European green toad	2

Scientific name	*Common name*	*Number*
Discoglossidae:		
Bombina bombina	Red-bellied toad	4
Bombina variegata	Yellow-bellied toad	5
Leptodactylidae:		
Ceratophrys calcarata	Colombian horned frog	2
Ceratophrys ornata	Argentine horned frog	3
Hylidae:		
Hyla septentrionalis	South American tree frog	1
Pipidae:		
Xenopus mülleri	Müller's clawed frog	1
Ranidae:		
Rana adspersa	African bull frog	12
Rana catesbiana	Bull frog	3
Rana clamitans	Green frog	2
Rana esculenta	European edible frog	1
Rana pipens	Leopard frog	2

FISHES

Anabas testudineus	Climbing perch	4
Anoptichthys jordani	Blind characin	8
Barbus everetti	Clown barb	2
Brachydanio albolineatus	Pearl danio	1
Carassius auratus	Goldfish	5
Danio rerio	Zebra fish	8
Hemigrammus ocellifer	Head-and-tail-light fish	2
Hyphessobrycon innesi	Neon tetra	10
Kryptopterus bicirrhos	Glass catfish	10
Lebistes reticulatus	Guppy	100
Lepidosiren paradoxa	South American lungfish	2
Mesonauta insignis		1
Pristella riddlei	Tetra	2
Protopterus annectans	African lungfish	2
Rasbora heteromorpha	Rasbora	10
Tanichthys albonubes	White Cloud Mountain fish	2
Trichogaster trichopterus	Blue gourami	2

ARACHNIDS

Latrodectus mactans	Black-widow spider	2

INSECTS

Blabera sp	Giant cockroach	100

MOLLUSKS

Achatina achatina	Giant land snail	4

STATUS OF THE COLLECTION

Class	Species or subspecies	Individuals	Class	Species or subspecies	Individuals
Mammals	189	670	Arachnids	1	2
Birds	322	1,179	Insects	1	100
Reptiles	137	513	Mollusks	1	4
Amphibians	23	27			
Fish	17	171	Total	691	2,675

Summary

Animals on hand July 1, 1951	2,821
Accessions during the year	1,575
Total number of animals in collection during the year	4,396
Removals for various reasons such as death, exchanges, return of animals on deposit, etc	1,721
In collection on June 30, 1952	2,675

Respectfully submitted.

W. M. MANN, *Director*.

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 8

Report on the Astrophysical Observatory

SIR: I have the honor to submit the following report on the operations of the Astrophysical Observatory for the fiscal year ended June 30, 1952:

The work of the Astrophysical Observatory is divided between two units: the division of astrophysical research, for the study of solar radiation problems, and the division of radiation and organisms, established "to undertake those investigations dealing with radiation bearing directly or indirectly upon biological problems." In addition to their regular programs, both divisions are conducting cooperative projects with other Government agencies. The division of astrophysical research at its Chilean field station maintains certain seismographic records for the Coast and Geodetic Survey and also records solar radiation received upon exposed fabrics, under contract with the Office of the Quartermaster General. The division of radiation and organisms has in progress special experiments for the Atomic Energy Commission and for the Biological Department, Chemical Corps, Camp Detrick, Md.

During the year the metal and glasswork shops serving both divisions of the Observatory were materially improved by the installation of modern lighting equipment, re-arrangement of the machines, repainting, reflooring, and the addition of specially built cabinets for storing raw materials. The instrument makers now operate with less eye strain, more convenience, and greater safety.

In August 1951 the Director of the Observatory attended meetings of the Sub-Commission on Actinometry of the World Meteorological Organization held at Brussels, Belgium. In the resolutions adopted by the Sub-Commission, the Smithsonian silver-disk pyrheliometer, designed and developed by Dr. C. G. Abbot, is recommended as an instrument for the measurement of direct solar radiation.

DIVISION OF ASTROPHYSICAL RESEARCH

The question of establishing a field station in the Clark Mountain (Calif.) region, mentioned in previous reports, is still undetermined.

W. H. Hoover, chief of the division, spent July and part of August at the Table Mountain (Calif.) field station, directing the work program and testing several new devices.

The ninth revised edition of the Smithsonian Physical Tables is in press. At the end of the fiscal year, Dr. Forsythe, who prepared the manuscript, had corrected approximately one-third of the galley proof.

Work in Washington.—The checking and appraisal of observations of sun and sky radiation made at two high-altitude field stations, Montezuma (Chile) and Table Mountain (Calif.), have continued under the direction of Mr. Hoover. Some progress has been made in the preparation of material for a new volume of the Annals of the Astrophysical Observatory.

Incident to the review of results during the past decade, an examination was made to determine what, if any, relationship is apparent between the solar-constant record and the number of sunspots. During the last maximum of sunspots in 1947, the total number of spots was greater than during any maximum since 1778. In 1947 the number averaged 151.6. In 1778 it was 154.4. The next greatest maximum, 139.1, occurred in 1870. A curve is here presented showing monthly mean values of the solar-constant compared with monthly means of sunspot numbers for the same days. It includes all solar constants graded fair or better during the 11-year period 1940 to 1951. A fairly regular increase in solar constants is apparent with increasing sunspot numbers.

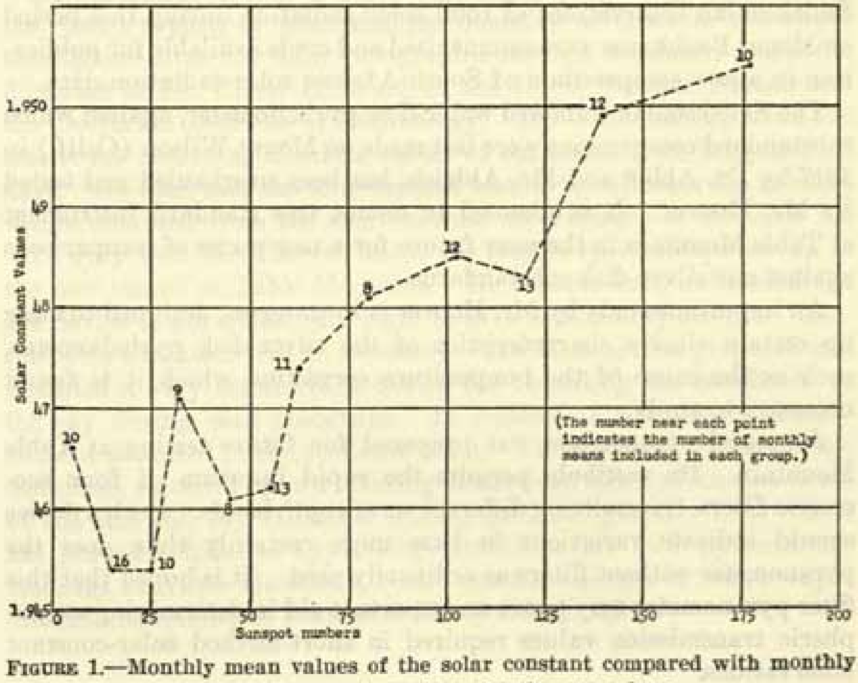


FIGURE 1.—Monthly mean values of the solar constant compared with monthly means of sunspot numbers for the same days.

Orders for silver-disk pyrheliometers, built in our shops and calibrated against the Smithsonian standard pyrheliometer, have continued to come in. During the year five instruments were prepared and sold at cost, as follows:

S. I. No. 84 to Centre National de la Recherche Scientifique, Paris, France.
S. I. No. 87 to Helsinki, Finland.
S. I. No. 88 to Institute for Scientific Research, Central Africa.
S. I. No. 89 to National Observatory of Athens, Greece.
S. I. No. 90 to University of Rhode Island.

As of now, a total of 89 silver-disk pyrheliometers have been furnished by the Astrophysical Observatory to interested observatories and institutions in many lands, thus making available throughout the world the Smithsonian standard scale of radiation. In addition, five Angstrom compensation pyrheliometers, modified in certain details as experience has dictated, were built and calibrated. Three were sold at cost to the Belgium Consulate General for use in the Belgian Congo.

During the year certain electronic devices were procured as funds permitted. These include a photopen recorder, Golay detector, and electron multiplier photometer. Tests are in progress to determine their most advantageous application to our special needs.

For five years, 1926 to 1931, the Astrophysical Observatory occupied Mount Brukkaros in Southwest Africa as a field observing station. At the request of the Meteorological Service of South Africa, the Smithsonian observations of total solar radiation during this period on Mount Brukkaros were summarized and made available for publication in a new compendium of South African solar-radiation data.

The Smithsonian standard water-flow pyrheliometer, against which substandard comparisons were last made on Mount Wilson (Calif.) in 1947 by Dr. Abbot and Mr. Aldrich, has been overhauled and tested by Mr. Hoover. It is planned to mount this standard instrument at Table Mountain in the near future for a new series of comparisons against our silver-disk substandards.

An important study by Mr. Hoover is in progress, designed to clear up certain elusive characteristics of the silver-disk pyrheliometer, such as the cause of the temperature correction which it is found necessary to apply.

A special pyranometer was prepared for future testing at Table Mountain. Its vestibule permits the rapid insertion of four successive filters, transmitting different wavelength bands. Such a device should indicate variations in haze more certainly than does the pyranometer without filters as ordinarily used. It is hoped that this filter pyranometer may prove an important aid in determining atmospheric transmission values required in short-method solar-constant observations.

At the request of the United States Weather Bureau, another special pyranometer was prepared and calibrated for use in standardizing the Weather Bureau's network of Eppley pyrheliometers. A leveling device and automatic shutter control were added to the pyranometer.

Last year's report mentioned a cooperative arrangement with the Meteorological Division, Chemical Corps, Camp Detrick, Md., to develop a new improved type of melikeron, for the measurement of outgoing radiation from the earth to space. One of these instruments has been completed and tested at Camp Detrick. A paper describing this development was read by Dr. S. C. Stern of Camp Detrick at the July meeting of the American Meteorological Society.

Dr. C. G. Abbot, research associate, has continued his studies of relationships between solar and terrestrial phenomena. His results are described in several papers in volume 117 of the Smithsonian Miscellaneous Collections.

Work in the field.—In May 1952 a new series of tape exposures was started at the Montezuma station, under contract with the Office of the Quartermaster General. These exposures are a continuation of the Quartermaster studies to determine the causes of the deterioration of tentage materials. The tapes include samples of various textiles, and the exposures and radiation measurements are similar to those described in former years.

At the Table Mountain station, the interesting study discussed in last year's report, to determine the quantity of ozone in the upper atmosphere from our daily bolographic records, continued under the direction of Dr. Oliver R. Wulf, of the U. S. Weather Bureau and the California Institute of Technology. Dr. Wulf has improved the means for obtaining absolute values of the ozone from long-method days. He then uses the long-method results to calibrate the relative values obtained from the short-method observations at air mass 2.5.

In July 1951 Mr. Hoover tested the double spectroscope set up in the new tunnel at Table Mountain. He reports that, unfortunately, the device is not sufficiently rigid to give satisfactory results. Considerable alteration will be necessary. Mr. Hoover also prepared and installed a very satisfactory device for recording the steadiness of the sky during each bolograph. It consists of a sensitive thermoelement mounted in the coelostat beam. The resulting galvanometer deflection, recorded upon a rotating drum, is an index of the steadiness of the sun and sky radiation during each bolograph. This record has proved helpful in appraising pyrheliometer and pyranometer readings at Table Mountain, where sudden changes in water vapor content and quality of haze occur fairly frequently.

DIVISION OF RADIATION AND ORGANISMS

(Report prepared by R. B. Withrow)

In last year's report the developmental responses of seedlings to light were discussed as to the possible biochemical reactions involved in the absorption of the light energy and the subsequent regulatory mechanism responsible for the development of seedlings into normal plants. The indications were that these growth or photomaturation responses were not directly associated with either chlorophyll synthesis or photosynthesis, but no strong photomaturation response had been obtained without detectable traces of chlorophyll. The problem remained, therefore, to secure leaf expansion and stem development approaching the normal occurring in sunlight without chlorophyll synthesis or photosynthesis.

During the past year bean seedlings were grown under a series of seven irradiances respectively of blue (436 mμ), red (630–700 mμ), and far red (710–1100 mμ and 725–1100 mμ) radiant energy. The extent of the photomaturation response was measured by taking weights of the leaves, and weights and lengths of the hypocotyl and epicotyl portions of the plants. Analysis for protochlorophyll, chlorophyll, carotenoid, and anthocyanin pigments were made in order to obtain a picture of the photosynthesis and photodecomposition of these pigments.

The maximum photomaturation response occurred in the red where the maximum chlorophyll synthesis and anthocyanin synthesis also occurred. With blue of the same energy as the red, the leaf expansion and decrease in hypocotyl length were much reduced. Although the amount of chlorophyll was less in the blue than the red, it was not decreased in proportion to the decrease in photomaturation response. In the far red, very marked photomaturation occurred at the lower irradiances employed without any measurable synthesis of chlorophyll, which first appeared with this region at 10^2 microwatts per square centimeter. Since all measurements were made with 10-cm. cells in a Beckman spectrophotometer, it is safe to assume that practically no chlorophyll was synthesized under these low-irradiance far-red conditions. Therefore, the evidence is conclusive that the photomaturation responses are not directly concerned either with chlorophyll synthesis or photosynthesis, but are due to a regulatory mechanism associated with a pigment having absorption in the far red. Absorption of this pigment also occurs in the blue, with the maximum in the red.

In addition, there is clear evidence that the synthesis of anthocyanin is also a photochemical response, separate and distinct from photosynthesis. Anthocyanin was always present in plants grown in complete darkness, but very marked increases occurred with the addition

of all wavebands employed. Anthocyanin synthesis was maximal in the red, which was from ten to one hundred times as efficient as the blue. At 10^{-6} microwatts per square centimeter, the anthocyanin content of plants grown with the red was doubled as compared to that of those in complete darkness. In the far red, where no photosynthesis could have occurred because of the absence of chlorophyll, the anthocyanin increased eighteen times with the 710–1100 mμ region and ten with the 725–1100 mμ region at the 10-microwatt energy level. This appears to be strong evidence that, contrary to previous theories, the light effect on anthocyanin synthesis is only indirectly related to photosynthesis and that anthocyanin synthesis can be the consequence of an independent photochemical reaction.

A second phase of the research has been concerned with the effect of growth regulators on the uptake of various nutrient salts by bean seedlings. It was reported previously that the nitrates, chlorides, and sulfates of potassium, calcium, and magnesium were absorbed less rapidly by plants treated with 10 γ of ammonium 2,4–D on the leaf or bud than by untreated plants. The reduction in uptake occurs within 24 to 48 hours after the application of the growth regulator as measured by a continuously recording electronic conductance bridge. These reduced uptake patterns appear to be chiefly related to decreased growth of the plants treated with the growth regulator. Unlike the other nutrient salts tested potassium acid phosphate, while eventually absorbed less rapidly when 2,4–D is used, is taken up by the treated plants at an increased rate for a short period beginning about 6 hours from the time of application of the regulator. Other work has indicated that about 6 hours is approximately the length of time required for the ammonium 2,4–D to reach the roots of bean seedlings. This increased rate of absorption has not as yet been correlated with any change in metabolism of the seedling.

Respectfully submitted.

L. B. Aldrich, *Director*.

Dr. A. Wetmore,
Secretary, Smithsonian Institution.

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APPENDIX 9

Report on the National Air Museum

SIR: I have the honor to submit the following report on the activities of the National Air Museum for the fiscal year ended June 30, 1952:

GENERAL STATEMENT OF CONDITIONS

The phase of Museum operations that caused the greatest concern and required most concentration of effort throughout the year was the care of the storage collection at Park Ridge, Ill. It will be recalled from previous annual reports that the former Douglas DC-4 Transport Airplane Plant there was the collecting depot for significant and historic aircraft selected for preservation by General of the Air Force H. H. Arnold. When these were turned over to the National Air Museum in 1949, it was believed most economical to leave them there until an adequate building could be provided in the Washington, D. C., area for the entire collection. An efficient organization was brought together by the Museum to preserve and guard these stored aircraft. Meanwhile that locality became designated as O'Hare Field, Chicago International Airport, and several United States Air Force units were established there, the Museum paying rent to the Air Force for the space it occupied in Building T-6. To that storage facility the Museum brought other aircraft and materials that could not be exhibited or cared for on the Washington premises in the Smithsonian buildings. It was believed that this facility would continue to operate until Congress gave further consideration to the report presented to that body by the Smithsonian, in response to the section in the Act of Establishment which authorized the planning of an adequate building.

With the advent of war in Korea it became evident that Government resources must be concentrated upon the production of combat aircraft instead of applied to the care of historic ones, and early in the fiscal year the international situation reacted directly upon the Air Museum when, on July 12, 1951, an eviction notice was served by the Air Force requiring removal of all Museum stored material from the premises in Building T-6. Because of the national emergency the needs of the Air Force required expanded manufacturing facilities for aircraft and it had been decided to reactivate Building

T–6 for aircraft production. While efforts were being made by the Museum to obtain use of premises in the northwest corner of the airport, it was learned that temporary housing for part of the storage collection could be provided in Building T–7, an adjacent hangarlike structure where Bays 5 and 6 totaling 60,000 square feet could be rented to the Museum. With winter approaching, this move to T–7 was better than undertaking the project of rehabilitating the quarters in the northwest corner of the airport, but because the space in T–7 would provide less than half of the area required it was necessary to place the remainder outdoors between Buildings T–6 and T–7. The problem of protection was partly met by choosing those specimens that could best withstand exposure, covering them with protective coatings and surrounding the area with a fence, so arranged that the largest boxes provided windbreaks for the aircraft. By moving to T–7 the eviction from T–6 was complied with 5 weeks ahead of the deadline of January 15.

Hardly had this move been started, however, before the Museum was served with notice to vacate Building T–7 by February 1, in order that those bays could be used for a fighter-interceptor squadron that is part of the air defense of the city of Chicago. This could not be complied with because no place could be located or prepared to receive the Museum material. Meanwhile the disassembling and packing project was expedited and more material was moved outdoors.

Modifications in Air Force decisions involving the use of these premises relaxed the pressure on the Museum to move and permitted planning on a more efficient, longer-range basis. Because the ultimate destination of this stored material is Washington, D. C., or vicinity, The National Capital Planning Commission was asked to assist. Following previous application for a site for a permanent National Air Museum Building, the Commission had recommended using a part of the Suitland building area. The Commission agreed to assign a 21-acre plot of this area for a storage site.

Using funds that had been saved for the most part by reduced rental charges at Park Ridge, the area at Suitland was surveyed, a roadway and building areas were cleared, and six prefabricated Butler buildings were purchased. Remaining funds for 1952 sufficed for the erection of only two buildings. With granting of the 1953 appropriation the other four buildings can be erected, and a portion of the material at Park Ridge can be shipped. The efforts made at Park Ridge by the Museum manager and assistants to preserve the material there in spite of these conditions are detailed in another section of this report.

The enforced concentration upon storage problems has necessarily reduced the amount of time that could be applied by the Washington office to local requirements. Here the exhibition program continues

to suffer from lack of space, and activities are limited by the relatively small force of personnel, yet every effort has been made to keep a high standard for the displays and informational services that are the two principal ways in which the Museum serves the public. These and other activities of the bureau are covered further in this report.

There have been changes and reductions in personnel, the most important being the retirement on April 30, 1952, of Carl W. Mitman after 41 years with the Smithsonian, closing his career in the position of Assistant to the Secretary for the National Air Museum. His thorough knowledge of museum techniques, educational methods, and Government procedures, combined with excellent administrative ability, gave to the National Air Museum a firm foundation during the critical days of its establishment. Paul E. Garber was made head curator on April 10.

Following the retirement of Mr. Mitman, the bureau gave up its administrative quarters in the northeast corner of the Arts and Industries Building, concentrating the offices in the group of rooms erected several years ago in the opposite corner of the same building.

The accessions for the year have brought additions to many parts of the collection, including full-sized aircraft, engines, instruments, experimental and scale-model aircraft, parachutes, and trophies. They also are evidence of a growing recognition of the function of the National Air Museum by other Government departments, the aircraft industry, and individuals who with confidence can entrust their significant treasures to the bureau's custody, enabling the Museum to not only keep abreast of recent developments but also to fill gaps in the background story.

ADVISORY BOARD

No meetings of the Board were held during the year; there was one change in personnel, Maj. Gen. Donald L. Putt, U. S. A. F., being replaced by Maj. Gen. Laurence C. Craigie, U. S. A. F. He and members of his staff have been particularly helpful in enabling adjustments to be made between the limited resources of the Museum and the eviction schedule of the Air Force at Park Ridge; and also in effecting the preparation of the site for the new storage area at Suitland, Md. The naval member of the Board, Rear Adm. Thomas S. Combs, and his civilian assistant for Museum liaison, Alfred V. Verville, have cooperated closely with the Museum officials in preparing and transferring selected naval specimens to the Museum and in preserving other significant naval air items on naval premises until the Museum can take custody of them. The civilian presidential appointees to the Board, Grover Loening and William B. Stout, have been of frequent assistance in recommending that certain desirable objects be procured and in offering other helpful suggestions.

STEPHENSON BEQUEST

Separate mention was made in the previous report of the bequest of George H. Stephenson of Philadelphia, Pa., to provide for the Air Museum an appropriate statue of Maj. Gen. William Mitchell. During this fiscal year Smithsonian officials with the cooperation of the Fine Arts Commission gave consideration to the designs and capabilities of a number of sculptors.

SPECIAL EVENTS AND DISPLAYS

For the annual meeting of the Smithsonian Board of Regents, held on January 18, the Air Museum prepared a display based on the recent development and use of helicopters, featuring as the central unit the prototype example of the "Hoppi-Copter," designed by Edward Pentecost as a manually supported helicopter for individual transportation. With this was shown a scale model of the Sikorsky XR–4, which accomplished the first cross-country helicopter trip in America, 1942. The original XR–4 is in the Museum collection but is stored for lack of exhibition space. Grouped with the scale model were a number of photographs illustrating the other full-sized helicopters in the collection. Of this group of eight, space is available for exhibiting only two.

The twenty-fifth anniversary of Col. Charles Lindbergh's trans-Atlantic flight in the *Spirit of St. Louis* increased the normally high interest in this airplane. Assistance was given to a number of authors, historians, and photographers who were recording the anniversary and to managers of radio and television programs who included references to this occasion in their broadcasts. Colonel Lindbergh himself visited the Museum during this period and sat once again at the controls of his plane as he made some notes on the flights in 1927; his commendation upon the excellent condition of this airplane, which has been in the Museum continuously since 1928, was most gratifying.

In connection with construction of the shop in the Aircraft Building last year a broad space was provided on its outer wall, adaptable for pictorial displays. With the cooperation of Consolidated Vultee Aircraft a series of photographic enlargements was selected and mounted there, illustrating the progress of design throughout the history of that company, ranging from the PT–1 of 1925 to the huge B–36 of today. The Museum intends to rotate this type of exhibit and will be pleased to make this same space available to other aircraft companies for similar displays.

SURVEY

The search for desirable specimens to add to the collection, and contacts to determine their characteristics and significance were carried

out this year largely by correspondence, most of the Museum's funds for travel being utilized for trips between Washington and the storage facility at Park Ridge, for administrative purposes. The results of survey are reflected in the list of accessions which is in the last pages of this Report. The following trips were primarily for survey purposes:

July 17, by the associate curator, Robert Strobell, to Lancaster, Pa., to inspect at the factory of Valley Frocks, Inc., a group of early parachutes and other equipment dating back to World War I.

August 14, by the curator, to Detroit, Mich., and vicinity, to check progress on scale models of aircraft under construction and inspect aeronautical material assembled for the Air Show display.

March 20, by the associate curator, to Dayton, Ohio, to confer regarding details of drawings of the Wright Brothers' *Kitty Hawk* aeroplane, and to discuss current projects at the Air Force Technical Museum.

March 24, by the curator, to Philadelphia, Pa., and vicinity, to examine a group of aircraft engines offered to the Air Museum by the Navy, to inspect a Fairchild FC-2 photographic airplane offered by Virgil Kauffman and to discuss developments in air photography with officials and technicians of the Aero Service Corporation.

IMPROVEMENTS IN SPECIMENS AND EXHIBITS

One of the outstanding specimens received during the year is the original experimental radio-controlled model which, through free-flight test, provided vital data for the design, construction, and operation of the Consolidated XP5Y-1 flying boat. Unfortunately this model, 1:10 size, had been badly damaged in transit. Its repair constituted a problem that required a knowledge of the original procedures as well as the skill of expert modelmakers. This combination of talents was embodied in the designer who was responsible for developing this progressive method of aircraft testing, Ernest Stout, and the exhibits workers of the Museum, Winthrop Shaw and assistant Peter Bisio. Working together they have restored the model to its original appearance. Another model restored in the shop is an original small glider of E. C. Huffaker, who worked as assistant to Professor Langley and made a brief visit to the camp of the Wright Brothers at Kitty Hawk in 1901. In the wall cases surrounding the outer wall of the new shop in the Aircraft Building, displays of natural flight, early concepts of human flight, lighter-than-air craft, and parachutes are being placed. Because these are elementary phases of aeronautics and the cases are near the entrance to the building they constitute an interesting introduction to the exhibits. Other exhibition cases that have been improved during the year include the one in which an early airfield is shown with aircraft of the period 1908-16, the case containing famous trophies that have inspired progress in aircraft design and performance, the memorial case to Amelia Earhart, and the three large cases in which progressive types of airplanes

used by the Navy, Air Force, and Air Mail are grouped in chronological sequence. Several additional models, listed in the lot of accessions at the end of this report, have expanded these groups.

Usual cleaning and preservation treatments were given to the Lilienthal glider, the *Kitty Hawk*, *Spirit of St. Louis*, Fokker D–7, Grumman F3F *Gulfhawk–2*, and Republic F–84 *Thunderjet*. Mannequins with clothing resembling that of Otto Lilienthal and Orville Wright were prepared with the cooperation of the L. A. Darling Co., and placed in the glider and *Kitty Hawk*, making their methods of control much more understandable to the public. The progressive line-up of power units along "Engine Row" in the Aircraft Building continued to be improved by rearrangements, additions, and selective substitutions. Two important specimens were put on display; namely, original rockets developed by Robert Goddard (1882–1945) who, in some of his earlier experiments was assisted by grants from the Smithsonian and later by the Daniel and Florence Guggenheim Foundation. These rockets, showing types of 1934–35 and 1939–41, were conditioned and labeled with the helpful assistance of Mrs. Goddard; additions to this group will soon be added. The display of the Hispano Suiza engine of World War I has been improved by placing with it two large photographs received from S. E. M. Hispano Suiza, Colombes (Seine), France, illustrating the original Birkigt design of 1916, and the engine used by the renowned French ace George Guynemer.

Each of the accessions received during the year that could be exhibited provided an improvement in the displays; it is regretted that lack of space prevents showing all of them. The Navy Department was responsible for adding 10 engines to the collection, several of them from the earliest years of human flight; but the outstanding addition was received from the Curtiss-Wright Corporation, with grateful acknowledgment to George Page, prominent aircraft designer, who has helped to protect this wonderful relic throughout the years until it could be placed in permanent care. This famous engine is the prototype for those made by Glenn Curtiss for the early airships of Thomas Baldwin and the pioneer airplanes then being developed by the Aerial Experiment Association headed by Alexander Graham Bell. Curtiss decided to test this engine in a motorcycle, and at Daytona Beach, Fla., January 24, 1907, established a world record for human speed that lasted for many years—137 miles per hour. As a motorcycle, this specimen is unique, but as a test bed for an airplane engine it is one of the most renowned in aeronautical history. The collection of trophies was greatly improved this year by the receipt of one of the most famous, the Collier Trophy, which since 1911 has inspired progress. Of the 35 awards of the Collier Trophy to date, 25 of them are now represented among the Air Museum's collections.

The Collier Trophy, together with the Brewer Trophy and the Klemin Plaque, will be withdrawn briefly each year for succeeding presentations and then returned to the Museum for continued public view; but the Wright Brothers' Memorial Trophy is the original replica example and will remain permanently in the Museum. Two examples of impressive contrast are provided by new accessions; these are the "Gibson Girl" radio, used for emergency rescue in World War II, compared to the Lear automatic pilot and radio equipment used by Capt. C. F. Blair, Jr., in his polar flight from Norway to Alaska in 1950; and the reproduction of the original Wright Brothers' wind tunnel, 1902, compared with a modern precision steel wind-tunnel model of the Grumman F7F *Tigercat*. Other accessions supplement existing exhibits. These are the model of the *Cloudster* received from Douglas Aircraft as an auxiliary specimen to their World Cruiser *Chicago;* and the droppable landing gear used in the take-offs for Wiley Post's substratosphere flights. Both the *Chicago* and Post's *Winnie Mae* have been in the collection for many years. Also in this category are the original telemetering and film instruments used in the supersonic flights of the Air Force's Bell X–1, which, now that they have been released by the National Advisory Committee for Aeronautics, can be placed with the plane in the Aircraft Building. Among the year's accessions, perhaps the most prophetic specimen is the Delta wing model, one of the basic concepts of this design. Further mention of each new specimen is given in the last part of this report.

STORAGE

Some of the difficulties encountered in finding quarters for housing the Air Museum's storage collection have been described. Among the assembled aircraft five were maintained flyable and of those, two—the B–29 *Enola Gay* and the B–17–D *Swoose*—were flown to other storage areas. The Beechcraft Bonanza *Waikiki Beech* was, at the request of the donors, Beech Aircraft, returned to them. The Douglas XB–42 *Mixmaster* was disassembled and moved away by truck to an Air Force storage area. Even after most of the boxed material had been moved into Building T–7, another partial move had to be made within the building when the roof developed serious leaks, and specimens had to be kept away from the dripping and puddling water. Following a careful scrutiny by the Advisory Board and officials of the Air Force and Air Museum of the aircraft that had been gathered at Park Ridge, 16 were scheduled during the fiscal year for separation from the collection. The handling of these planes as they left for other Air Force Bases or educational institutions and elsewhere was a large task. Disassembly of nine full-scale aircraft preparatory to boxing presented unique problems because many of these were obsolete

or of foreign make with little or no printed data available to govern procedure. Twenty-five aircraft were boxed during the year, each one presenting its own problems of handling, placing, bracing, and enclosing; 30 boxes were required for the total, some planes needing extra containers for wings and components. Many of the boxes in which aircraft had originally been received required repair during the year, and all those that were placed outdoors had to be roofed with waterproof covering and sprayed with heavy Abesto liquid. This exterior protection supplemented the careful coating of the aircraft and engines inside with Parelketone, Cosmolene, and other applications, each best suited to the surface being protected. Nine engines were boxed during the year, but at the close of June all 151 engines were due for another inspection, preservative coating, and dehydration treatment. In many instances the handling, disassembly, and preservation of specimens required special study and care by the staff to determine best procedures.

Because of the precarious status of the storage housing, few items of new material were brought to Park Ridge. Enforced concentration on other aspects of the work left no opportunity for inventorying, but guarding was maintained on a 24-hour schedule, even through severe winter nights. During one particularly bad blizzard all hands had to drop other assignments and make a powered snow shovel to clear paths to the outdoor boxes and aircraft. With it all some time was found to assist research workers using the collection for study purposes and to prepare some educational displays requested by the Air Force for recruiting purposes.

ASSISTANCE TO OTHER AGENCIES

The tangible evidence of aeronautical progress and history embodied in the collection, the extensive files maintained as auxiliary data for the material on display and in storage, and the expert knowledge of the staff are frequently called upon to be of service to government and industry and to students, engineers, authors, historians, and others. This is one of the most interesting phases of the work and pays a direct return to the nation for the maintenance of the collection.

It is particularly gratifying when the possibility of accident can be forestalled. The Bell Supersonic airplane X–1 became a source for such service during the year. The National Advisory Committee for Aeronautics, the Navy, and Air Force are continuing to use similar aircraft for high-speed and extreme-altitude research. In July the National Advisory Committee for Aeronautics was faced with the problem of determining the safety factor and life expectancy of the high-pressure nitrogen spheres in supersonic aircraft that were flying at Edwards Air Force Base on regular test hops. When NACA

found that the only spheres available at that base for tests were in their operational airplanes they turned to the National Air Museum for assistance rather than ground their airplanes and interrupt their essential research. The Museum agreed to lend the spheres from the X-1. The test consisted of pressurizing the spheres to their maximum of 1,500 p. s. i. and then reducing the pressure to zero, thus completing one cycle. The spheres indicated failure at approximately 1,800 cycles. It was found that NACA's airplane was very close to the safety factor established as a result of these tests; therefore, their airplane was grounded for overhaul. At the close of the year arrangements had been made to reinstall the spheres in the Museum's Bell X-1.

The Department of Justice, in connection with patent claims, has been investigating basic types of attachments used in parachute gear and found interesting examples among the early parachutes in the collection. This Department was also assisted in looking up original types of engine mounts and shieldings. The technical-data office of the Bureau of Aeronautics was assisted in compiling records of trophies and awards, in which naval personnel were represented. The historical office of the Air Force was given assistance in setting up forms and methods for recording historic specimens, based on procedures proven through the years in Museum practice. The Signal Corps was helped in tracing types of kites used to support radio antennae, and the Coast Guard consulted the Museum specimens and records to trace techniques used in air-borne human pick-up gear.

Educational institutions that benefited from Air Museum assistance included local schools that were advised regarding their aeronautical curriculum. The University of Pittsburgh was helped in tracing details of the aerodynamic testing devices constructed and used by Prof. S. P. Langley, third Secretary of the Smithsonian, when he was at the Allegheny Observatory in 1886 before coming to this Institution. The Jam Handy organization of Detroit, engaged in preparation of training films and texts for the Navy and other users, turned to the Air Museum for help in compiling a history of helicopter development. The Musée de l'Air, Paris, France, through its distinguished conservateur, Charles Dollfus, requested aid in improving its files on the NC-4, U. S. Navy flying boat, 1919, first to fly across the Atlantic; and the RB-1, racing plane of advanced design entered in the Gordon Bennett Race of 1920. It was a particular pleasure to assist Mr. Dollfus, in view of his many kindnesses to the National Air Museum.

Assistance to industry has been in connection with filling in lost records of past accomplishments in a variety of instances. The contacts that are most gratifying are those in which the Museum recognizes the significance of some treasured object preserved from the

days of the company's pioneer origin, and it is agreed to place it in the Museum where it can take its deserved place in the collection.

Over 700 correspondence requests for information have been answered during the year and 256 photographs distributed.

The committees upon which the head curator served during the year include the Brewer Trophy Committee for the National Aeronautic Association which annually chooses an outstanding person who has contributed to youth education in aeronautics; the National Science Fair board of judges, which selects deserving students to receive higher education in science; and the Kill Devil Hills Memorial Association Committee, which is planning to erect at Kitty Hawk, N. C., a museum to commemorate those accomplishments of the Wright Brothers that were performed at that location.

The head curator gave several lectures during the year on various phases of aeronautics, including kites, the air mail, development of airports, and different aspects of the history of aeronautics; and the associate curator, Robert Strobell, has conducted tours of the collection for different groups, notably the international exchange group of flight cadets from 16 nations who were guests of the Civil Air Patrol.

IMPROVEMENTS IN REFERENCE MATERIAL

Great improvement in the reference material this year was accomplished by the associate curator and two clerical assistants. This material includes the Air Museum's library of books and periodicals, the original correspondence and source records for specimens, extensive data on all phases of aeronautics in the form of scaled dimensioned drawings, illustrations, texts, catalogs, clippings, and excerpts from correspondence in which detailed information was received or given; and the photograph file which is a numbered and cross-referenced collection of mounted prints for which negatives are maintained and from which prints can be supplied at cost. During the year this collection has increased substantially with particular emphasis upon aircraft of World War II. The process of indexing, captioning, and mounting was improved so that all material received during the year was indexed and filed, and the backlog reduced. Improvements were also made in the system of recording accessions and specimens.

For several years the National Air Museum has been collecting periodicals in an effort to establish a functional reference library. Individual collections received from the National Advisory Committee for Aeronautics, R. M. Kinderman, Scott Appleby, Smithsonian Institution duplicate stacks, and other sources remained in storage until it was indicated that sufficient material was available to establish the periodical library. Further impetus was given to the project when it was learned that the Division of Aeronautics, Library of Congress,

was planning to dispose of its large collection of duplicate periodicals. Arrangements were made to screen these duplicates, select issues required to fill gaps in the National Air Museum collection, and transfer the material to the Museum. Accordingly the first step was taken in March when the National Air Museum's collections were screened and cataloged so that the required issues could be selected from the Library of Congress. About 6,000 periodicals were selected. Early in May the integrating of all the collections was started, with an estimated 18,000 periodicals on hand. Space was provided in the east room of the office suite. By the first week in June the periodicals had been placed in chronological order ready for reference use. This periodical library now consists of all the major aeronautical titles published in the United States and two titles published in England. While some volumes are incomplete, all years are covered by at least one title. The intention is to establish a ready reference library of major titles only. The periodicals are now being cataloged on cards which will serve the usual record purposes and in addition list shortages for intensified search to complete the volumes.

Detailed drawings of the Wright Brothers' *Kitty Hawk* aeroplane were prepared by the Musical Arts and Educational Foundation, Dayton, Ohio, under the direction of L. P. Christman.

Other additions to the reference files were received from W. B. Stout, who lent drawings of the famous Ford-Stout airliner of the 1930's; Ivan Jerome, who improved the file on helicopters; Maj. Kimbrough Brown, long a friend of the Museum who, now in Europe, sent enriching material on foreign aircraft and some rare books; Capt. Holden C. Richardson, U. S. N., who, under assignment from the Navy Department in the interests of the Museum, prepared data from which a model of the Navy 82–A seaplane could be constructed, this being the first plane designed by the Navy and Captain Richardson's original project in 1916. At the close of the fiscal year Captain Richardson was preparing drawings and data on the NC–4. E. H. Heinemann of Douglas Aircraft sent illustrations of Douglas types, performance charts, and other very informative drawings; Fred Wiseman, of Berkeley, Calif., sent copies of contemporary accounts of his pioneer flight with air mail in 1911; R. W. Griswold II was very helpful in improving the files on delta wing configurations; and Capt. Charles F. Blair supplied descriptions of his renowned flight over the North Pole, May 29, 1951.

The following reference material, considered especially noteworthy, has been separately entered in an acknowledgment file:

Warren M. Bodie and James J. Sloan, Aero Historical Society, Van Nuys, Calif.: A collection of 16 photographs and 7 negatives of racing aircraft and other significant types.

Warren M. Bodie and George R. Lawlor, Manhattan Beach, Calif.: A three-view dimensioned scale drawing of the Curtiss R–6 Army Racer, 1922, drawn by Mr. Lawlor.

Vincent J. Burnelli, New York: A collection of 1,192 photographs pertinent to the Aeromarine Plane and Motor Corporation.

Department of the Navy, Bureau of Aeronautics, Washington, D. C.: A collection of 130 enlarged photographs covering naval aviation history from 1911 to 1951.

RESEARCH

The many requests for information received during each year require extensive research by the staff, while the preparation of displays entails extended study in order to prepare correct labels and present the material in its best and most complete form. In addition, the staff members, when other obligations permit, engage in separate research projects with a view to improving the collections and files. A study of biographical material on noted airmen of World War I has yielded interesting facts and exhibition material. The development of helicopters is a project undertaken in connection with the Aviation Industries Association and several manufacturers and has brought in significant specimens, photographs, and texts. Appreciation is expressed to those authorities who have assisted with other research undertakings; these include Mrs. Esther C. Goddard, who personally checked labels to be exhibited with the rockets developed by her late husband; Burdette Wright, who supplied helpful references on the Curtiss P–40; and James Ray and his son, who gave information on autogiro theory and operation.

ACCESSIONS

This year the bureau received 110 specimens from 21 sources, comprising 30 separate accessions. Those from Government departments are recorded as transfers; others were received as gifts, except as noted. Each has been entered in the permanent records of the Museum and formally acknowledged.

Air Force, Department of, Washington, D. C.: Nose and cockpit section of a Republic XP–84 *Thunderjet* complete with instruments and equipment showing the pilot's compartment of a type now in service in Korea (N.A.M. 737).

American Helicopter Society, Bridgeport, Conn.: The Alexander Klemin Award, a placque presented annually by the Society for notable achievement in rotary wing aeronautics (N.A.M. 732, loan).

Bendix Aviation Corp., North Hollywood, Calif.: A "Gibson Girl" automatic radio transmitter with kite-supported antenna used in World War II for air-sea rescue (N.A.M. 749).

Chrysler Motor Corp., Detroit, Mich.: A flying model airplane, built by Henry Struck, which, in a competitive sport contest at Alameda, Calif., July 20, 1949, sponsored by the donors and sanctioned by the Academy of Model Aeronautics of the National Aeronautic Association, attained a speed of 80.634 mph, surpassing the former Russian record (N.A.M. 726).

CONSOLIDATED VULTEE AIRCRAFT CORP., San Diego, Calif.: (Through Ernest Stout and with cooperation of the Department of the Navy.) A radio-controlled 1:10-size free-flying model with which many important characteristics of the full-scale Convair XP5Y-1 flying boat prototype were determined (N.A.M. 736).

CURTISS-WRIGHT CORP., Wood Ridge, N. J.: (Through George Page.) The original motorcycle made by Glenn H. Curtiss, 1906, and used as a test bed for his 8-cyl. 40-hp Vee aircraft engine with which he established a world speed record of 137 mph January 24, 1907 (N.A.M. 734). (Through the Wright Aeronautical Division.) A collection of 17 exhibition scale models of airplanes produced by the Curtiss-Wright Corp., Airplane Division, during the period 1928–44. Models vary in scale (N.A.M. 721).

DOUGLAS AIRCRAFT CO., Santa Monica, Calif.: An exhibition model, scale 1:16, of the Douglas *Cloudster*. One of the first designs produced by Donald Douglas and his associates, 1921 (N.A.M. 747).

EDUCATIONAL AND MUSICAL ARTS, INC., Dayton, Ohio: Scale drawings, dimensioned and in detail, of the Wright Brothers' *Kitty Hawk* aeroplane of 1903, drawn by L. P. Christman, using as a basis the original aeroplane, the original drawing by the Wright Brothers, and notes made by and in the presence of Orville Wright (N.A.M. 738).

HOPPI-COPTER, INC., Seattle, Wash.: The prototype "Hoppi-Copter" designed in 1945 by Edward Pentecost as a manually supported one-man helicopter (N.A.M. 729).

HUBBELL, CHARLES H., Cleveland, Ohio: An exhibition model, scale 1:16, of the Wright Brothers' Type EX aeroplane *Vin Fiz* in which C. P. Rodgers made the first transcontinental flight, 1911. The model made by Mr. Hubbell illustrates the aeroplane as it appeared at the take-off, September 17; many repairs and replacements had altered its appearance when it completed the flight 84 days later (N.A.M. 740, purchase).

LEAR, INC., Grand Rapids, Mich.: The radio equipment and accessories for the automatic pilot installed in the P-51 airplane *Excalibur-III* in which Capt. C. F. Blair, Jr., flew from New York to London, thence to Bardufoss, Norway, across the North Pole to Fairbanks, Alaska, and on to New York, 1951 (N.A.M. 745).

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, Washington, D. C.: Instruments used in the original trans-sonic flight of the Air Force Bell X-1, October 14, 1947, comprising 4 telemetering instruments and 3 film-recording instruments (N.A.M. 727). A wind-tunnel model, scale 1:7, of the Naval Grumman fighter airplane, type XF7F-1 *Tigercat*, 1943, complete with supports and manometering extensions, as used in the 8-ft. high-speed wind tunnel at Langley Field, Va., for research tests on the F7F series (N.A.M. 728). A free-flight sling-shot glider model of the Ludington-Griswold delta wing design, 1944, and the instrument panel from the German Lippisch delta wing aircraft, 1945 (N.A.M. 730).

NATIONAL AERONAUTIC ASSOCIATION, Washington, D. C.: The Frank G. Brewer Trophy awarded annually, since 1943, for "the greatest achievement in the field of air youth education and training" (N.A.M. 733, loan). The Collier Trophy, awarded annually, since 1911, for "the greatest achievement in aeronautics in America the value of which has been thoroughly demonstrated by actual use during the previous year" (N.A.M. 735, loan). (Through John Victory.) The Wright Brothers' Memorial Trophy awarded annually, since 1948, for "significant public service of enduring value to aviation in the United States" (N.A.M. 739).

NATIONAL CASH REGISTER Co., Dayton, Ohio: (Through Carl Beust.) A full-sized reproduction (5 ft. x 16 in.) of the Wright Brothers' wind tunnel, 1902, complete with balances, airfoils, and other test shapes, and with its 2-bladed fan mounted on a grinder-head and supported on a wooden post as in their original installations (N.A.M. 741).

NAVY, DEPARTMENT OF, Washington, D. C.: Original wind-tunnel model of a Sturtevant S-4 seaplane, 1916 (N.A.M. 723). A rocket engine, regeneratively cooled, designed by James H. Wyld, and tested, 1938 (N.A.M. 731). (Through the Office of Naval Research, Special Devices Center, Port Washington, L. I.) A General Electric I-16, J-31 jet engine, cut-away example, 1,600 pounds static thrust, at 16,500 r. p. m., 1942 (N.A.M. 743). Two jet aircraft engines—a German Junkers *Jumo* 004, 1,980 pounds static thrust at about 8,700 r. p. m., 1943, and an English DeHavilland *Goblin*, 3,000 pounds static thrust at 10,200 r. p. m., 1943; both having parts sectioned and cut away to show construction and operation (N.A.M. 744). Seven reciprocating aircraft engines—a Wright Brothers' 4-cyl. upright 30-hp. at 1,200 r. p. m. of 1910; a Wright Brothers' 60-cyl. upright 60-hp. at 1,400 r. p. m. of 1912; a Curtiss 6-cyl. upright 60-hp. at 1,500 r. p. m. of 1913; a Curtiss K-6, 6-cyl. upright 150-hp. at 1,700 r. p. m. of 1918; a Gnat A. B. C. (English) 2-cyl. opposed, 45-hp. at 1,915 r. p. m. of 1919; a Ranger V-770-8, 8-cyl. inverted Vee, 520-hp. at 3,150 r. p. m. of 1941; and a Packard-Merlin (American version of English Rolls-Royce), V-1650-7, 12-cyl. Vee, 1,490-hp. at 3,000 r. p. m. of 1945 (N.A.M. 748).

NEWCOMB, CHARLES J., Baltimore, Md.: An exhibition model, scale 1:16, of the Glenn L. Martin TT airplane, one of the first tractor designs ordered by the Aviation Section of the U. S. Signal Corps and the Navy, 1914. This was a 2-place biplane powered with a Curtiss 80-hp engine and with a speed of 65 mph. It was described by Grover Loening, then Aeronautical Engineer for the Signal Corps, as the Army's "first really safe and satisfactory training airplane" (N.A.M. 725, purchase).

PARKER, WILLIAM D., Bartlesville, Okla.: The droppable landing gear, radio set, and loop antenna used by Wiley Post during his continental substratosphere flights in the *Winnie Mae*, 1935 (N.A.M. 746).

PRATT & WHITNEY AIRCRAFT DIVISION, UNITED AIRCRAFT, East Hartford, Conn., with assistance of Harvey Lippincott: Engine accessories embodying significant developments of the World War II period, comprising 7 carburetors, 3 automatic engine controls, and 7 other accessories, cut away to show construction (N.A.M. 742).

STOUT, WILLIAM B., Phoenix, Ariz., with cooperation of the University of Detroit: The Stout *Sky Car*, a 2-place high-wing monoplane, all-metal construction, with pusher engine, designed as a general-purpose sport plane, 1931 (N.A.M. 750).

TOPPING, E. W., of Topping Models, Akron, Ohio; Exhibition model, scale 1:48, of the Glenn L. Martin Co. P4M-1 *Mercator*, long-range patrol airplane, 1949 (N.A.M. 724).

VALLEY FROCKS, INC., Lancaster, Pa.: A selected collection of parachutes, parachute parts, and other aeronautical gear dating from 1918 to 1942 (N.A.M. 722).

Respectfully submitted.

PAUL E. GARBER, *Head Curator.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 10

Report on the Canal Zone Biological Area

SIR: It gives me pleasure to present herewith the annual report of the Canal Zone Biological Area for the fiscal year ended June 30, 1952.

BUILDINGS AND EQUIPMENT

Construction of the new 2-story laboratory begun last year was completed. The entire ground floor is now of reinforced concrete, extending 5 feet beyond the building on all four sides. The ground under the concrete was treated with sodium arsenite, as a protection against termites; all four sides were walled in with terra-cotta blocks faced with cement; and the building was surrounded by a concrete ditch. The lower windows are in aluminum frames, and all windows are provided with plastic screens. A photographic dark room, 15 x 11 feet, is included. Two laboratory rooms, 15 x 23 feet, were built, each to accommodate two to four scientists. These rooms will be provided with beds and dressers, and it is hoped to install dry closets in each. Funds to install sinks, work tables, and shelves will need to be supplied later.

The ground behind the building was leveled and a pit dug for an additional concrete water tank to store the runoff from the roof of the building. Since this reservoir is urgently needed, it is hoped that it can be completed during the next fiscal year.

The ground floor of the zinc-meta-arsenite building, just below the main laboratory building, was covered with reinforced concrete and will be available for laboratory use. The building has two rooms, each with a separate entrance, which will comfortably accommodate two persons in each room. The lower floor of the main laboratory has been cleared of miscellaneous storage material, and this has about doubled the available working space for scientists.

The library and herbarium now in the Haskins building are being transferred to rooms on the upper floor of the new building. When this change is completed, the kitchen equipment will be moved into the larger, fireproof Haskins building. The toilets and showers, now in the main laboratory building, will then be moved into the old kitchen building.

The large main building, which accommodates six persons, is in satisfactory general condition but will soon need repairs to screening

and the addition of a dry storage room. To reduce the fire risk, the attic is no longer used for drying purposes.

The resident manager's house and the building used for the Eastman Kodak Co.'s research on deterioration and corrosion are both in good shape. The Barbour cottage, which can accommodate two to four persons, is in good repair. The old Chapman building is serviceable but not in too good condition; with some repairs it can last about two years more. It accommodates four persons, and all the ground floor is used for laboratory purposes.

The building now occupied by the caretaker and the dormitory for the cook are in good shape; but the dormitory for the laborers needs repairs.

The trail-end houses on Barbour Point and Burrunga Point now are usable only as temporary shelters from rain. The treated-wood house at the end of the Drayton Trail and the Z-M-A house (Fuertes House) are in good condition. The shelter at the end of Zetek Trail is in fairly good condition but needs some repairs.

The old generators for light and power are no longer in shape to operate, except one 5 KVA, and that one is far from satisfactory. The new 15 KVA Diesel-driven generators, now on order, should give satisfactory service for at least 10 years.

The floating equipment is in good condition.

MOST URGENT NEEDS

The most pressing need is for a concrete platform building at the dock to house the two new generators soon to arrive and the Diesel-oil storage tank, with loading and unloading equipment at Frijoles. Next in order is the concrete water-storage tank behind the new building.

There is a real need for suitable dry closets; these should be made during the coming fiscal year. Reducing the humidity to control corrosion and deterioration cannot always be accomplished by heat. In some cases the use of dehumidifiers is preferable, especially in the photographic darkroom and where chemicals are to be stored.

In the new building, sinks, shelves, and closets should be installed.

SCIENTISTS AND THEIR STUDIES

The principal purpose of the Canal Zone Biological Area is to provide a safe tropical environment for research. In view of the far-flung interests of our nation, it is of vital importance that problems related to tropical conditions be solved in advance of the need for information on those conditions in defense operations. Work of this character is done by many scientists from universities and institutions,

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and at no expense to the Government. This research should receive every encouragement.

During the 1952 fiscal year, 48 scientists were on the island. The high cost of transportation to the Canal Zone still keeps many from coming, and some of those who do come cannot spend as much time on the island as they would like. A list of the season's investigators, with a brief summary of their researches, follows:

Investigator	*Principal interest or special study*
Atwater, Mr. and Mrs. R. M., executive secretary, American Public Health Association.	Inspection of facilities for scientists.
Beale, Dr. James A., in charge of division of forest insect investigations, U. S. Bureau of Entomology and Plant Quarantine.	Inspection of termite tests
Blair, J. P., New York Zoological Society.	Study of tropical environment.
Bourliere, Dr. F., professor of medicine, Faculté de Médecine, Rue Huysmans, Paris.	Ecology of mammals, particularly primates.
Brunn, Dr. Anton H., director of oceanographic exploration, Danish Deep Sea Expedition (1950–52).	General observation.
Bull, John L., Jr., secretary, Linnaean Society of New York.	Birds and insects.
Cherbonnier, Mr. and Mrs. E. C., member of advisory council, Agricultural Research Administration, St. Louis.	Mammals and birds.
Dickinson, Sam, artist, University of Kansas, Lawrence, Kans.	Collection and preparation of material for tropical-habitat museum group.
Dunn, Dr. and Mrs. Emmett R., professor of zoology, Haverford College, Haverford, Pa.	Reptiles and amphibians.
Eisenmann, Dr. Eugene, New York, N. Y.	Birds; published first complete annotated list of birds of island during year.
Ellis, Dr. Hazel R., head of biology department, Keuka College, Keuka Park, N. Y.	Bird behavior; fruit crow; general biology.
Fairchild, Dr. Graham B., staff entomologist, Gorgas Memorial Laboratory, Panama City.	Photography of tropical environment.
Hall, Dr. E. Raymond, professor of zoology, University of Kansas, Lawrence, Kans.	Collection and preparation of material for tropical-habitat museum group.
Ingles, Dr. and Mrs. Lloyd C., professor of zoology, Fresno State College, Fresno, Calif.	General zoology; photographic record; made first record of 5-toed armadillo (*Cabassous centralis*) on the island.
Jackson, Dr. William, Johns Hopkins University, Baltimore, Md.	Ecology of ants.
Johnson, Hon. and Mrs. Leroy, Member of Congress from California.	Conservation.
Kelly, Mrs. Junea W., president, northern division, Cooper Ornithological Club, Alameda, Calif.	Birds.

Investigator	*Principal interest or special study*
Kerr, Charlotte, training, health and sanitation division, Institute of Inter-American Affairs.	Observation of tropical environment.
Laughlin, Robert M., student, Princeton University, Princeton, N. J.	Birds, mammals, and moths.
Logan, Elwood, photographer, American Museum of Natural History.	Army ants; photographic record.
Long, Mrs. Roberta, Alameda, Calif.	Birds.
Lundy, William E., assistant paymaster, Panama Canal Co., Balboa Heights, C. Z.	Birds, mammals, and insects.
Martin, Dr. George W., professor of botany, State University of Iowa, Iowa City.	Fungi.
Mausteller, Dr. John E., professor of forestry, Michigan State College, Lansing, Mich.	Humid tropical environment.
Mielche, Hakon, author, Danish Deep Sea Expedition (1950–52).	General observation.
Milne, Dr. Lorus J., professor of zoology, University of New Hampshire, Durham, N. H.	General zoology, especially invertebrates.
Milne, Dr. Margery, assistant professor of zoology, University of New Hampshire.	Invertebrates; photographic record.
Milotte, Mr. and Mrs. Alfred, Walt Disney Productions, Burbank, Calif.	Photography of tropical environment.
Morris, Robert C., entomologist, U. S. Bureau of Entomology and Plant Quarantine.	Investigation of termite control.
Nelson, Mrs. Edith, Alameda, Calif.	Birds.
Perrygo, Watson M., exhibits preparator, Smithsonian Institution.	Birds.
Rettenmeyer, Carl, student, Swarthmore College, Swarthmore, Pa.	Behavior of army ants.
Schneirla, Dr. T. C., curator, department of animal behavior, American Museum of Natural History.	Behavior of army ants.
Schnitzer, Mr. and Mrs. Albert, Elizabeth, N. J.	Birds and mammals.
Schultz, Mrs. Marguerite M., botanist, University of Kansas, Lawrence, Kans.	Collection and preparation of material for tropical-habitat museum group.
Soper, Dr. Cleveland C., director, Tropical Research Laboratory, Eastman Kodak Co., Panama City.	Deterioration and corrosion tests of photographic equipment and supplies; advice on operation of plant.
Therrien, H. P., Miami, Fla.	General observation; photography.
Vowles, Dr. David M., Fulbright exchange professor, Tufts College, Medford, Mass.	Morphology of ants as related to behavior.
Walker, Hastings H., M. D., Leahi Hospital, Hawaii.	Observation of tropical environment.
Welden, Arthur L., graduate student, State University of Iowa, Iowa City.	Fungi.
Wetmore, Dr. Alexander, Secretary, Smithsonian Institution.	Birds; inspection of plant.
Young, George, taxidermist, University of Kansas, Lawrence, Kans.	Collection and preparation of material for tropical-habitat museum group.

VISITORS

In addition to the scientists, 602 other visitors came to the island during the year. Among these were Paul A. Blanquet, chief engineer of the Suez Canal; Dr. David Potter, of Clark University, Worcester, Mass.; Dr. and Mrs. E. H. Kennard, of Washington, D. C.; J. R. Eisenmann and Mr. Woodin, of Pittsburgh, Pa.; Dr. Frank E. Mazland, Jr., of Carlisle, Pa.; Elton E. Hooser, of the U. S. Bureau of Entomology and Plant Quarantine, Washington, D. C.; several Boy Scout troops, including the Explorers' Post; and several groups of Girl Scouts. For these Scout groups the visits were educational in nature.

There were also members of the Liceo of Panamá, several groups from LaSalle College, members of the Junior College of the Canal Zone, under the leadership of Prof. George E. Lee, members of the Servicio Geografico del Ejercito de Brasil and the 370th Engineer Amphibious Support Regiment, the Diablo Heights and Balboa High School Camera Clubs, members of the Institute of Inter-American Affairs, the Inter-American Geodetic Survey, the Air Corps School, and officials of the Canal Zone Government, the Panama Canal Company, and the Panama Embassy.

ADDITIONS TO THE LIST OF VERTEBRATES

The following vertebrates were added to the list published in the 1950 report:

MAMMALIA:
- *Desmodus rotundatus murinus* (vampire bat).
- *Cabassous centralis* (5-toed armadillo).

REPTILIA:
- *Liotyphlops albirostris.*
- *Ninia maculata.*
- *Trimetopon barbouri.*
- *Pseudoboa neuwiedii.*

AMPHIBIA:
- *Hyla venulosa.*

These 7 species, with the 173 given in the list previously published, and the 306 kinds of birds, make a total of 486 vertebrates known from the island.

DONATIONS

The resident manager donated to the library a set, complete to date with index volume, of the 26 volumes of Biological Abstracts, a

set of the Journal of Parasitology, and a long series of complete bound volumes of the Experiment Station Record; also considerable laboratory glassware.

RAINFALL

In 1951, rains of 0.01 inch or more fell on 48 days (154 hours) during the dry season (January to April), and on 194 days (764 hours) during the wet season (8 months); a total for the year of 242 days, 918 hours. Rainfall was 5.44 inches above the 27-year average. During the dry season the excess amounted to 7.56 inches, and during the wet season there was a deficiency of 2.12 inches. Five of the eight wet-season months registered deficiencies, amounting to a total of 11.24 inches. October was the wettest month, with 19.43 inches (27 days, 128 hours). March was the driest month, with 0.30 inch (4 days, 11 hours). A new 1-hour record was established on October 12, 4.11 inches. The previous high was 3.68 inches.

TABLE 1.—*Annual rainfall, Barro Colorado Island, C. Z.*

Year	*Total inches*	*Station average*
1925	104. 37	------
1926	118. 22	113. 56
1927	116. 36	114. 68
1928	101. 52	111. 35
1929	87. 84	106. 56
1930	76. 57	101. 51
1931	123. 30	104. 69
1932	113. 52	105. 76
1933	101. 73	105. 32
1934	122. 42	107. 04
1935	143. 42	110. 35
1936	93. 88	108. 98
1937	124. 13	110. 12
1938	117. 00	110. 62
1939	115. 47	110. 94
1940	86. 51	109. 43
1941	91. 82	108. 41
1942	111. 10	108. 55
1943	120. 29	109. 20
1944	111. 96	109. 30
1945	120. 42	109. 84
1946	87. 38	108. 81
1947	77. 92	107. 49
1948	83. 16	106. 43
1949	114. 86	106. 76
1950	114. 51	107. 07
1951	112. 72	107. 28

TABLE 2.—*Comparison of 1950 and 1951 rainfall, Barro Colorado Island, C. Z. (inches)*

Month	Total		Station average	Years of record	Excess or deficiency	Accumulated excess or deficiency
	1950	1951				
January	0.20	2.21	1.75	26	+0.46	+0.46
February	1.87	3.76	1.30	26	+2.46	+2.92
March	0.48	0.30	1.24	26	−0.94	+1.98
April	2.73	8.53	2.95	27	+5.58	+7.56
May	7.86	12.19	10.83	27	+1.36	+8.92
June	14.66	10.94	11.39	27	−0.45	+8.47
July	12.37	5.37	11.47	27	−6.10	+2.37
August	11.48	11.29	12.27	27	−0.98	+1.39
September	7.20	9.62	10.02	27	−0.40	+0.99
October	14.02	19.43	13.39	27	+6.04	+7.03
November	24.19	16.15	19.46	27	−3.31	+3.72
December	17.45	12.93	11.21	27	+1.72	+5.44
Year	114.51	112.72	107.28			+5.44
Dry season	5.28	14.80	7.24			+7.56
Wet season	109.23	97.92	100.28			−2.12

The maximum yearly rainfall of record on the island was 143.42 inches, and the minimum was 76.57 inches. For short periods the following were the maximums: 5 minutes, 0.85 inch; 10 minutes, 1.40 inches; 1 hour, 4.11 inches; 2 hours, 4.81 inches; 24 hours, 10.48 inches.

FISCAL REPORT

During the fiscal year 1952, $11,558.12 in trust funds was available. This sum included a balance of $226 from 1951 and $3,000 contributed by the Smithsonian Institution from its private funds. Of this amount $11,294.09 was spent, leaving a balance of $264.03.

The following items are paid out of trust funds: Food, wages, freight and express, office expenses, and miscellaneous expenses such as parts for the automobile, kitchen equipment, and general upkeep. This year food represented 41.8 percent of the total expended, and wages, 53.8 percent.

The Smithsonian Institution allotted $16,646.96 from Government-appropriated funds, of which $16,600.38 was expended. Of this amount $7,580 was for two new 15–KVA Diesel-driven generators, and $4,217.78 for contracts to complete the lower floor of the new building erected this year. Approximately $1,850 from allotted funds was used for the purchase and transportation from Frijoles to the island of gravel, sand, cement, and reinforcing steel for the completion of this lower floor.

During the year fees from scientists totaled $3,722, more than four times as much as the amount received for the fiscal year 1951. Visitors' fees amounted to $1,503. Reimbursements for supplies furnished amounted to $756.72.

The rates for scientists and visitors have not been raised since the laboratory started in 1923, despite the rising costs of food, wages, materials, and services; but increased costs have reached the point where the laboratory is now reluctantly forced to increase its rates. The new rates now in effect are $3 per person for 1-day visitors, $4 a full day for scientists from institutions that support the laboratory through table subscriptions, and $5 a full day for all others. A 1-day visit includes the use of the launch to and from the island, the noon meal, and the guide in the morning. A full day for scientists includes three meals and lodging.

The following institutions continued their support to the laboratory through the payment of table subscriptions:

Eastman Kodak Co.	$1,000
New York Zoological Society	300
American Museum of Natural History	300
Smithsonian Institution	300

It is most gratifying to again record donations from Dr. Eugene Eisenmann of New York and E. C. Cherbonnier of St. Louis.

ACKNOWLEDGMENTS

Thanks are due to the Canal Zone Government for its whole-hearted cooperation; to the Panama Canal Company, especially Alton P. White, chief of the Dredging Division, and J. A. Driscoll, assistant chief, for their technical help, and the Commissary Division for its efficient services; to Maj. George Herman, Chief of Police, and the officers under him; and to officials and employees of the Panama Railroad for their able assistance.

Respectfully submitted.

James Zetek, *Resident Manager.*

Dr. A. Wetmore,
Secretary, Smithsonian Institution.

APPENDIX 11

Report on the Library

Sir: I have the honor to submit the following report on the activities of the Smithsonian Library for the fiscal year ended June 30, 1952.

Probably not since 1866, when the Smithsonian Deposit in the Library of Congress was established by Act of Congress, has there been an event in the history of the Smithsonian Library more epoch-marking than the transfer, after more than a hundred years, of the librarian's office from the Smithsonian Building to the Natural History Building and the dismantling of the old office library reference room, in order to effect a consolidation of all major library functions of the Institution. The National Museum Library, as a separate branch, was merged with the Smithsonian Library, and its staff, functions, and equipment were consolidated with the units of the Smithsonian Library. The consolidated library will hereafter be known as the Smithsonian Library. The position of assistant librarian in charge of the National Museum Library was changed to that of chief of the reference and circulation section of the Smithsonian Library. The change became effective on November 2, 1951.

The Museum Library had long been the largest of the Institution's branch libraries, with the most comprehensive subject coverage in its basic reference collections. Its reference services had never been limited to the curatorial staff of the Museum but were given to the whole Institution, and interlibrary loans were handled by its loan desk. Its physical separation from the administrative offices of the library in the Smithsonian Building resulted in a considerable and increasing amount of duplication of cataloging and other record keeping and of the acquisition of reference books. It is hoped that the present centralization of staff, functions, records, and materials will result in better and more economical library service to the whole Institution.

The change in quarters affected the work of the acquisitions section somewhat less than that of the other sections. It had an exceptionally busy year. Its records show the receipt of 60,512 publications, most of which came either by mail or through the International Exchange Service from 92 different foreign countries, dominions, colonies, and protectorates, as well as from all the States of the Union. The library continues to owe the largest part of this wide coverage of the special

literature needed by the scientific and curatorial staff of the Institution to the cordial exchange relations maintained with scientific and other cultural institutions throughout the world. These relations are continually being extended, and there were 531 new exchanges arranged during the year, while 7,899 different publications were received in response to 497 special requests for volumes or parts of serial publications needed to fill gaps in our collections.

Acquisitions by purchase included 1,278 books and 332 subscriptions for foreign and domestic serial publications not obtainable by exchange. Most of the books bought were recent publications, but a few of the many out-of-print works still much needed were purchased as they came into the market. It is highly desirable to be able to buy the most needed of these old books when copies are advertised for sale, but many of them are prohibitively expensive for a small budget, when they are available at all.

As always, friends of the Institution made many generous gifts to the library. Especially noteworthy among the larger donations was a selection of more than a thousand volumes from the library of the late Gen. John J. Pershing, presented by his son, Francis W. Pershing, especially for the use of the division of military history in the National Museum.

The library is deeply indebtedly to many members of the Smithsonian staff for their generosity and thoughtfulness in giving the library copies of their own publications and other books and papers. Stamp collectors everywhere will, directly or indirectly, have reason to be especially grateful to Franklin R. Bruns, Jr., for the more than 1,500 publications on stamps he has donated from his own library to the sectional library in the division of philately. Many other gifts to the sectional library were obtained through his good offices.

Of the grand total of 22,774 publications transferred to the Library of Congress during the year, 5,573 were books and serial publications individually stamped and recorded as additions to the Smithsonian Deposit. Others were 2,481 doctoral dissertations from European universities, and 14,720 foreign and domestic documents, and many miscellaneous publications on subjects not immediately pertinent to the work of the Institution.

Of the 3,216 publications transferred to the Army Medical Library, 581 were medical dissertations. To other government libraries were sent 425 publications on subjects in their special fields of interest.

There were one or two fairly large and a number of small withdrawals from the library's huge collection of duplicates, but the collection continued to grow. The 11,420 pieces selected and sent to the United States Book Exchange, for exchange credit, made no noticeable impression on it. The collection needs the exclusive time and attention of a small staff of its own, working under the direction of the

chief of the acquisitions section, to keep it in order and to make the best possible use of it for exchange purposes.

In the catalog section, the merging of the separate catalogs of the Museum books and serials with the central catalog and serial records of the Institution was begun immediately and has gone forward as fast as circumstances would permit. There is an enormous amount of work to be done in such an enterprise where more than a million cards must be handled with scrupulous accuracy in unifying entries and eliminating unnecessary duplication. Under the most favorable conditions it will take a long time to complete it, but when it is finished the Institution will have the most complete record it has ever had of the library's collections and, it is hoped, the most effective aid to their use.

In addition to the work of reorganization in the catalog section, 5,779 publications were cataloged, 20,175 parts of serial publications were entered, and 30,488 cards were added to catalogs and shelflists.

The work of the reference and circulation section is most difficult to measure and evaluate statistically because figures are very imperfect indices of the many indeterminate variables involved in reference services to the staff and bringing together the books and their users. However, statistics show that 11,730 publications were borrowed for use outside the library, exclusive of 7,314 books and periodicals assigned to sectional libraries for filing which are circulated within the divisions to which they are assigned. Interlibrary loans of 1,231 publications were made to 99 different Government, university, and other institutional libraries throughout the country. For use within the Institution, the library borrowed 1,357 publications from the Library of Congress, many of which were Smithsonian Deposit copies, and 405 publications were borrowed from other libraries.

More than 16,000 reference questions were answered in response to letters and telephone calls and to inquirers who came to the library in person.

Funds allotted for binding permitted only 623 volumes, mostly currently completed volumes of periodicals, to be prepared and sent to the Government Printing Office, but 1,563 old books were repaired in the library. The library is in no sense a museum of fine books, but it nevertheless has many valuable volumes, and not a few irreplaceable ones in its working reference collections that are actually collector's items. How to give them the proper housing and the continuous care that they ought to have to maintain them in good condition is one of the library's most serious problems.

The principal need of the library continues to be more and better-arranged space, with adequate provision for growth. It also needs a staff of competent librarians commensurate in size with the requirements of the Institution for library service. It needs more funds for

books and especially for binding. Many of the physical and organizational changes inaugurated during the year were good, considered as initial steps in long-range planning, but plans can only be brought to fruition if they are firmly and continuously supported by the means to carry them out.

SUMMARIZED STATISTICS

ACCESSIONS

	Volumes	Total recorded volumes, 1952
Smithsonian Deposit at the Library of Congress	738	584, 213
Smithsonian library (includes former office and Museum branches)	4, 026	287, 645
Astrophysical Observatory (includes Radiation and Organisms)	219	14, 040
Bureau of American Ethnology	107	35, 068
National Air Museum	78	288
National Collection of Fine Arts	230	12, 685
National Zoological Park	5	4, 204
Total	5, 403	938, 143

Neither incomplete volumes of serial publications nor separates and reprints from serial publications are included in these figures.

EXCHANGES

New exchanges arranged — 531
152 of these were for the Smithsonian Deposit.
Specially requested publications received — 7, 899
1,137 of these were obtained to fill gaps in Smithsonian Deposit sets.

CATALOGING

Volumes and pamphlets cataloged — 5, 779
Cards added to catalogs and shelflists — 30, 488

PERIODICALS

Periodical parts entered — 20, 175

CIRCULATION

Loans of books and periodicals — 11, 730
Circulation of books and periodicals in sectional libraries is not counted except in the division of insects.

BINDING

Volumes sent to the bindery — 623
Volumes repaired in the library — 1, 563

Respectfully submitted.

Leila F. Clark, *Librarian.*

Dr. A. Wetmore,
Secretary, Smithsonian Institution

APPENDIX 12

Report on Publications

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches for the year ended June 30, 1952:

The Institution published during the year 18 papers in the Smithsonian Miscellaneous Collections, 1 Annual Report of the Board of Regents and pamphlet copies of 19 articles in the Report appendix, 1 Annual Report of the Secretary, and 2 special publications.

The United States National Museum issued 1 Annual Report, 24 Proceedings papers, 1 Bulletin, and 1 paper in the series Contributions from the United States National Herbarium.

The Bureau of American Ethnology issued 1 Annual Report, 4 Bulletins, and 1 paper in the series Publications of the Institute of Social Anthropology.

The National Collection of Fine Arts issued 1 publication; and the Freer Gallery of Art published title page and table of contents of 1 volume in the Occasional Papers series.

The final number of Ars Islamica (comprising volumes XV–XVI) was issued in August 1951. This journal, published by the University of Michigan under the editorship of Dr. Richard Ettinghausen, of the Freer Gallery of Art, was seen through the press by the editorial staff of the Smithsonian Institution. Future numbers, to be known as Ars Orientalis, will be published jointly under the imprint of the University of Michigan and the Smithsonian Institution.

At the end of the year galley proof of the ninth revised edition of the Physical tables was beginning to come in.

Of the publications there were distributed 144,166 copies, which included 32 volumes and separates of Smithsonian Contributions to Knowledge, 34,691 volumes and separates of Smithsonian Miscellaneous Collections, 25,863 volumes and separates of Smithsonian Annual Reports, 2,350 War Background Studies, 2,238 Smithsonian special publications, 5 reports and 262 sets of pictures of the Harriman Alaska Expedition, 52,653 volumes and separates of National Museum publications, 17,964 publications of the Bureau of American Ethnology, 3,541 publications of the Institute of Social Anthropology, 1,140 catalogs of the National Collection of Fine Arts, 596 volumes and pamphlets of the Freer Gallery of Art, 13 Annals of the Astrophysical

Observatory, 2,182 reports of the American Historical Association, and 636 miscellaneous publications not published by the Smithsonian Institution (mostly Survival Manuals).

In addition, 33,471 picture pamphlets, 89,385 guide books, 67,591 natural-history, Smithsonian buildings, and art postcards, 30,334 sets of photo cards and picture postcards, 25 sets and 12 prints of North American Wild Flowers, and 9 volumes of Pitcher Plants were distributed.

SMITHSONIAN PUBLICATIONS

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 114

Smithsonian Meteorological Tables. Sixth revised edition. Compiled by Robert J. List. Whole volume. x+527 pp. (Publ. 4014.) [Oct. 10] 1951.

VOLUME 115

Biological investigations in Mexico, by Edward Alphonso Goldman. Whole volume. xiii+476 pp., 71 pls., 1 fig. (Publ. 4017.) July 31, 1951.

VOLUME 116

No. 3. Two runic stones, from Greenland and Minnesota, by William Thalbitzer. 71 pp., 7 figs. (Publ. 4021.) Aug. 30, 1951.

No. 5. Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains, by Franco Rasetti. 277 pp., 34 pls., 5 figs. (Publ. 4046.) Sept. 18, 1951.

No. 7. The butterflies of Virginia, by Austin H. Clark and Leila F. Clark. 239 pp., 31 pls., 1 fig. (Publ. 4050.) Dec. 20, 1951.

Title page and table of contents. (Publ. 4061.) [Feb. 4] 1952.

VOLUME 117

No. 1. North American fireflies of the genus *Photuris*, by Herbert Spencer Barber. With preface and notes by Frank A. McDermott. 58 pp., 3 figs. (Publ. 4051.) Nov. 27, 1951.

No. 2. Additional forms of birds from Colombia and Panamá, by Alexander Wetmore. 11 pp. (Publ. 4052.) Sept. 25, 1951.

No. 3. Relationships of certain genera of fungus gnats of the family Mycetophilidae, by F. R. Shaw and M. M. Shaw. 23 pp., 45 figs. (Publ. 4053.) Dec. 27, 1951.

No. 4. A revised classification for the birds of the world, by Alexander Wetmore. 22 pp. (Publ. 4057.) Nov. 1, 1951.

No. 5. Annotated list of birds of Barro Colorado Island, Panama Canal Zone, by Eugene Eisenmann. 62 pp. (Publ. 4058.) Feb. 7, 1952.

No. 6. The scaphopod mollusks collected by the First Johnson-Smithsonian Deep-Sea expedition to the Puerto Rican Deep, by William K. Emerson. 14 pp., 1 pl. (Publ. 4059.) Feb. 26, 1952.

No. 7. Host relationships of moths of the genera *Depressaria* and *Agonopteris*, with descriptions of new species, by J. F. Gates Clarke. 20 pp., 6 pls. (Publ. 4083.) Apr. 23, 1952.

No. 8. The sand crab *Emerita talpoida* (Say) and some of its relatives, by R. E. Snodgrass. 34 pp., 11 figs. (Publ. 4086.) Apr. 15, 1952.

No. 9. Precipitation and temperature in Washington, D. C., for 1951 and 1952, by C. G. Abbot. 5 pp., 2 figs. (Publ. 4087.) Mar. 18, 1952.

No. 10. Periodicities in the solar-constant measures, by C. G. Abbot. 31 pp., 6 figs. (Publ. 4088.) May 28, 1952.

No. 11. Important interferences with normals in weather records, associated with sunspot frequency, by C. G. Abbot. 3 pp., 1 fig. (Publ. 4090.) May 20, 1952.

VOLUME 118

Smithsonian Logarithmic Tables (to base e and base 10), by George Wellington Spenceley, Rheba Murray Spenceley, and Eugene Rhodes Epperson. Whole volume. xii+402 pp. (Publ. 4054.) [Mar. 26] 1952.

ANNUAL REPORTS

Report for 1950.—The complete volume of the Annual Report of the Board of Regents for 1950 was received from the printer on October 15, 1951:

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1950. ix+522 pp., 84 pls., 47 figs. (Publ. 4025.)

The general appendix contained the following papers (Publs. 4026–4044):

Beyond the Milky Way, by Thornton Page.

The luminous surface and atmosphere of the sun, by Bertil Lindblad.

What is an elementary particle? by E. Schrödinger.

The composition of our universe, by Harrison Brown.

The Wright Brothers as aeronautical engineers, by M. P. Baker.

Chemical achievement and hope for the future, by Linus C. Pauling.

Electroencephalography, by W. Grey Walter.

Energy from fossil fuels, by M. King Hubbert.

Permafrost, by Robert F. Black.

Earthquakes in North America, by B. Gutenberg.

Wolf Creek meteorite crater, Western Australia, by D. J. Guppy and R. S. Matheson.

Natural history in Iceland, by Julian Huxley.

Praying mantids of the United States, native and introduced, by Ashley B. Gurney.

Man's disorder of nature's design in the Great Plains, by F. W. Albertson.

Food shortages and the sea, by Daniel Merriman.

Economic uses of lichens, by George A. Llano.

The origin and antiquity of the Eskimo, by Henry B. Collins.

Archeology and ecology on the Arctic slope of Alaska, by Ralph S. Solecki.

Samuel Seymour: Pioneer artist of the Plains and the Rockies, by John Francis McDermott.

Report for 1951.—The Report of the Secretary, which will form part of the Annual Report of the Board of Regents to Congress, was issued January 18, 1952:

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1951. ix+160 pp., 4 pls. (Publ. 4056.)

SPECIAL PUBLICATIONS

The Smithsonian Institution. 30 pp., 13 pls. (Publ. 4048.) [Aug. 9] 1951.

Classified list of Smithsonian publications available for distribution May 1, 1952. Compiled by Lester E. Commerford. 61 pp. (Publ. 4084.) [May 14] 1952.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum continued under the immediate direction of the editor, John S. Lea. Gladys O. Visel, assistant editor, retired on February 29, 1952, after 35½ years' service in the Institution. The Museum issued during the year 1 Annual Report, 24 Proceedings papers, 1 Bulletin, and 1 paper in the series Contributions from the United States National Herbarium, as follows:

ANNUAL REPORT

Report on the progress and condition of the United States National Museum for the year ended June 30, 1951. iv+112 pp., 5 pls. [Jan. 10] 1952.

PROCEEDINGS

VOLUME 99

Title page, table of contents, list of illustrations, and index. Pp. i–viii+541–573. Feb. 7, 1952.

VOLUME 101

No. 3287. New finds of Pleistocene jaguar skeletons, by Edward McGrady, H. T. Kirby-Smith, and Harvey Templeton. Pp. 497–511, pl. 16, figs. 97–102. Oct. 16, 1951.

No. 3288. An annotated checklist of the mosquitoes of the subgenus *Finlaya* (genus *Aedes*), by Kenneth L. Knight and Elizabeth N. Marks. Pp. 513–574. Feb. 12, 1952.

No. 3289. A new subspecies of marine isopod from Texas, by Robert J. Menzies. Pp. 575–579, figs. 103 and 104. Aug. 3, 1951.

No. 3290. Studies of certain apogonid fishes from the Indo-Pacific with descriptions of three new species, by Ernest A. Lachner. Pp. 581–610, pls. 17–19. Dec. 18, 1951.

VOLUME 102

No. 3291. Contributions to the morphology and the taxonomy of the Branchiopoda Notostraca, with special reference to the North American species, by Folke Linder. Pp. 1–69, pls. 1–7, figs. 1–31. June 27, 1952.

No. 3292. A study of an intermediate snail host (*Thiara granifera*) of the Oriental lung fluke (*Paragonimus*), by R. Tucker Abbott. Pp. 71–116, pls. 8 and 9, figs. 32–45. Feb. 26, 1952.

No. 3293. Some marine asellote isopods from northern California, with descriptions of nine new species, by Robert J. Menzies. Pp. 117–159, figs. 46–71. May 29, 1952.

No. 3294. Australasian stilt-legged flies (Diptera: Tylidae) in the United States National Museum, by George C. Steyskal. Pp. 161–180, figs. 72–74. Feb. 26, 1952.

No. 3295. *Aphotaenius*, a new genus of dung beetle (Coleoptera: Scarabaeidae), by O. L. Cartwright. Pp. 181–184. Mar. 7, 1952.

No. 3296. Preliminary analysis of the vertebrate fossil fauna of the Boysen Reservoir area, by Theodore E. White. Pp. 185–207, figs. 75–80. Apr. 2, 1952.

No. 3297. A new crayfish from Alabama, with notes on *Procambarus lecontei* (Hagen), by Horton H. Hobbs, Jr. Pp. 209–219, figs. 81, 82. Mar. 27, 1952.

No. 3298. Moths of the genera *Mulona* Walker and *Lomuna*, a new and closely related genus (Arctiidae: Lithosiinae), by William D. Field. Pp. 221–230, pls. 10 and 11. Mar. 19, 1952.

No. 3299. A new species of commensal amphipod from a spiny lobster, by Clarence R. Shoemaker. Pp. 231–233, fig. 83. Mar. 27, 1952.

No. 3300. A new genus of Central American milliped (family Euryuridae), with notes on the American genera, by Richard L. Hoffman. Pp. 235–243, fig. 84. Apr. 24, 1952.

No. 3301. An emended diagnosis of the copepod genus *Pupulina* (Caligoida), with descriptions of new species and a redescription of the genotype, by Mildred Stratton Wilson. Pp. 245–263, pls. 12–15. Mar. 19, 1952.

No. 3302. Echinoderms from the Marshall Islands, by Austin H. Clark. Pp. 265–303. Mar. 27, 1952.

No. 3303. A new species of insect of the order Protura, by Grace Glance. Pp. 305–314, figs. 85 and 86. Apr. 25, 1952.

No. 3304. New American cynipid wasps from galls, by Lewis H. Weld. Pp. 315–342, pls. 16 and 17. Apr. 24, 1952.

No. 3305. Notes on mammals from the Nile Delta region of Egypt, by Henry W. Setzer. Pp. 343–369 Apr. 2, 1952.

No. 3307. *Schizostella*, a new genus of brittle-star (Gorgonocephalidae), by Austin H. Clark. Pp. 451–454, pl. 40. Mar. 19, 1952.

No. 3308. Moths of the genus *Epeiromulona*, a new genus of Lepidoptera, by William D. Field. Pp. 455–469, pls. 41–46. Apr. 25, 1952.

No. 3309. A review of the stink bugs of the genus *Mecidea*, by R. I. Sailer. Pp. 471–505, pls. 47 and 48, figs. 88 and 89. June 27, 1952.

No. 3310. Review of the fishes of the blennioid genus *Ecsenius*, with descriptions of five new species, by Wilbert M. Chapman and Leonard P. Schultz. Pp. 507–528, figs. 90–96. Apr. 24, 1952.

BULLETINS

201. The Mysidacea of the United States National Museum, by Walter M. Tattersall. Pp. i–x + 1–292, 103 figs. Oct. 4, 1951.

CONTRIBUTIONS FROM THE UNITED STATES NATIONAL HERBARIUM

VOLUME 30

Part 4. Studies of Pacific Island plants, X. The Meliaceae of Fiji, Samoa, and Tonga, by A. C. Smith. Pp. i–iii + 469–522. May 6, 1952.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

M. Helen Palmer, editor of the Bureau since 1939, retired on March 31, 1952, after nearly 34 years' service in the Institution. During the year the Bureau issued 1 Annual Report, 4 Bulletins, and 1 paper in the series Publications of the Institute of Social Anthropology, as follows:

ANNUAL REPORT

Sixty-eighth Annual Report of the Bureau of American Ethnology, 1950–51. ii + 40 pp. [Feb. 20] 1952.

BULLETINS

146. Chippewa child life and its cultural background, by Sister M. Inez Hilger. xiv + 204 pp., 31 pls., 1 fig. Dec. 21, 1951.
147. Journal of an expedition to the Mauvaises Terres and the Upper Missouri in 1850, by Thaddeus W. Culbertson. Edited by John Francis McDermott. viii+164 pp., 2 maps. Apr. 29, 1952.
148. Arapaho child life and its cultural background, by Sister M. Inez Hilger. xv+253 pp., 40 pls., 1 fig. June 26, 1952.
149. Symposium on local diversity in Iroquois culture. Edited by William N. Fenton. v+187 pp., 21 figs. Dec. 17, 1951.

PUBLICATIONS OF THE INSTITUTE OF SOCIAL ANTHROPOLOGY

No. 14. The Indian caste of Peru, 1795–1940: A population study based upon tax records and census reports, by George Kubler. vi+71 pp., 2 pls., 1 fig., 20 maps. June 18, 1952.

PUBLICATIONS OF THE NATIONAL COLLECTION OF FINE ARTS

The opening of the Adams-Clement Collection. 23 pp., 7 pls. (Publ. 4055.) November 1951.

PUBLICATIONS OF THE FREER GALLERY OF ART

OCCASIONAL PAPERS

VOLUME 1

Title page and table of contents. 3 pp. (Publ. 4049.) [July 23] 1951.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are by him communicated to Congress, as provided by the act of incorporation of the Association. The following report volume was issued this year:

Annual Report of the American Historical Association, 1950. Vol. 1, Proceedings. [Oct. 24] 1951.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Fifty-fourth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, on February 11, 1952.

APPROPRIATION FOR PRINTING AND BINDING

The year's printing and binding allotment from congressional appropriation was entirely obligated at the close of the year. The allotment for the coming fiscal year ending June 30, 1953, totals $92,320, divided as follows:

General administration (Annual Report of the Board of Regents, with Appendix; Annual Report of the Secretary)	$17,000
National Museum	34,945
Bureau of American Ethnology	12,000
Astrophysical Observatory	5,000
National Air Museum	500
Service divisions (Annual Report of the American Historical Association; blank forms; binding; print shop)	22,875
Total	92,320

Respectfully submitted.

PAUL H. OEHSER,
Chief, Editorial Division.

DR. A. WETMORE,
Secretary, Smithsonian Institution.

Report of the Executive Committee of the Board of Regents of the Smithsonian Institution

For the Year Ended June 30, 1952

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s. 6d.—$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, and other incidental expenses, together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of $550,000.

Since the original bequest, the Institution has received gifts from various sources, the income from which may be used for the general work of the Institution. These, including the original bequest, plus savings, are listed below, together with the income for the present year.

ENDOWMENT FUNDS

(Income for the unrestricted use of the Institution)

Partly deposited in the United States Treasury at 6 percent and partly invested in stocks, bonds, and other holdings

Fund	Investment	Income present year
Parent fund (original Smithson bequest, plus accumulated savings)	$728,924.14	$43,722.58
Subsequent bequests, gifts, and other funds, partly deposited in the U. S. Treasury and partly invested in the consolidated fund:		
Avery, Robert S. and Lydia, bequest fund	55,548.78	2,920.40
Endowment fund	371,778.10	18,383.27
Habel, Dr. S., bequest fund	600.00	30.00
Hachenberg, George P. and Caroline, bequest fund	4,230.45	211.46
Hamilton, James, bequest fund	2,924.62	171.22
Henry, Caroline, bequest fund	1,272.20	63.60
Hodgkins, Thomas G. (general gift)	147,864.18	8,547.26
Porter, Henry Kirke, memorial fund	301,253.66	15,058.94
Rhees, William Jones, bequest fund	1,087.61	60.26
Sanford, George H., memorial fund	2,036.41	112.79
Witherspoon, Thomas A., memorial fund	135,746.21	6,784.73
Special fund		92.00
Total	1,024,242.20	52,433.93
Grand total	1,753,166.34	96,156.51

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These, plus accretions to date, are listed below, together with income for the present year.

Fund	Investment	Income present year
Abbott, William L., fund, for investigations in biology	$110,163.98	$5,434.88
Arthur, James, fund for investigations and study of the sun and annual lecture on same	42,068.52	2,102.63
Bacon, Virginia Purdy, fund, for traveling scholarship to investigate fauna of countries other than the United States	52,700.44	2,633.99
Baird, Lucy H., fund, for creating a memorial to Secretary Baird	25,326.11	1,265.82
Barney, Alice Pike, memorial fund, for collecting of paintings and pastels and for encouragement of American artistic endeavor	20,426.28	854.34
Barstow, Frederick D., fund, for purchase of animals for Zoological Park	1,051.66	52.58
Canfield Collection fund, for increase and care of the Canfield collection of minerals	40,231.62	2,010.74
Casey, Thomas L., fund, for maintenance of the Casey collection and promotion of researches relating to Coleoptera	13,184.81	554.83
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks	29,621.70	1,480.51
Dykes, Charles, bequest fund, for support in financial research	45,293.53	1,894.10
Eickemeyer, Florence Brevoort, fund, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr	11,433.77	564.01
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects	6,913.21	345.53
Hitchcock, Albert S., library fund, for care of the Hitchcock Agrostological Library	1,659.80	82.97
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air	100,000.00	6,000.00
Hrdlička, Aleš and Marie, fund, to further researches in physical anthropology and publication in connection therewith	31,758.78	1,512.29
Hughes, Bruce, fund, to found Hughes alcove	20,134.51	1,006.35
Long, Annette and Edith C., fund, for upkeep and preservation of Long collection of embroideries, laces, and textiles	571.16	28.55
Maxwell, Mary E., fund, for care and exhibition of Maxwell collection	20,632.28	1,031.20
Myer, Catherine Walden, fund, for purchase of first-class works of art for use and benefit of the National Collection of Fine Arts	19,939.31	996.61
Noyes, Frank B., fund, for use in connection with the collection of dolls placed in the U. S. National Museum through the interest of Mr. and Mrs. Noyes	1,010.59	21.37
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection	7,797.08	389.71
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to $250,000	143,387.14	7,081.80
Rathbun, Richard, memorial fund, for use of division of U. S. National Museum containing Crustacea	11,187.84	559.19
Reid, Addison T., fund, for founding chair in biology, in memory of Asher Tunis	30,807.63	1,650.11
Roebling Collection fund, for care, improvement, and increase of Roebling collection of minerals	126,950.45	6,345.11
Rollins, Miriam and William, fund, for investigations in physics and chemistry	98,769.57	4,936.61
Smithsonian employees' retirement fund	30,151.84	1,592.24
Springer, Frank, fund, for care and increase of the Springer collection and library	18,863.34	942.80
Strong, Julia D., bequest fund, for benefit of the National Collection of Fine Arts	10,517.25	525.67
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof	421,512.60	19,955.16
Walcott, Mary Vaux, fund for publications in botany	60,888.72	1,793.75
Younger, Helen Walcott, fund, held in trust	58,796.92	1,966.00
Zerbee, Frances Brincklé, fund, for endowment of aquaria	997.77	49.87
Total	1,614,750.21	77,661.32

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of $1,958,591.42, as an endowment fund for the operation of the Gallery.

The above fund of Mr. Freer was almost entirely represented by 20,465 shares of stock in Parke, Davis & Co. As this stock advanced in value, much of it was sold and the proceeds reinvested so that the fund now amounts to $6,752,796.55 in selected securities.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes	$1, 753, 166. 34
Invested endowment for specific purposes other than Freer endowment	1, 614, 750. 21
Total invested endowment other than Freer endowment	3, 367, 916. 55
Freer invested endowment for specific purposes	6, 752, 796. 55
Total invested endowment for all purposes	10, 120, 713. 10

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the U. S. Revised Statutes, sec. 5591		$1, 000, 000. 00
Investments other than Freer endowment (cost or market value at date acquired):		
Bonds	$677, 763. 74	
Stocks	1, 566, 862. 25	
Real estate and first-mortgage notes	13, 610. 03	
Uninvested capital	109, 680. 53	
		2, 367, 916. 55
Total investments other than Freer endowment		3, 367, 916. 55
Investments of Freer endowment (cost or market value at date acquired):		
Bonds	$3, 682, 580. 68	
Stocks	3, 070, 009. 40	
Uninvested capital	206. 47	
		6, 752, 796. 55
Total investments		10, 120, 713. 10

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1952[1]

Cash balance on hand June 30, 1951		$536, 209. 02
Receipts, other than Freer endowment:		
Income from investments	$182, 036. 91	
Royalties on sale of publications	11, 183. 45	
Gifts and contributions	137, 938. 19	
Sales of publications	39, 082. 13	
Miscellaneous	15, 653. 73	
Proceeds from real-estate holdings	1, 458. 44	
Proceeds from other stocks and bonds (net)	62, 600. 71	
Payroll withholdings and refunds of advances (net)	1, 650. 18	
Total receipts other than Freer endowment		451, 603. 74
Receipts from Freer endowment:		
Interest and dividends	$299, 451. 42	
Total receipts from Feer endowment		299, 451. 42
Total		1, 287, 264. 18
Disbursements other than Freer endowment:		
Administration	$78, 482. 08	
Publications	54, 862. 42	
Library	615. 78	
Custodian fees and servicing securities	3, 141. 93	
Miscellaneous	4, 611. 95	
Researches	113, 942. 68	
S. I. Retirement System	3, 284. 76	
U. S. Government and other contracts (net)	4, 925. 34	
Purchase and sale of securities (net)	122, 054. 29	
Total disbursements other than Freer endowment		385, 921. 23
Disbursements from Freer endowment:		
Salaries	$106, 307. 29	
Purchases for collections	153, 457. 19	
Custodian fees and servicing securities	10, 962. 54	
Miscellaneous	22, 493. 26	
Purchase and sale of securities (net)	97, 058. 88	
Total disbursements from Freer endowment		390, 279. 16
Total disbursements		776, 200. 39
Cash balance June 30, 1952		511, 063. 79
Total		1, 287, 264. 18

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

ASSETS

Cash:			
United States Treasury current account	$299,379.74		
In banks and on hand	211,688.05		
	511,063.79		
Less uninvested endowment funds	109,887.00		
		$401,176.79	
Travel and other advances		15,724.39	
Cash invested (U. S. Treasury notes)		600,778.01	
			$1,017,679.19
Investments—at book value:			
Endowment funds:			
Freer Gallery of Art:			
Stocks and bonds	$6,752,590.08		
Uninvested capital	206.47		
		6,752,796.55	
Investments at book value other than Freer:			
Stocks and bonds	$2,244,625.99		
Real-estate and mortgage notes	13,610.03		
Uninvested capital	109,680.53		
Special deposit in U. S. Treasury at 6 percent interest	1,000,000.00		
		3,367,916.55	
			10,120,713.10
			11,138,392.29

UNEXPENDED FUNDS AND ENDOWMENTS

Unexpended funds:			
Income from Freer Gallery of Art endowment			$421,279.02
Income from other endowments:			
Restricted		$237,044.08	
General		111,490.84	
			348,534.92
Gifts and grants			247,865.25
			1,017,679.19
Endowment funds:			
Freer Gallery of Art		$6,752,796.55	
Other:			
Restricted	$1,614,750.21		
General	1,753,166.34		
		3,367,916.55	
			10,120,713.10
			11,138,392.29

The practice of maintaining savings accounts in several of the Washington banks and trust companies has been continued during the past year, and interest on these deposits amounted to $822.31.

In many instances, deposits are made in banks for convenience in collection of checks, and later such funds are withdrawn and deposited in the United States Treasury. Disbursement of funds is made by check signed by the Secretary of the Institution and drawn on the United States Treasury.

The foregoing report relates only to the private funds of the Institution.

The Institution gratefully acknowledges gifts from the following:

Laura D. Barney, additional funds for the Alice Pike Barney collection of paintings and pastels, etc.

Laura Welsh Casey Estate, for addition to the Thomas Lincoln Casey fund.

Charles Dykes Estate, for use in financial research.

Joint Committee on Invertebrate Paleontology, through Raymond C. Moore, for illustrations fund for Foraminifera.

E. R. Fenimore Johnson, additional funds for researches in underwater photography.

E. A. Link, Link Aviation Corporation, for field expenses in historical research (marine archeology).

Frank B. Noyes Estate, for use in connection with the collection of dolls placed in the U. S. National Museum through the interest of Mr. and Mrs. Noyes.

Wenner-Gren Foundation, for Graham publication fund.

Wenner-Gren Foundation, for work on the archeology of Mexico.

Wenner-Gren Foundation, for anthropological research.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1952:

Salaries and expenses	$2,553,200.00
National Zoological Park	620,800.00

In addition, funds were transferred from other departments of the Government for expenditure under the direction of the Smithsonian Institution as follows:

International Information and Educational Activities (transferred to the Smithsonian Institution from the State Department)	$42,000.00
Working Fund (transferred to the Smithsonian Institution by the Institute of Inter-American Affairs)	45,705.00
Working Funds, transferred from the National Park Service, Interior Department, for archeological investigations in river basins throughout the United States	157,803.00

The Institution also administers a trust fund for partial support of the Canal Zone Biological Area, located on Barro Colorado Island in the Canal Zone.

The report of the audit of the Smithsonian private funds follows:

WASHINGTON, D. C., *September 9, 1952*

TO THE BOARD OF REGENTS,
SMITHSONIAN INSTITUTION,
Washington 25, D. C.:

We have examined the accounts of the Smithsonian Institution relative to its private endowment funds and gifts (but excluding the National Gallery of Art and other departments, bureaus or operations administered by the Institution under Federal appropriations) for the year ended June 30, 1952. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

The Institution maintains its accounts on a cash basis and does not accrue income and expenses. Land, buildings, furniture, equipment, works of art, living and other specimens and certain sundry property are not included in the accounts of the Institution.

In our opinion, the accompanying financial statements present fairly the position of the private funds and the cash and investments thereof of the Smithsonian Institution at June 30, 1952 (excluding the National Gallery of Art and other departments, bureaus or operations administered by the Institution under Federal appropriations), and the cash receipts and disbursements for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

PEAT, MARWICK, MITCHELL & CO.

Respectfully submitted.

ROBERT V. FLEMING,
VANNEVAR BUSH,
CLARENCE CANNON,
Executive Committee.

GENERAL APPENDIX

to the

SMITHSONIAN REPORT FOR 1952

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 staff members and collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report of 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 1952.

Reprints of the various papers in the General Appendix may be obtained, as long as the supply lasts, on request addressed to the Division of Publications, Smithsonian Institution, Washington 25, D. C.

Radio Astronomy[1]

By J. A. Ratcliffe
Cavendish Laboratory, Cambridge, England

Our knowledge of astronomical bodies is almost entirely derived from observations of the electromagnetic waves which they emit. The earth's atmosphere forms a very complete absorbing blanket for most of these radiations; but there are two "windows" in the atmosphere, one in the region of optical wavelengths and one in the region of short radio wavelengths. Radio astronomy deals with the study of those radiations which reach the earth from outer space and are transmitted through the radiofrequency "window" to the surface of the earth.

If the radiation is received on a tuned radio receiver, it is found that it fluctuates rapidly in an irregular manner, and if the resulting signal is listened to with telephones it sounds like a rushing noise. The reception and amplification of weak irregular noise in a radio receiver present a difficult problem, because the resistances and valves in the amplifier themselves produce similar random noise. The separation of the received noise from the amplifier noise is usually achieved by switching the amplifier rapidly back and forth between the aerial and a controlled source of radio noise. If the noise produced by the controlled source is not the same as that produced in the aerial, there will be a fluctuating component in the output. This may be recorded, and it provides a measure of the noise received by the aerial.

Once it has been established that radiofrequency waves are incident on the earth from outside, it is, of course, desirable to use some kind of "radio telescope" to find their direction of arrival. The simplest type of radio telescope consists of a concave mirror with a receiving aerial at its focus and is similar to an optical reflecting telescope. The accuracy with which the direction of arrival of waves can be determined with any apparatus of this kind is, however, limited by the ratio between the width of the mirror and the wavelength of the

[1] Substance of a Friday Evening Discourse at the Royal Institution (Great Britain) delivered on November 23, 1951. Reprinted by permission from Nature, vol. 169, March 1, 1952.

waves used. The wavelength of radio waves is so much greater than that of light waves that it would require an aerial 150 miles wide to give the same angular accuracy as an optical telescope with a lens 1 inch wide. It is obvious that, with radio telescopes, we cannot hope to approach the accuracies which are possible with waves of light; but in an attempt to get the best possible accuracy large mirrors have been constructed. One of the largest, used by the workers at Manchester, has an aperture of about 220 feet and is used on a wavelength of 1.9 m. It is interesting to notice that, if our eyes could observe angles with only the same limited accuracy as the mirror, the sun would not appear as a clear disk in the sky, but it would look like a diffuse blur about twice its present size. All the stars in the sky would appear this same size, so that we should simply see a general diffuse radiation corresponding to the overlapping of all their blurred images. Where there was a particularly bright star there would appear to be a diffuse bright patch of this same size.

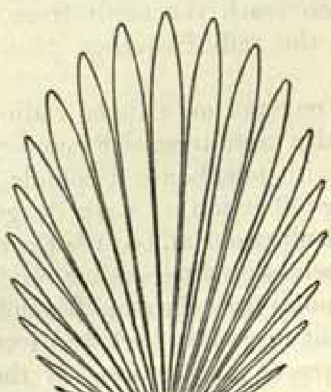

FIGURE 1.—Receptivity diagram of aerial arrays used in radio astronomy. From Proc. Roy. Soc., A, vol. 193, 1948.

Large mirrors are costly and difficult to construct accurately, and there is a physical limitation to their size. It has long been appreciated in optical astronomy that in principle it is not necessary to use the whole of the mirror to achieve the full angular accuracy and that only the portions at the edge are required. This principle has been applied in the following way in radio astronomy. Two aerial arrays are used, separated by as great a distance as possible in the east-west direction. The two arrays are connected to a single receiver at the midpoint, and the combination then has different receiving powers in different directions. The receptivity diagram has the form represented in figure 1, in which maxima alternate with minima. When the earth rotates, the reception pattern is carried around with it, so

that an astronomical source of radiation which subtends a very small angle would be received with periodically increasing and decreasing intensity. If the source subtends an angle comparable with the angle between two maxima, then it will always overlap one or other of them and the response will not vary much. If there is a small concentrated source, superposed on a general background of diffuse radiation, it will produce an oscillating trace, whereas the diffuse radiation will produce a steady trace. Figure 2 shows the type of record obtained in practice. It indicates the presence of a general background of diffuse radiation the intensity of which varies with time as the different parts of the sky come under observation, with two strong isolated sources which produce the two oscillating traces at times when the receptivity diagram is swept past them by the movement of the earth.

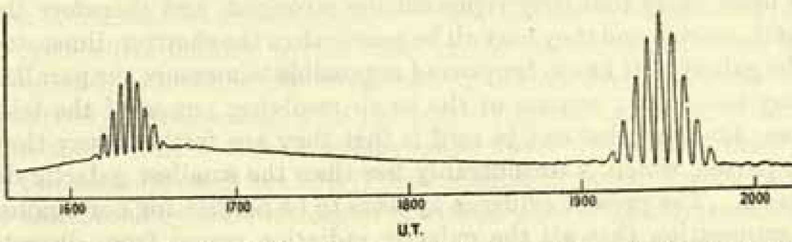

FIGURE 2.—Record of two isolated sources of radiation against a background of diffuse radiation. From Ryle, M., Reports on Progress in Physics, vol. 13, 1950.

We now turn to examine some of the results which have been obtained by the observation of astronomical sources. Records of the type shown in figure 2 have indicated the existence of a large number of discrete sources of radiation distributed throughout the sky and have enabled their positions to be fixed within the angular accuracy appropriate to the apparatus used.

The discrete sources of radiation which have been detected in this way have been called radio stars. Their intensities cover a wide range and the strongest are so intense that at a wavelength of 5 m. two are stronger than the sun. It is interesting to inquire whether the radio stars are, in fact, also visible stars, but in asking this question we must remember that, on account of the limited angular accuracy of the radio telescopes, it is not possible to locate the radio stars as accurately as the visible one. Within the limits of $\pm\frac{1}{4}$ minute of arc, to which any radio star can be located, there are always a large number of visible stars. It seems clear, however, that the most intense radio stars do not coincide with the most intense visible stars, and that no visible star of magnitude greater than 12 lies in the region ascribed to any one of the four strongest radio stars. It appears that the intensity of radio stars is not related simply to the intensity of the light which they emit.

In addition to the radio stars, there is also a general background of radiation which cannot be resolved into discrete sources. The distribution of intensity in this unresolved background is found to follow closely the contours of the galaxy as determined from star maps. It appears that the disklike assembly of visible stars which forms our galaxy has associated with it sources of radio radiation which are also distributed throughout this disk, so that we receive most radiations from its plane, just as we see the Milky Way as a concentration of stars in this plane.

The question now arises whether the galactic radiation is, in fact, smoothly distributed over the galaxy or whether it is the sum of radiations from innumerable radio stars which have not yet been resolved. The fact that the discrete sources so far discovered are distributed roughly evenly in all directions is not significant, because it is most likely that they represent the strongest, and therefore the nearest, sources and they may all be nearer than the shortest dimension of the galaxy. It has so far proved impossible to measure the parallax of any radio star, because of the small resolving power of the telescopes; the most that can be said is that they are farther away than 1/20 parsec, which is considerably less than the smallest galactic dimension. The present evidence appears to be neither for nor against the supposition that all the galactic radiation comes from discrete radio stars which are at present unresolved.

The fact that the radiation comes from the galactic plane, and hence probably from sources throughout the galaxy, suggests that our galaxy is probably also radiating outward into space. If this were so, we might expect other galaxies to send some measurable radiation to us. It has, in fact, been found that four very distant galaxies, presumably similar to our own, fall within the somewhat inaccurate directions found for four of the radio stars.

We now turn to consider the radio radiation received from the sun. It is found that when the sun is not appreciably disturbed by the presence of sunspots, the intensity varies with the wavelength of the radiation. This fact has an important theoretical significance which will be discussed later. The distribution of emission across the quiet solar disk has also been determined on several wavelengths, and it is found that the "radio" sun is somewhat larger than the "optical" sun and that, unlike the optical radiation, the radiation falls off gradually near the edge.

When the sun is known, from optical observation, to be disturbed, the radio radiation is often considerably enhanced. The enhanced radiation is very variable, and sometimes sudden bursts of radiation are associated with solar flares. Experiments with special aerials have shown that the sources of enhanced radiation coincide fairly accurately with visible sunspots.

Now let us inquire how these facts can be explained. We first consider the radiation from the undisturbed sun, and note that it has all the characteristics of the light which would be radiated in the complete spectrum of electromagnetic waves from a hot body. The radiation from a body at a high temperature would include an appreciable amount of energy in the region of radio wavelengths, and if this radio radiation were really a part of the continuous spectrum it would have the characteristics of noise which are observed in the solar radiation. If we assume that the radiation comes from an area slightly larger than the solar disk (as shown by experiment) we can use the observed intensity of the radiation to calculate the temperature of the region from which it originates. When this calculation is performed, it is found that the equivalent solar temperature is about one million degrees, which is greater than that (6000° K.) deduced from observation of the visible light from the sun. Now the solar corona is supposed to have a temperature of the order of one million degrees and to be completely ionized, so that it consists of free electrons colliding, comparatively infrequently, with the positive nuclei of atoms. Calculation shows that it would radiate radio waves of the kind observed. If this assumption is made, it is then possible to extend our knowledge of the corona by observations of the radio waves. It is interesting to note that because the corona extends considerably beyond the visible disk of the sun we should expect the "radio sun" to be larger than the visible one, as is, in fact, found.

After having said that there is a reasonably good theory for the emission of radio waves from the quiet sun, we now have to admit that there is no correspondingly simple explanation of the enhanced radiation from sunspots.

When we turn to consider the galactic radiation also, it cannot be said that any firm theory has yet been proposed. It is first natural to ask whether a series of bodies like the sun, distributed throughout the galaxy, could produce the observed radiation. In this connection we note that, if all the visible stars emitted radio waves like the quiet sun, the total radiation would only be about 10^{-8} of that observed from the galaxy. If they all emitted like the sun when it is most disturbed, the total radiation would still fall short by a factor of about 10^{-2}. But the great constancy of the radiation from each of the 50 or so radio stars so far observed makes it seem unlikely that they emit by any mechanism corresponding to that which occurs on the disturbed sun. If we assume that the strongest observed radio star (that in the constellation of Cassiopeia) is at the distance of the nearest visible star, and that the total number and distribution of radio stars and of visible stars are the same, then we could account for the total radiation from the galaxy. If it is supposed that the whole of the galactic radia-

tion cannot be accounted for by radiation from discrete radio stars, then it is necessary to postulate radiation from the interstellar matter. Although the possibility of this has been considered in some detail, it cannot be said that any theory which would explain the observed intensity has yet been advanced.

When we seek a mechanism to explain the radiation from the observed discrete radio stars, we first notice that they differ from the sun in that they radiate comparatively much more strongly in the radio frequencies than in the visible part of the spectrum, as if they had photospheres which are much cooler than the sun and coronas which are much hotter. But no detailed theory has yet been accepted to explain them.

It appears likely that, in the immediate future, experimental radio astronomers will concentrate their attention on devices for achieving increased angular accuracy, in an attempt to observe more radio stars and, if possible, to measure their parallaxes and angular sizes. A search for the emission of characteristic "line" spectra from the galaxy and from the sun will also probably be carried out, particularly in view of the most interesting recent discovery that waves of length 21 cm. can be observed, owing to hydrogen, in certain directions in the galaxy. On the theoretical side, attention will probably be directed toward theories to explain the radiation from sunspots and from radio stars.

Reprints of the various articles in this Report may be obtained, as long as the supply lasts, on request addressed to the Division of Publications, Smithsonian Institution, Washington 25, D. C.

The Sun, the Moon, and the Tides[1]

By Rear Admiral Leo Otis Colbert

U. S. Coast and Geodetic Survey (Retired)

Little or no mention is made in early recorded history of the rise and fall of the sea, which we call the tide. This lack of interest on the part of those writers and historians who lived along the shores of the Mediterranean was due to the small tidal changes which occur there. The earliest reference appears in the writings of Herodotus, the Greek historian, who wrote of the voyages of early navigators. In a description of the Arabian coast he mentions an arm of the sea in which "every day the tide ebbs and flows." A century and a half later Pytheas of Massilia wrote of the tidal movement and noted that there was a relationship between the tide and the moon. Pytheas had gained his information because he was one of the few who had ventured out of the Straits of Gibraltar into the open ocean. He had sailed to the shores of Britain, where the ebb and flow of the sea is much more noticeable.

In the first century of the Christian Era the tides are ascribed definitely to the action of the sun and moon. In his Natural History, Pliny describes some of the principal phenomena of the tides, but knowledge of how the sun and moon provided the force necessary to influence the tides was not developed until many centuries later. In 1687, Sir Isaac Newton stated that the tides were a necessary consequence of the law of gravitation. He simplified the problem by supposing the sea to cover the whole earth with a layer of water of considerable depth. By mathematical formula he showed that the relative masses and positions of the sun, moon, and earth could produce a regular movement in the overlying water.

Under the stated circumstance, the mathematicians assure us that the tides would be uniform. At any place, the time of the moon's passage of the local meridian would mark the time of a high water. Six hours later a low water would occur. The greatest range in the tides would occur at the Equator and the least difference between high and low waters would be at the Poles. The character of the tide at any place would depend upon the distance from the Equator—in

[1] Nineteenth James Arthur lecture, given under the auspices of the Smithsonian Institution on April 8, 1952.

other words, the character of the tide would depend upon the latitude of the place.

Newton had proved that it was the attracting forces of the sun and moon, with differing effects upon the solid earth and the waters of the oceans, which gave rise to the tides. Further development of this theory and of the problem of the tide has been the work of many eminent mathematicians, including Bernoulli, Euler, Laplace, Airy, Lord Kelvin, Poincaré, and others in Europe; and in the United States, Ferrel and Harris.

TIDES AT VARIOUS PLACES

Knowledge of tidal causes and conditions becomes important when they affect navigation, commerce, and the lives of people who live close to the sea. Most of the great ports of the world are situated on tidal waters, and the state of the tide is an important feature. The schedules of ocean liners and of large modern steamers can usually be arranged to take advantage of the more favorable conditions of the tide and tidal current for entering ports and docking in congested harbors.

It is frequently necessary for a steamer to traverse many miles of tidal waterways. For example, we may cite the Inland Passage to Alaska where there is a considerable fluctuation in the rise and fall of the tide. Except for the entrances into the main inlets and sounds, numerous islands restrict the inside route. The navigator must know the state of the tide at critical places along his course. Shoal water in a strait between two main inlets, which would be hazardous at low tide, could be navigated without danger at a higher stage.

As a member of the United States Coast and Geodetic Survey field party on board the ship *MacArthur*, which made the original hydrographic surveys of Cook Inlet, Alaska, I recall our difficulties in erecting tide staffs to measure the great range of the tides in the vicinity of the present city of Anchorage. At that time there were no piers or other structures to which the staffs could be secured. Mud flats extended offshore for several miles from the high-water mark. A series of staffs were erected across these flats, and an observer, stationed in a small boat, recorded the tide as it rose or fell on successive staffs. Near this location, our record measurement was a 35-foot difference in height between high and low water.

The need for information on tidal conditions in our coastal waters became apparent toward the close of the last century when systematic hydrographic surveys were inaugurated in pioneer regions and in some rapidly growing seaports. This need brought about the development of the automatic tide gage and of improved mathematical equipment for analyzing tidal observations. With such gages installed at strategic tidal locations, we have been able to accumulate much infor-

mation, in recent years, on the behavior of the tide at various seaports and along the open coast.

When a tide gage is operated through a full month, there is traced on a continuous roll of paper a line showing the rise and fall of the tide for that period. Observations are usually continued month after month, and, at basic stations, year after year. From the curve traced on the tide-gage record, there can be obtained the times of high and low water, the heights, the range of tide, and the height of water at any intermediate time between high and low water. Studies of the tide curves at various ports have disclosed differences in time, range, and characteristics. We have learned of varieties in the tides which occur because different water areas react to the same tide-producing forces in different ways.

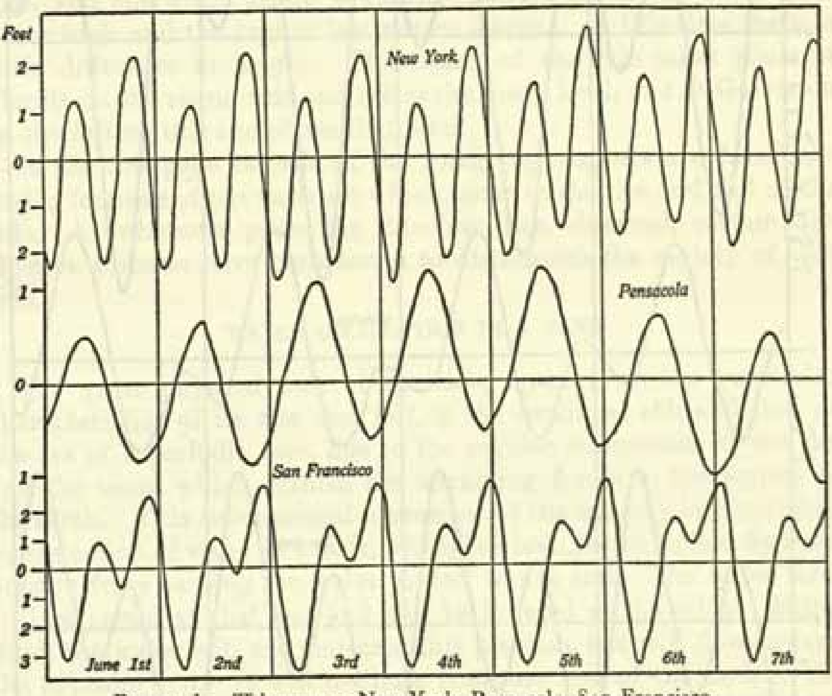

FIGURE 1.—Tide curves, New York, Pensacola, San Francisco.

Let us look at the tide curves of some of our coastal seaports and note the differences exhibited. Figure 1 shows the actual curves, recorded on automatic tide gages, of the rise and fall of the tide on the same day at New York, Pensacola, and San Francisco—that is, for a seaport along the Atlantic, the Gulf, and the Pacific coasts. At each port, the central horizontal line represents the mean level of the sea, above and below which the water has risen or fallen in the amounts shown in feet to the left. At New York there are two high and two low waters in a period of a day; the morning and evening tides do not differ much and the tide has risen above the mean level of the

sea about as much as it has fallen below that level. At Pensacola the tide has risen and fallen only once each day, and it is generally equally above and below the mean level. At San Francisco there are two highs and two lows each day, but there is a difference between the two high waters and between the two low waters.

The characteristic features of these tides are repeated throughout the year, and are the normal characteristics of these three seaports.

Typical tide curves at Seattle, Honolulu, and San Diego are shown in figure 2. At each of these ports, there are two high and two low

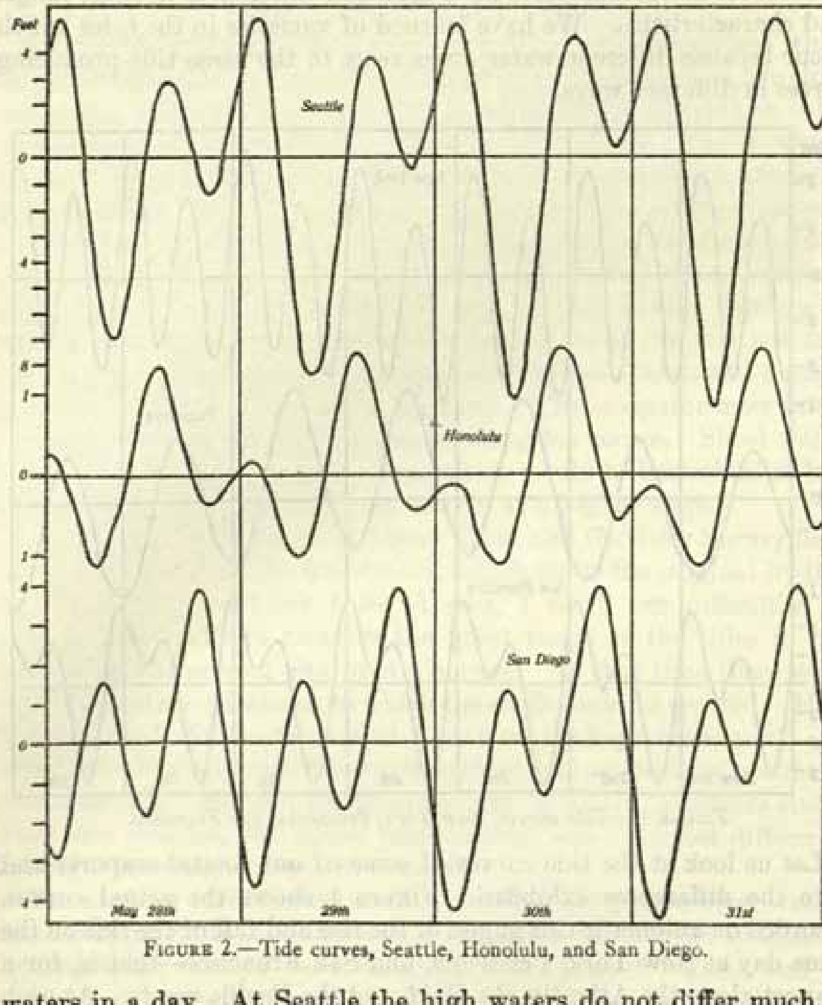

FIGURE 2.—Tide curves, Seattle, Honolulu, and San Diego.

waters in a day. At Seattle the high waters do not differ much in height, but the low waters exhibit a marked difference. Note that on the last day, the difference in height of successive low waters is 10½ feet. At Honolulu the curve shows that the difference in height of the high waters is more marked than for the low waters. If we

compare the characteristics of the tides of these two ports, we note that at Seattle a lower low water is followed by a lower high water, and a higher low is followed by a higher high. At Honolulu, a lower high is followed by a lower low and a higher high is followed by a higher low.

At San Diego there is a further contrast to each of the other two ports. Here both the high and low waters of a day differ considerably from each other, and the difference between successive high waters about equals that between successive low waters.

There is another variety of tide for which we may refer to tidal observations made at Galveston, Tex., and, halfway around the world, at Manila in the Philippine Islands for the same 4 days. At both ports two high and two low waters each day gradually shift to one high and one low. There is usually a stand of the tide when the lower high and the higher low waters merge. At this time there is little difference in height. This stand of the tide takes place at Manila on the rising tide and below the mean level, and at Galveston on the falling tide and above that level.

In the tide-gage records of the foregoing seaports are found the major features of the varieties which occur in the rise and fall of the tide. At whatever place the tide has been observed, certain distinctive features have been found to distinguish the variety of that tide.

WATER OSCILLATION IN A TANK

The great physical fact of the tide, apart from the particular characteristics of its rise and fall, is the continual ebb and flow of the sea at a periodic rate, due to the regular movements of the sun and the moon which furnish the attracting forces to the waters of the earth. This fundamental movement of the sea may be illustrated by the action of water in a tank, which has been put in motion by some outside force causing the water to flow to one end. The water level will be raised at that end and will be lowered at the other. Being fluid, the water will not maintain this position, but will flow toward the opposite end. It will oscillate from one end of the tank to the other, the period of oscillation depending upon the length of the tank and the depth of the water. The movement of the water will follow what is known as a stationary wave motion. The greatest change in water level will occur at the ends of the tank, but across the middle there will be no change. This line of no change, or axis, is the "nodal line" of the tank.

If the movement of water occurred in two tanks placed end to end to form two sections of a combined tank, and the partitions between the two were removed, the water would oscillate or swash about two axes or nodal lines in the combined tank. There would now be three

locations of high water and of low water, at the middle and at the ends of the combined tank. It is evident that a further combination of different tanks into one irregular-shaped basin would support a stationary wave motion in sections and that there might be three or more nodal lines. The water would come to rest eventually unless the movement were continued by the original external force which put it in motion. We know that when the force is continued to be applied with the rhythm of the period of movement of the stationary wave in that particular basin, the water will continue to oscillate.

TIDE-PRODUCING FORCES

In nature, the external force is astronomic. Tides are caused by the attractions of the sun and the moon. The tide-producing forces are the result of the difference in effects of the attraction of these heavenly bodies on the waters of the sea and on the solid earth. The tide-producing forces vary directly as the mass and inversely as the cube of the distances of the heavenly bodies from the earth. Although the mass of the sun is many times that of the moon, the inverse effect of the cube of the vast distance to the sun, as compared with the nearness of the moon to the earth, reduces the effect of the sun's tide-producing force to less than one-half that of the moon.

It is evident, under Newton's law, that the gravitational pull of the earth mass would overcome any vertical pull of the sun and moon which would tend to lift the sea directly below; but owing to the great mobility of water, it is equally obvious that horizontal movement could be induced into a body of sea water by the pulling force of these rotating bodies. It is the horizontal component of the combined attractive forces of the sun and moon that sets in motion the waters of the ocean basins and gives rise to tidal movement.

Dr. Rollin A. Harris, a tidal scientist of the United States Coast and Geodetic Survey, proposed the stationary-wave theory for the tidal movement and delineated various ocean basins that should properly respond to the tide-producing forces to maintain oscillating systems. Dr. Harris developed his tidal theory mathematically in 1900. A study of tide observations at numerous places along the seacoasts of the world has proved the correctness of Dr. Harris's theory and, in a general way, the correctness of the marginal limits he had described.

OCEAN TIDAL BASINS

In most cases there are geographic land boundaries or submerged bottom features that determine the configuration of the various ocean tidal basins. The natural period of oscillation depends upon the shape of the basin and the mean depth of water. The period of

oscillation corresponds to the period of the principal tide-producing force. When the moon is the predominant force, this period is 12 hours and 25 minutes sun time or exactly 12 lunar hours.

There are two large basins in the Atlantic that respond to the action of the moon to produce the tides in that ocean. The larger of these extends across the North and South Atlantic Oceans with the eastern coasts of North America at one end and the Antarctic Ocean at the other end. The lateral limits in the open ocean may only be approximated, but in other areas natural geophysical features can be recognized. Such natural boundaries are the east coast of North America, including the islands and reefs extending from the Florida coast to the Windward Islands, the west coast of Africa from Portuguese Guinea to Liberia and from Cape Fria to the Cape of Good Hope. (See fig. 3.)

We may consider that this basin is made up of three sections, in order to follow the movement of the stationary wave. The oscillation that has been set up by the astronomic force will cause the water to rise to its highest level at the ends and at junctions of the sections, and there would be no change in water level across the axis or the nodal line of each section.

At the present time there are no means for measuring the tide in open ocean areas. Tides can be observed along the coasts and on the off-lying islands of the continents that encompass this basin. Referring to the eastern end of this Atlantic basin, the nodal line of this section touches the Windward Islands of the eastern Caribbean. At this location there should be little or no change in the tide. From tidal observations along the shores of these islands, we find this to be true.

If we proceed northwest along the shores of the West Indies to the coast of Georgia, we should find increased ranges in the tide. Tidal observations confirm this. For the coast of Puerto Rico, the rise and fall is 1 foot; for the Bahamas, 2 feet; and for the Georgia coast, 6 feet.

The period of oscillation of the water checks with the observed times of high water and low water along the various coasts of the continents of this main Atlantic basin. Twelve hours after the moon passed over the meridian of Greenwich, the oscillation of the water brought high water to the east coast of North America. Six lunar hours later there was low water along this coast.

The tides observed along other shores of the Atlantic Ocean are caused by the movement of water in a smaller basin, which consists of two sections with two nodal lines. Eight hours after the moon's transit of Greenwich, high water will occur on the coasts of Iceland, Greenland, and Labrador at one end of this basin and on the coast of South America, between Natal in Brazil and Trinidad.

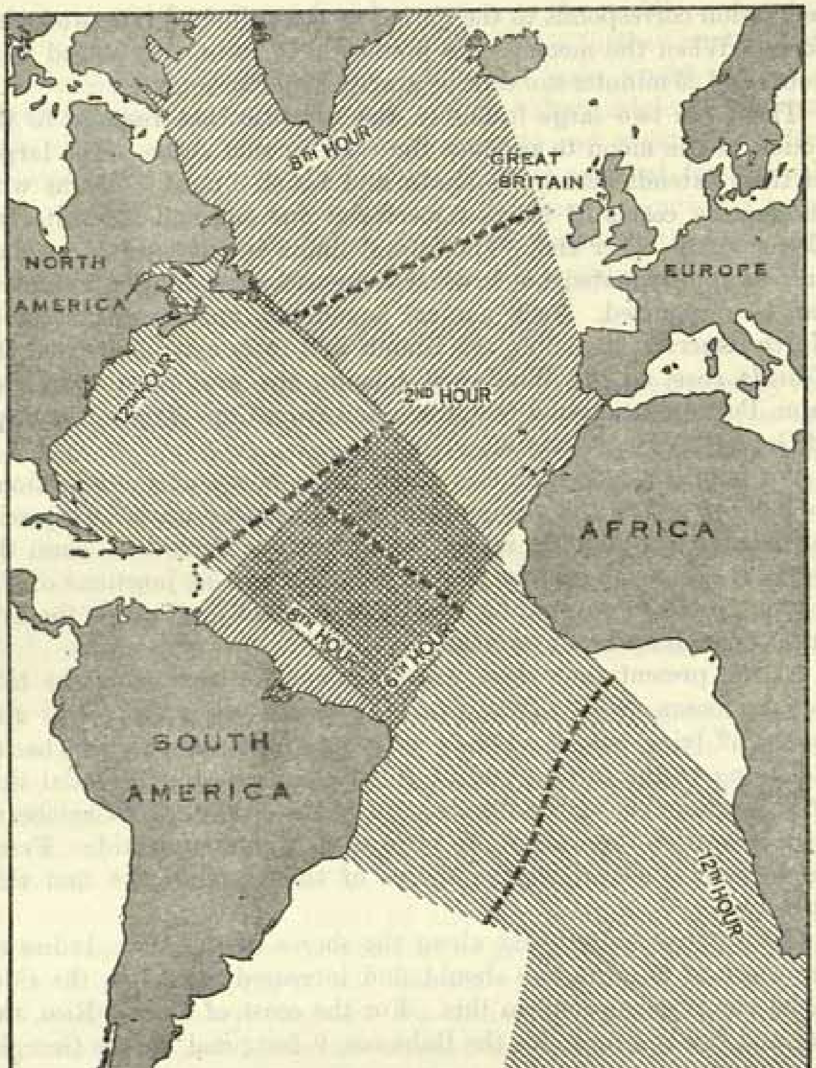

FIGURE 3.—Tidel basins in the Atlantic Ocean.

The waters of the Caribbean and the Gulf of Mexico are not included within either of the Atlantic basins. The area in which these waters lie is not of the proper length and depth to sustain the system of oscillation of those basins. These waters are separated from the larger basin by the islands and submerged reefs that extend from Florida to the northeast coast of South America. They respond to

a minor tide-producing force and there is a small daily rise and fall.

A tidal basin exists in the extreme western part of the Indian Ocean. Its geographical limits are well defined on one side and end by the east coast of Africa and the shore line of the Arabian Sea. The island of Madagascar lies along the middle of the other side. This basin is overlapped by two other basins which extend across the Indian Ocean from east to west (fig. 4). The southern of these is clearly defined at the ends by the coasts of Africa and Australia. The northern basin is bounded mainly by the south coast of the continent of Asia and the shore line of northwest Australia.

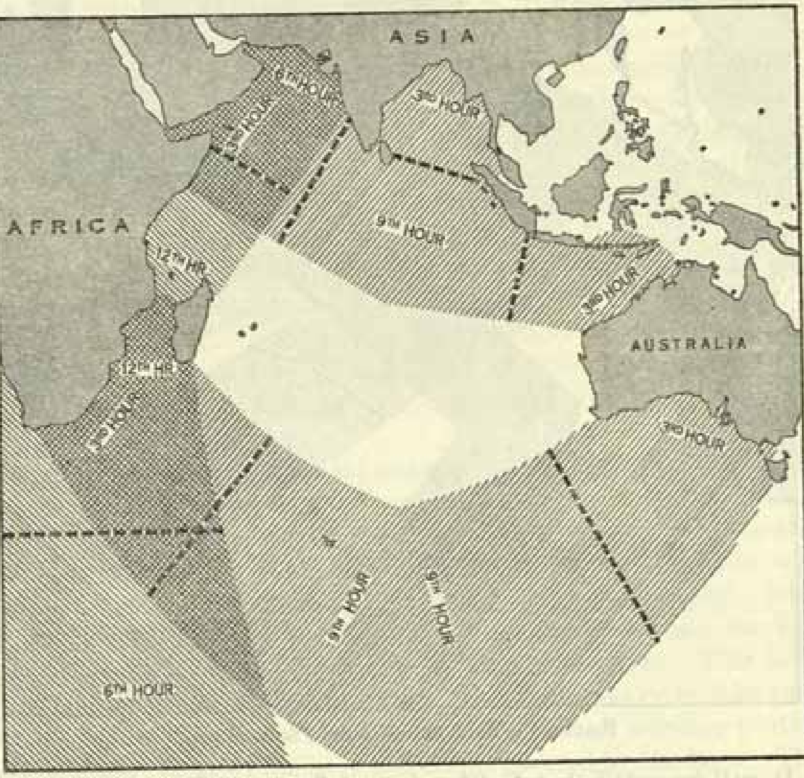

FIGURE 4.—Tidal basins in the Indian Ocean.

Where the east-west basins overlap the north-south basin in the western part of the Indian Ocean, high water comes halfway through the period of oscillation of the overlapping basins, one occurring at the third hour and the other at the sixth hour. The stationary wave of one basin will bring high water at the time when the water in the other has receded to sea level and neither the time nor range of the tide is influenced by the overlap.

High water occurs at the third hour along the shore line of the northern part of the Bay of Bengal, in sections of the coast of Aus-

tralia, and the southern tip of Africa. In the strait between Madagascar and the African coast the time of high water is 12 hours after the transit and low water occurs 6 hours later.

The ocean basins of the Pacific that definitely respond to the semidaily tide-producing forces of the moon are shown in figure 5. There is a major basin that covers most of the Pacific Ocean area. A narrow second basin crosses the major basin. It extends from the California coast to the Fiji Islands and New Zealand and thence to the southern tip of South America.

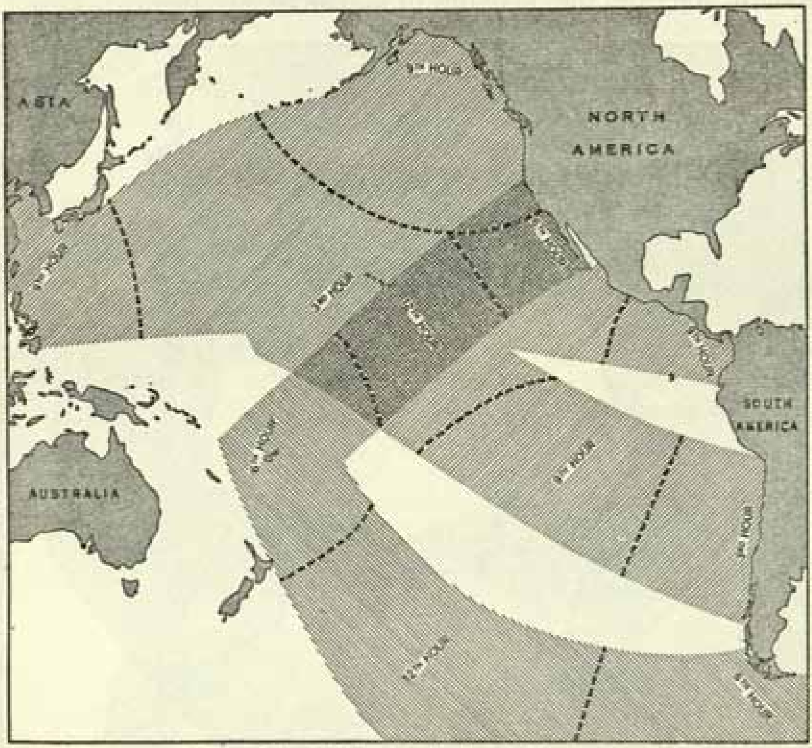

FIGURE 5.—Tidal basins in the Pacific Ocean.

It will be noted that California and Lower California in Mexico form a geographic end to this basin. The oscillation of the waters tends to increase the height of the tide at this location. High water occurs at the sixth hour after the moon's Greenwich passage.

In the major basin, high water occurs along the shore of the Gulf of Alaska on the ninth hour after the moon's Greenwich passage.

Long series of tidal observations on the open coast of off-lying islands have assisted in checking the geographical limits of the great Pacific tidal basin and of the location of the nodal lines. One of the latter touches the coast of Japan, at Aomori, where there is a small range of tide. There are small ranges, 1½ feet, nearAcapulco on the

coast of Mexico and less than 1 foot in the Caroline Islands near another nodal line.

It was noted previously that the tides were small in the Caribbean and in the Gulf of Mexico. At the Atlantic entrance to the Panama Canal, near Colón, there is a range of 1 foot. At Balboa, on the Pacific entrance, there is a considerable rise and fall, amounting to 12 to 16 feet. This large range is partly accounted for by the geographic location of this entrance at the end of a loop in the basin, where the highest level is reached by the oscillation of the waters.

In the vicinity of the Aleutian Islands, there is practically no semidaily tide. This archipelago, extending in an arc over 900 miles from the Alaskan Peninsula, separates this Pacific basin from the Bering Sea basin. The waters in each basin oscillate under different influences of the sun and moon. When differences in elevation are built up between the Pacific side and the Bering Sea side of these islands, the passes between them become what has been termed "spillways." Tidal heights in the passes are not great, but the currents are strong. Flood currents frequently flow for 18 hours at the rate of 4 knots. The ebb, flowing southerly, is of shorter duration but exceeds 6 knots, with velocities as high as 9 knots in some of the narrower and shoaler passes. Under these conditions, heavy tide rips occur. Some of these tide rips are 8 feet high and could seriously endanger a small ship.

In speaking of turbulent tidal waters, another type should be mentioned, namely the tidal bore. This is caused wherever the shore and bottom characteristics restrict the rise of the tide until a substantial difference in elevation is built up. Frequently a wall of water will advance across the shallow area at considerable initial velocity. During the survey of Cook Inlet, which I mentioned earlier, we had occasion to observe this tidal bore in Turnagain Arm. This bore could capsize or swamp a small boat. It was necessary to take precautions before the turn of the tide to insure that all working parties and boats were clear of the flats and shoals covered by the bore. The tidal bore in the Bay of Fundy is well known.

COTIDAL LINES

In speaking of the principal tidal basins in the oceans, mention was made of some of the locations where high water occurred at the height of the semidaily movement of the stationary wave, induced by the oscillation of the waters in various sections. The times of high water were related to periods following the time of the moon's transit of the meridian of Greenwich. The various locations of high water, as produced by all tidal forces, have been delineated by cotidal lines. In figure 6 there are shown the cotidal lines the Atlantic Ocean from the

first through the twelfth hour after the moon's transit of Greenwich. The semidaily cycle is complete in 12 lunar hours.

It will be noted that a cotidal line for the twelfth hour follows the general trend of the coast of North America from Halifax in Nova Scotia to Cape Canaveral in Florida and then turns off to the Bahamas.

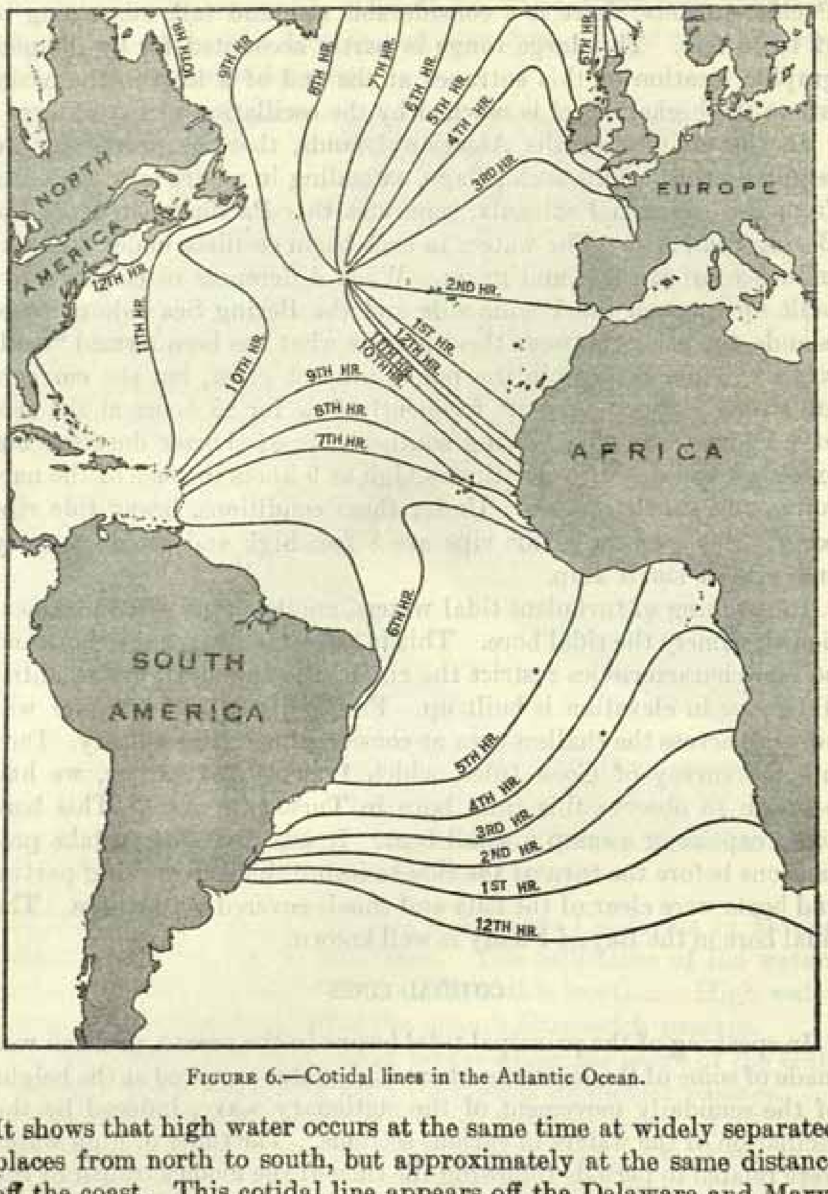

FIGURE 6.—Cotidal lines in the Atlantic Ocean.

It shows that high water occurs at the same time at widely separated places from north to south, but approximately at the same distance off the coast. This cotidal line appears off the Delaware and Maryland coasts in figure 7, which shows the cotidal lines in Chesapeake and Delaware Bays at intervals of lunar hours.

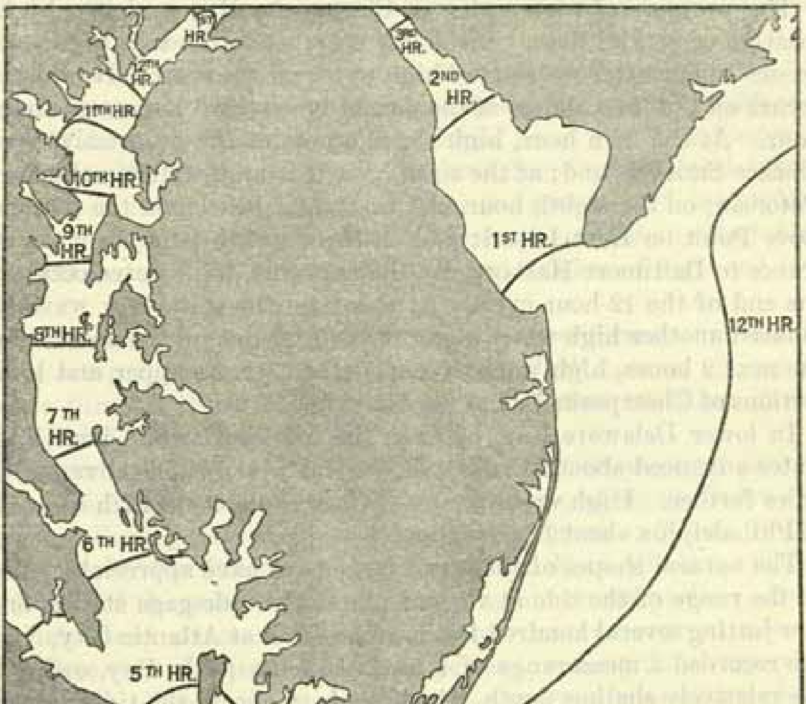

FIGURE 7.—Cotidal lines in Chesapeake and Delaware Bays.

From the theory of the tides, we know that the stationary ocean-wave movement may set up a progressive wave when the effects of this movement are extended to the waters of bays, harbors, and inlets of a coastal area. The progressive wave is prominent in Delaware and Chesapeake Bays and in New York Harbor.

The progress of high water in Chesapeake Bay is shown by the location of cotidal lines. Inside the entrance to the bay, high water occurs 1 hour after the time of high water off the coast. High water occurs on the lines shown at the second hour, third hour, and fourth hour. At the fifth hour, high water occurs as the progressive wave reaches Smith Island; at the sixth hour it is high water in the lower Potomac; on the eighth hour, at Chesapeake Beach; on the tenth, at Love Point on Kent Island; and on the eleventh hour near the entrance to Baltimore Harbor. At the next line, high water occurs at the end of the 12-hour cycle. At this time the stationary wave has induced another high water along the cotidal line off the coast. For the next 2 hours, high waters occur at the extreme upper and lower sections of Chesapeake Bay at the same time.

In lower Delaware Bay, between the first and second hour, high water advanced about 25 miles; during the next hour it advanced 15 miles farther. High water occurs at Chester about the fifth hour and at Philadelphia about 1 hour later.

The natural shapes of these two large bays have appreciable effect on the range of the tide at various places. A tide-gage station on a pier jutting several hundred feet into the ocean at Atlantic City, N. J., has recorded a mean range of 4 feet. In Chesapeake Bay, owing to the relatively shallow depth, which tends to absorb the tidal energy, and the increased width above the entrance, the normal range of tide is reduced; near the mouth of the Potomac it is about 1 foot. On the other hand, the funnel-like shape of lower Delaware Bay increases the range from 4 feet offshore to 6 feet at Philadelphia.

In both these bays, especially in the Chesapeake, high winds will disturb the normal range and time of high and low waters. Strong southeast winds cause water heights to rise and northerly winds to reduce them several feet from the normal levels. Hurricane winds have increased heights 5 to 6 feet.

TIDAL PREDICTIONS

In the early part of the last century there was need for predictions of tides for many seaports of the world. It was necessary to know when high and low water would occur, and what the amount of the rise and fall of the sea would be. The depth of water in many ports was a critical feature which determined the time of entry, loading, and departure for sailing ships. It was widely recognized that the predominant feature of the tidal movement was the relationship of time of high and low waters to the time of the moon's passage overhead; and that the higher or lower tides occurred during certain phases of the moon. A series of observations of the tide at an isolated port were usually sufficient to furnish this connection approxi-

mately. The mariner was given the information on the nautical chart in the form of a tidal note.

In more recent years the need for precise prediction of the tide became important. Knowledge of exact tide conditions and the ebb and flow of tidal currents at definite periods and hours was needed months in advance for engineering purposes and for coastwise and transoceanic commerce. As contrasted with the general and incomplete information on the early charts, there is now printed in tide tables accurate and detailed data on the time and heights of high and low water.

By the exchange of information with other maritime countries, tide tables are printed for ports and seacoasts of all oceans. A casual glance through these tables would show the great variation in the tide for different geographic locations.

For preparation of the tide tables, long and tedious computations are avoided by the use of computing machines, such as the Coast and Geodetic Survey tide-predicting machine designed and built in the bureau under the direction of Dr. Harris and E. G. Fischer. Along each side of the machine are set the harmonic constants for a given seaport. Derivatives of 37 component curves may be set on a series of pulleys over which a flexible chain passes to sum up their respective movements. The machine carries out four operations simultaneously, namely, (1) draws the curve of the predicted tide, (2) marks on the curve the time of each high and low water, (3) indicates the time and heights of high and low water on dials, and (4) exhibits on these dials the height of the tide at any desired time.

The first predicting machine was devised by Lord Kelvin, who applied the harmonic analysis to the problem of predicting the tide. Complexities in this problem are caused partly by the varying configurations of the shores and hydrographic features of different bodies of water, but principally by variations in the combined effects of the tide-producing forces of the sun and moon. The orbits of the sun and moon are elliptical; they are inclined to the plane of the earth's Equator and the periods of revolution differ for these celestial bodies. By the method of harmonic analysis are computed the amplitudes and phases of simple tides such as would be produced by a number of suns and moons revolving in simple circular orbits, all in the plane of the Equator. The complicated effects of the tide-producing forces of sun and moon are broken down into a sufficient number of component curves to take care of the variations of the true sun and moon from such simple circular movements.

SOLAR TIDES

One frequently hears the expression "the tide follows the moon." We have noted that the nearness of the moon overcomes the much

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greater mass of the sun and that the waters in great tidal basins of the oceans oscillate predominantly to the lunar semidaily tide-producing force. The axis of a tidal basin may be so situated that the waters will receive the maximum effect of one force and the minimum effect of the other.

In two ocean areas it has been found that the waters are under the minimum influence of the moon. These waters respond to the period of the tide-producing force of the sun. This condition gives rise to the solar tides, which are found at Tahiti and in Torres Strait. Although there is a slight variation, in minutes only, we have at Tahiti the unusual feature of high water coming each day at noon and at midnight, and low water at 6 in the morning and 6 in the evening.

The tide at Tahiti has a small range. More recently a larger solar tide has come to light on Tuesday Island, a small island in Torres Strait about 15 miles from the northern point of the Australian mainland. Here the tide has a mean range of over 3 feet, and high water comes about the same time day after day. Low water occurs 6 hours later, also at the same time each day.

To summarize briefly, we have noted that the tide-producing forces of the sun and the moon bring about the rise and fall of the sea waters of the earth; and that the response of the waters in the various ocean basins, modified by the hydrographic features and their geographic locations in those basins, results in the varieties of the tide that we observe along the coasts and in the bays, harbors, and seaports of the world.

Engineering and Pure Science[1]

By W. F. G. Swann
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I have often wondered why the cathedrals of medieval times didn't fall down. If I enter one of these edifices I feel disturbed by a number of conflicting emotions. I say to myself: "Now, Swann, you are not an architect, and you do not know anything about building churches. However, you do know a little bit about the theory of elasticity and how to calculate the stresses in various structures; you know a little bit about the things which are fundamental in providing that the cathedral shall not fall down, and yet, the fellow who designed that dome did not have any knowledge at all of these matters." I start with the feeling that I ought to be able to design a much better dome than he has, and yet, if somebody sentenced me to this task, and even if I should, in my own humble way, muddle through the calculation necessary in my opinion to insure safety, I should never have the courage to erect the dome until I had talked with some practical engineer and asked him whether he thought that my dome really would stand up in practice, or tumble down, to my great disappointment and humiliation.

Now, why didn't the dome built by that ignorant medieval architect—who knew nothing about the equations of elasticity, who had no differential or integral calculus, who had no knowledge of mechanics and of all the things which it would seem he should have known—why should his dome stand up, whereas mine would probably fall down? I feel very humiliated about the matter.

EXPERIENCE VERSUS SCIENCE

In the development of modern technical industry, two partners are called upon to cooperate—practical experience and what is called scientific research. Experience is the product of 6,000 years of civilization. Science is the product of 300 years, and in its relation to industry as a working partner, it is a product of less than 50 years.

[1] Reprinted by permission from Physics Today, vol. 4, No. 6, June 1952.

It is, therefore, not remarkable that this healthy, white-haired Methuselah who is Experience looks occasionally with suspicion at the energetic young upstart who is Science. Nor is it remarkable that the young upstart, looking back at his partner, regards him occasionally as a stubborn old fogey, hidebound in his ways, and extolling continually the merits of horse sense. However, it has to be admitted that the old fogey seems fairly prosperous, in spite of the ancient cut of his clothes; and moreover, that he has much money in the bank which he has accumulated as the result of his methods and which—humiliating thought—provides in one way or the other much of the daily bread of the young scientist. How shall we appraise the relative merits of these partners? How can we plan for their most successful cooperation? How can we bring the old fellow to realize to the full the value which lies in what sometimes seem to be the high-falutin, impracticable activities of the youngster? Is there anything of value in those methods of horse sense, of cut and try, of long experience, which can be recommended to the youngster as things to be valued? And if so, how and in what form can we persuade the youngster to utilize this value?

I picture an old violinist, highly skilled in his art, but devoid of scientific knowledge. There comes to him a young physicist who says: "My friend, I have been watching you play that instrument and I am going to tell you how to play it better, for I am a student of acoustics and know all about the laws of sound." "Very well," says the old violinist, "here is the violin—play it." "Oh no," says the young physicist, "I would not wish to use that instrument at all. It is, indeed, a very stupid instrument, with no scientific background. It is strung with a cat's inside and played with a horse's tail. It has a form dictated by no scientific principles and the only information I have been able to find with regard to it is to the effect that the form had something to do with the supposed figure of the Virgin Mary. I would like to study a very simple case first." And so our young physicist suspends a simple stretched string between two fixed points in space and he discusses all the various modes of vibration. He discusses how the frequency of vibration determines the pitch, how the overtones determine the quality, and so forth. The old violinist, much impressed but much bewildered, says: "All right, here is the bow. Now play it." On drawing the bow across the string, the old violinist hears nothing, for we all know that a string so mounted would emit practically no sound at all. The old violinist complains that he cannot hear anything, but the young physicist feels that it is very unreasonable of him to insist upon what he deems the relatively minor matter of hearing something and proceeds to argue that it is much better to understand what you do not hear than to hear what

you do not understand. But the old violinist is sad about this matter and goes away a little comforted by the fact that although he may not know what he is doing, he knows how to do it.

THE SCIENTIFIC APPROACH

And so it is characteristic of the ways of the scientific attack to take a simplified problem and, by studying that thoroughly, hope that one may proceed to understand and control the complex problem. In the field where the man of science has had the matter in hand from the beginning, this procedure has been very successful. Thus, he started with pure academic interest to inquire why electricity was emitted from hot wires in a vacuum. These experiments led to others and ultimately to the thermionic vacuum tube and to the whole science of electronics. In this development, the physicist had everything under control from the beginning. There were other matters starting in the realm of pure academic interest which became welded with the matters pertaining to the discharge of electricity from hot wires. All these infants, born more or less in isolation and with no great individual prospects, were brought together by the man of science, who nurtured their development, watched over their progress, marshaled them from time to time into more efficient groups as regards their potentialities, until finally we had in the world of today radio, television, and a hundred other things whose operations, if viewed for the first time, would seem so complicated, so unrelated, and so miraculous that no brain would have the courage to interpret them. If we could imagine some supergenius of the inventor kind who, by a rule of thumb and horse sense—it would have to be a very special kind of a horse—had arrived where we have arrived today in the science of electronics, but without knowledge of the basic fundamentals pertaining to the subject, and had presented us with the various pieces of equipment, with sales bulletins telling us how to turn on the switches to set it in operation, we would have a marvelous time for a week; and even if the apparatus continued to function for longer, I venture to say that further improvement in its operation would take place very slowly indeed, if at all.

INVENTORS

As distinct from the procedure of the conventional man of science, one has that of the inventor. Frequently the inventor is very hazy as regards the fundamental principles that control the phenomena with which he deals. In a certain sense, this is an advantage to him in his method of working because he tends to compensate for his lack of power as regards rigidity of prediction by the utilization of knowledge of an enormous number of experimental facts and processes which he combines in all sorts of ways in search of the end he desires. There

is apt to be a high mortality in the expected achievement; but valuable end products frequently appear, even when, in the light of a strict appraisal of affairs as represented by the scientific knowledge of the day, it would seem that they never should have appeared.

The inventor walks in a territory which the man of science has mapped out in regions of assured fertility, dubious fertility, and almost certain sterility. The man of science is inclined to conserve his efforts by walking in the rather limited realm of assured fertility, but the inventor walks with courage everywhere. He sees a pasture which he thinks has promise. The physicist would explain to him that his reasons for expecting something from that region are invalid, and in 90 percent of the cases they are, but the inventor walks nevertheless. He walks persistently, so that every now and again he finds some spot which is rich in content, not perhaps for the reasons that he expected it to be, but for other reasons of which he may be only partially conscious. If we should trace these reasons to their origin, they might constitute a set of heterogeneous associations with no very obvious logical connection, but which, through the scheme of profound regularity inherent in nature, have conspired to give a suggestion which is fruitful in spite of the very dubious foundations upon which the suggestion is made.

It is characteristic of one who concerns himself almost exclusively with the practical needs of a science or art that wide experience should supplement in considerable degree refinement of exact prediction. I have been accustomed to state as my experience that when there is a controversy between an artist—a musician, for example—and a man of science in relation to something which concerns the actual practice of the art, then in 90 percent of the cases the artist is right and the man of science is wrong. However, the situation does not end here, because unfortunately the artist proceeds to give the reasons for what he says. Then everything that he says is wrong and the man of science has merely to sit back and pull him up at the end of each sentence, leaving him completely bewildered, but unconvinced nevertheless.

There was a celebrated inventor whose employees hung upon the walls of his laboratory a placard which stated: "The poor fool didn't know enough to know that it couldn't be done, so he went ahead and did it." You know, the telephone never should have worked. Think of the impossible situation with which we are presented in this device. Think of the cables that carry the telephone current in the form of electrons. In the absence of the current, the electrons are moving in all directions. As many are moving from left to right as are moving from right to left; and the nothingness which is there is composed of two equal and opposite halves, about a million million

amperes per square centimeter in the one direction and a million million amperes per square centimeter in the other direction. The telephone current constitutes an upsetting of the balance to the extent of one-hundredth of a millionth of an ampere per square centimeter, or about one part in a hundred million million million. Then if this one part in a hundred million million million is at fault by one part in a thousand, we ring up the telephone company and complain that the quality of the speech is faulty.

In the realm of pure experience, one has frequently started out with something which is very complicated at the beginning. By trying this and that, one has arrived at a number of procedures which are not unrelated, which in some cases are redundant, and which in others are even inconsistent with one another, and yet, through the process of trial and error and much lapse of time, there has resulted a set of operations and procedures that work in reasonably satisfactory manner. That which we call understanding is now much less fundamental and, indeed, less powerful than the understanding of the scientist, but is in some sense effective. Our old violinist can certainly play his instrument and make it sound good. He tells his student to imbue his soul with the spirit of good tone and good tone will come from the instrument. The student tries to follow this advice. He does a lot of wrong things and the master lambastes him continually with all sorts of other criticisms. He tells him that he slouches too much when he plays—that he is lazy—that unless he holds his bow more firmly the spirit of tone in his soul cannot permeate through to the instrument. And so, as a result of a lot of trials and errors and of doing this and that, sometimes consciously and sometimes unconsciously, the student succeeds in producing the good tone. Possibly he still retains the feeling that his soul produced the tone, and it does no harm if he should think that, so long as the idea in its implementation is supplemented, consciously or unconsciously, by all that heterogeneous conglomeration of other things which really conspire to produce the ultimate end.

THE NATURE OF PHYSICAL LAWS

As a physicist I seek a logical framework of knowledge in which all parts of my science are related in unambiguous ways. I am unhappy about two different criteria bearing upon the same subject unless I can understand clearly whether they are independent or related.

And yet, out of this completely formulated system of laws which represents my ideal, I could obviously pick certain isolated elements and put them into forms which would stand by themselves and which would hide their relationship. These isolated elements could well serve as a useful guide to the artisan or general practical man even

though the language appropriate to their more complete setting in the fundamental frame might be unintelligible to them. We see this kind of thing happening in almost every branch of physics that finds a utilitarian service.

Of course, the reason for this state of affairs lies in the fact that the fundamental laws frequently express their consequences in forms which are not conveniently adaptable to problems. However, it is possible to dress them up in different kinds of clothes suitable to the various realms in which they have to function, and sometimes the clothes are so different that it is hard to recognize in them the same individual. However, from the practical standpoint, this existence of different forms of raiment is not to be decried, however much it may irritate the master of fundamentals to see his beloved concepts so variously represented. Occasionally the whole success of utilization of the concepts depends upon the raiment. An example is to be found in a problem which, for a considerable time, taxed the genius of the great Newton. This problem concerned the proof of the fact that a spherically symmetrical distribution of matter obeying the law of inverse squares acts, at external points, as though all the matter were concentrated at the center. By the utilization of Gauss's theorem, it is possible to prove this result, which baffled the great Newton for so long, and to write the proof on the area of a postage stamp; yet Gauss's theorem is no more than the law of inverse squares garbed in such a form as to make it particularly at home in the realm of spherical symmetry.

And so, in meditating upon our ancient and medieval architects, I have to believe that, though unconscious of the general fundamental laws, they nevertheless sensed many things which were true and were able to mold them into a frame of procedure which was sufficiently concrete and self-consistent to serve as a guide in their operations. *We* should feel very insecure in this frame, fearing that something had been forgotten, unless we could see the elements of that frame as consistent parts of the more complete whole. However, there is another respect in which the rule-of-thumb procedure has something to be said for it. Many problems which are controlled by fundamentals perfectly well known to us are incapable of solution by known mathematical procedures and we are driven to illustrate the matter by appeal to simplified cases. If I tap a table with my finger, I say that I understand in a general way how the vibrations which ensue come about. I think of those interactions of elasticity and inertia which are fundamental to the solution of the problem. I can even write down the differential equations which control the solutions, and yet no mathematician on earth is clever enough to work out the solution for this particular case.

Now, frequently, the rule-of-thumb procedure, while deficient in the obviousness of its relation to fundamentals, is apt to take care of complications in circumstances which might be almost infinitely difficult for any mathematician to take care of by trying to solve for the consequences of the fundamentals. Thus, if an authority on acoustics should endeavor to construct a violin without collaboration with an exponent of that craft, I doubt that he would produce as good a violin as Stradivari. Moreover, I rather surmise that if Antonio Stradivari and Nicolo Amati came to life today and held a discussion with the great violinmakers of our epoch, the discussion would be much more harmonious than would one between engineers of these periods.

When the physicist is presented with a complex situation, where the complexity has not grown under his own guiding hand, he may feel temporarily at a loss to know where to begin the attack upon his problem. His standard method of procedure is to take the simple, understand it thoroughly, and build up from it the complex. When he cannot start with the simple, his natural desire would be to peer through the complex in the hope of finding the simple as the origin of it all in the background, as one might suppose a person, suddenly coming upon a television apparatus, seeking to peer through the complexity of operation down to those fundamentals which constituted the experiment of 40 years ago. Having found the fundamentals in this way, he would like to watch the offspring of these fundamentals develop through themselves, their children, and their grandchildren, to the television set which is before him. In this way, he would feel that he could understand the operation of the set and be in a position to keep it in order and possibly improve it.

However, when the complex is presented to the physicist, he is faced with several difficulties. In the first place, the complex is apt to be made up of a heterogeneous mixture of methods and principles, some of dubious relevance and some even inconsistent. Or even, if irrelevancy and inconsistency are absent, the complexity of the situation may be such that it is very difficult, if not humanly impossible, to trace matters back to their fundamentals. One then has to deal with empirically discovered laws which one must believe to have their origin in more fundamental laws, although he may not be able to trace that origin. Such empirical laws are represented in perhaps their nearest approach to their fundamentals by the ordinary laws of stress and strain applicable in the theory of elasticity. In a vein farther removed from the fundamentals one has such empirical regularities as have dictated the general shape and method of construction of a violin.

The fact is that the solution of a problem involves two parts, the fundamental laws which control all problems of the class studied, and the features (boundary conditions) which determine the particu-

lar case in which we are interested. Sometimes the contribution of the latter to the features which interest us is simple and the problem is one for exact solution by the theoretical physicist. Sometimes the said contribution is complicated, but important, and the solution becomes more the problem of him who applies approximate, or even rule-of-thumb, methods.

THE DEVELOPMENT OF METHODS OF THOUGHT

It is of interest to inquire whether the fundamentals of thinking are necessarily very different today from what they were in past ages. In this connection, it is perhaps not without interest to transport oneself in imagination to the time of Galileo and inquire as to the nature of the thinking of those days. Galileo wrote a book called *Two New Sciences*, in which he presents his ideas in the form of a supposed discussion between three interlocutors, Salviati, who represents himself, Sagredo, and Simplicio.

Again and again in these discourses we see the mind of Galileo doing the same kind of thinking that a good experimental physicist or, for that matter, a good mathematical physicist does in the laboratory today, and we cannot question the fact that if Galileo, with all that he had and no more than he had 300 years ago, were planted in one of our laboratories today, he would be an outstanding physicist in the problems which are of interest to us today.

In this general epoch, we see the birth of Hooke's law on the proportionality between stress and strain, and we see the accumulation of those fundamentals going back even to far earlier days, which constitute the basic principles upon which the present engineering science is based. However, I think it safe to say that, by and large, we must regard the pre-Newtonian era as one in which the laws available, such as they were, were of an empirical kind, and even in the later epochs, extending almost to the present time, the fundamental laws were empirical. The growth of the power of mathematical physics, brought about by the invention of the calculus and by the developments of Newton, Lagrange, and others, enabled mankind to extract in richer form the more complete consequences of the empirical laws of hydrostatics, elasticity, dynamics, and so forth, and, indeed, until the advent of the electrical age scientific attention was devoted largely to the unraveling of the consequences of such laws. It is true that in the field of optics there were primitive attempts at theories devised to give a richer content to such empirical laws as existed in that field. Such attempts, however, were guided largely by the ideas of elasticity and inertia characteristic of the mechanical domain.

THE SEARCH FOR REALITY

The advent of the electrical era, initiated primarily by Faraday, Henry, Ampère, Oersted, etc., a little more than 100 years ago, found its formal development in the work of Clark Maxwell. The man of science of the day was mechanically minded and sought to understand all things in terms of the thoughts appropriate to elastic waves in solids and fluids. Maxwell's theory was an almost insurmountable stumbling block, inviting, as it did, concepts which were ultra-abstract in terms of the thinking of the day. The matter is illustrated by a comment in Sir Arthur Schuster's *Theory of Optics*, written as late as 1904, and it must be remembered that Schuster was one of the world's high priests of natural philosophy in that epoch. He writes: "The study of physics must be based on a knowledge of mechanics, and the problem of light will only be solved when we have discovered the mechanical properties of the ether." Writing in another place on Maxwell's equations, he remarks: "The fact that this evasive school of philosophy has received some countenance from the writings of Heinrich Hertz renders it all the more necessary that it should be treated seriously and resisted strenuously."

The search for reality in which to frame the new thoughts born of electrodynamics so persistent at that time has changed considerably in its aims as the years have rolled by. In my student and early teaching days it was the custom, following the lead of Maxwell and his school, to seek an explanation of electrodynamic phenomena on purely dynamical bases. If we wanted to make somebody understand a circuit with self-induction, capacity, and resistance, we would refer to a ball vibrating in a viscous fluid at the end of a spring. We would say: "Now the self-induction in this circuit is like that mass on the end of the spring. This capacity itself is like that spring. The electrical resistance of the wire is analogous to the viscosity of the liquid, and so forth." By thinking of the spring and ball, which we of the older generation felt we understood more or less, we endeavored to accommodate our thinking so as to understand the electrical problem. Today all this appears to be changed. At an early age youngsters start to play with radios and to acquire quite a little knowledge concerned with the essentials of their operation. This fact has reversed the whole situation as regards reality in the mind of youth, and the youngster of today and the older youngsters who are doing research in our laboratories seek to understand dynamics by showing that it is like electrodynamics. And if the youngster wishes to understand how a ball bobs up and down on the end of a spring when immersed in oil, he is apt to say: "Now, this weight is just like that inductance. The spring is like the capacity, the viscosity of the fluid is like the resistance of the wire. Now, you know

that the electrical circuit will oscillate; and in a similar kind of way, the ball and spring oscillate. You know that if the electrical circuit is stimulated by an external force of frequency equal to its own, it will resonate and build up a big amplitude; and for exactly similar reasons, the ball on the end of the spring builds up an amplitude when subjected to an external force which harmonizes with the system in frequency. Thus, since you understand all about the nature of the electrical oscillations of the circuit, you ought to be able to stimulate your brains to the point of understanding why and how a ball bobs up and down on the end of a spring in oil."

No longer does the engineer seek to understand his electrical problems through mechanical ones, but when he gets a mechanical problem, the first thing he does is to seek the electrical analogue and think in terms of that—he seeks the equivalent electrical circuit. And so this concept, reality, is indeed like a chameleon, changing its color to harmonize with the setting of its time. Ah! reality, what an elusive thing it is and how its search has tormented mankind from time immemorial. Reality, that will-o'-the-wisp of philosophy! You may think you have it in your hand but find that you have merely the shadow of something else. You will pursue that something else; you will clutch it, and again it will feel real until you find that your consciousness of its touch is no more than the tingle of your own blood as your hands clasp upon it. Reality is the most alluring of all courtesans, for she makes herself what you would have her at the moment; but she is no rock on which to anchor your soul, for her substance is of the stuff of shadows; she has no existence outside your own dreams and is oft no more than the reflection of your own thoughts shining upon the face of nature.

The concepts which one is willing to accept into his category of thinking and to regard as natural without further inquiry as to their origin change with the epoch, and today the average mathematical physicist at any rate encounters no obstacle in classical electrodynamics. Indeed, he would be very content and feel that he had a very understandable picture of nature if all atomic phenomena could be brought into a picture in which classical electrodynamics was the only controller of that picture. Today, however, he finds himself driven to new realms of abstraction in understanding the atom. If he had been forced into these realms 100 years ago, he probably would have given up and have felt that if he were to have no further security in the matter of what I might call common-sense understandableness, he might as well go back another couple of hundred years and join with the forces of the astrologers or the alchemists. However, realizing what has happened to his mental accommodation in the past, first through Newtonian dynamics—which was by no means a

concretely understandable matter in its day—through electrodynamics, he is now more or less content to adapt himself to any new philosophy which fits the facts and he is willing to forego too much desire for understandability in terms of horse sense.

THE ORIGIN OF PERIODS OF STAGNATION

Perhaps I may here make a slight digression in relation to the general significance of scientific theories. The matter has a bearing upon that cycle of depression in science in which, every now and again, we seem to come to the conclusion that everything worth while has been done and nothing remains but to cull over the old material. What is the reason for this condition of affairs? I think the reason is not far to seek. When a new set of phenomena reveal themselves, the man of science seeks to correlate these phenomena in the form of a theory. Sometimes in the formulation of the postulates of the theory there are details which are artificial to him, there are starting points which seem unreal, so the theory is at first abstract and few understand it. To the layman, in fact, some of the postulates of the theory may seem to be nonsense. However, the working purpose of the theory is not primarily to give pictorial satisfaction to the lay mind, but rather to correlate the phenomena which it concerns. The theory is a means by which, through the process of saying few things, we may deduce many as a consequence. Having molded the theory so as to comprehend all the newly discovered phenomena, the theory of itself starts to predict other phenomena; and it is well worth while to look for these phenomena. And so there comes a period in which science devotes itself to verifying the predictions of the theory and tracing its consequences to their limit. In the olden days, this took a long time. In modern times it has taken increasingly shorter and shorter periods, as the would-be Ph. D.'s and their mentors stalk around like roaring lions seeking something to measure. In any case, before very long everything that the theory suggests as an object of measurement has been measured and every phenomenon which it has predicted has been found, if it is a good theory. By this time, the theory has acquired a good deal of prestige. It has been responsible for suggesting many new discoveries. Those postulates and premises in the theory which were a little repugnant to us in the beginning have become more natural and reasonable in our eyes. They sit well in the realm peopled by the interesting phenomena they have brought into it. They, the nonsense of yesterday, have become the common sense of today. And now, the theory, having grown old in a useful life, becomes rather like a conventional old gentleman who, radical in his youth, has become conservative with age, who now hates to see anything other than what he has been

accustomed to, and who is able to exert great influence by virtue of the respect in which he is held through his good deeds of the past. Radical in his youth, he has become extremely conservative in his own radicalness. The old theory, having in its active youth exhausted all its potentialities in saying: "Do this, and thou shalt find that," now starts to adopt a negative attitude in saying: "It is not worth while to do such and such, because it is guaranteed beforehand that you will find nothing if you do." "To find anything," says the old theory, "would constitute nonsense in my creed, and would be very humiliating to me. It would be contrary to common sense, the new common sense of my era." And so the old theory now becomes as declamatic in saying that certain things are impossible, as before it was declamatic in holding that other things must occur. It is for this reason that in the autumn of the life of some far-reaching theory of physical phenomena, science seems to have come to an end. The phenomena divide themselves into two categories: first, those which are known or are such obvious consequences of the known facts, or of the theory correlating them, that it does not seem worth while to investigate them further; and secondly, those which look as though they are probably embraced by the theory but in a form beset with such complications of calculations as would render the dissection of their whole story beyond the power of man. As a result of this, there seems nothing more to do; research seems to have come to an end and science to be dead. Then some irrepressible individual discovers a phenomenon which goes violently contrary to the theory. After due castigation by the old gentlemen, in the form of the devotees of the theory, the results of the young upstart are confirmed by others and have to be accepted. The theory must then be remolded or possibly completely rebuilt so as to include the new facts. In this rebuilt theory, much that before seemed impossible is now rendered likely. Suggestions which would have been dismissed as impossible with the briefest thought in the light of the old theory, have a reasonable place in the realm of possibilities of the new theory. And again common sense grumbles at having to readjust itself to a new form. In his proper domain, common sense is a counselor of priceless value; and it is because he justly inspires such confidence in that domain that he becomes the most dangerous of deceivers of those who seek his guidance outside of it. For "common sense" seeks to pin all thoughts of the new to the fabric of the old, and so, ofttimes, it distorts the meaning of the new by destroying that form which was inherent in its own right, and for no purpose other than to fit it to a pattern in which it has no place. The result is a bizarre and shapeless thing out of harmony with the form into which it has been forced, and out of harmony with the form which was its own. Common

sense in natural philosophy repatterns itself from age to age. At each stage of its development it seeks to generalize the ideas born of the experience of the immediate past and to weld them into bonds which sometimes restrain the future. Thus, the breeders of error in the epoch to come are sometimes the truths of the days which have gone. So beware how you extol too much the virtues of good old horse sense, for I fear that, in the last analysis, horse sense is the kind of sense that a horse has.

I think with some regret of many experiments which in my youth occurred to me as worthy of being tried, but which on further meditation I failed to perform because in terms of common sense, as exemplified by the theories of the day, they seemed destined to give trivial results. Sometimes I wish that I had not thought so much and had done the experiments in any case, for in later years many of these experiments have been done and have given results of value, results which are harmonious in the frame of thought of today, however strange they would have appeared in the light of our concepts of 40 years ago. If a proposed experiment lies far within the boundaries of established facts and theories and would, according to their diagnosis, give a perfectly clear-cut result, I do not deem it worth while to do the experiment. If someone comes with a scheme for perpetual motion involving the utilization of ordinary machinery and the like, I give him but little attention. If he claims that, since the experiment has never been done, one cannot predict with surety what result it would give, I have to agree with him, as I would also agree with him if he claimed that the sun might not rise tomorrow morning. I then answer to the effect that while no one can predict the result of an untried experiment, the *chance* of his perpetual motion experiment giving a valuable result is, in my judgment, so small that we should not be justified in discontinuing the other experiments which we are doing in its favor. If, however, I am confronted with an experiment which lies near the horizon between the known and the unknown, I prefer to give it the benefit of the doubt; for it is such boundary dwellers as these that establish connection with the knowledge of today and that of tomorrow.

EMPIRICISM

And now perhaps it will be well if I get back to what is supposed to be the main theme of this discourse, the relation of engineering to physics.

In speaking of the empiricism I have perhaps implied that today we have something better than empiricism. In the last analysis, this is not true. All our laws of nature are empirical. However, the desire of the theoretical physicist is to limit empiricism in the sense that from the fewest number of empirical starting points he can

deduce the richest law content. His aim is to take what was formerly half a dozen apparently unrelated empirical statements and represent them all as a consequence of perhaps two empirical statements.

It is perhaps well, in this connection, to recognize two degrees of empiricism. There is the empiricism characteristic of the situation up to and including atomic processes, and there is the empiricism of the correlation of the atomic processes themselves, which second form of empiricism most physicists would not be willing to count as empiricism at all, but as a getting down to the last elements of understanding.

Taking the first realm of empiricism, however, the complete story of the content of a law is, as I have remarked, contained in mathematical form, which it is not easy to simplify to a form applicable to all cases. However, the practical need of getting matters down to a degree which enables a large number of people to use the principle results in seeking some kind of simplification which is sufficient to cover a fairly wide realm of practical experience. Here the laboratory man or the practical engineer takes hold, and after a time his intuitions become sharpened so that he adopts a kind of thinking which simulates a more exact frame of thinking but is, as it were, a self-contained set of laws of its own. One has an example of this in matters pertaining to electrical circuits where, provided that the wavelength of any oscillations concerned in the circuits is long compared with the dimensions of the circuit, we can think in terms of a certain type of simplification. There grow the concepts of capacity, inductance, impedance, to which the practical engineer, stimulated perhaps by rivalry with the medical profession, feels the urge to add another number of Godforsaken words, such as admittance, transconductance, etc. In this connection, I have thought of a new term, "abuttance." Although this may seem like the doctor's discovery of a "cure" for which there is no disease, I present it to the radio engineers in the hope that they will find a meaning for it.

In terms of the simplified laws, the practical man proceeds to manipulate these various quantities and to become very clever at predicting what will happen in this case and in that. Occasionally, however, situations arise in which the simplified laws no longer are adequate. The practical man does something about this by making some kind of correction as far as possible in the language of his old formulation. As knowledge advances, however, more and more of such cases arise and the patches on the patched-up framework become more obvious than the framework itself.

And now, superposed upon all that I have spoken of so far, which has concerned itself for the most part with what we may call the classical physics of matter in bulk, we have, in the last few years, encountered a realm in which the fundamentals of physics are no longer diluted so as to show their effects only as averaged quantities—

as temperatures—as pressures—as elasticity, etc. The advent of electronic physics has brought us down to the properties of the atomic particles themselves. In the photoelectric cell, in the photomultiplier, in the radio vacuum tube, and a dozen similar devices, the matters which determine successful operation are things which can be understood only in terms of the fundamental processes of nature or, at any rate, I think it would be safe to say that it is not much more difficult to understand them in these terms than to understand them in terms of some artificial scheme of simplification devised because one has learned to expect simplification in the past and to hope for it in the future.

And then, as the realms of empiricism in the ordinary properties of matter have become exhausted, the new realms of enlightenment following our modern picture of the structure of solids have tempted us to hope that, even here, the barrier of knowledge need not be fixed by the laws of empiricism or, if we like, by an extrapolation of the past, but rather by the possibility of prediction in relation to what we know from the atomic structure of matter itself.

It is a matter of great importance to understand what governs the strength of materials, what governs the dependence of this strength upon temperature, particularly in the light of modern requirements in high temperature operation such as is encountered in turbines. The atomic picture is very illuminating in this field and can, in many cases, point the way to success, whereas to achieve that success by what we may call the Edisonian method of multitudinous trials would involve untold expenditure of time and effort. We have not reached the stage at which we can design substances of any desired characteristics, but we have reached the stage at which our knowledge of atomic physics provides us with very good hunches as to courses of procedure which have a good chance of being successful. Of course, one of the most spectacular of all such predictions is that involved in the act of man in creating an entirely new element, plutonium, in connection with his work on atomic energy.

Now, in order to manipulate atomic properties successfully, it is necessary to think in terms of atomic laws, and such laws are rather artificial to the thinking of the conventional metallurgist. However, in the last analysis, they are really no more artificial than the laws with which he has become familiar. It is for the future to season the younger generation with a broader sensitivity to the forms of nature's laws, so that he may not, forever, stay with his feet bound in the mud of classical antiquity of which he has already exhausted most of the good essence. It is necessary to bring him to a stage where he is not limited to looking at the new fields from afar but is enabled to walk in them with confidence, and pluck such good fruit as comes his way.

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Man's Synthetic Future[1]

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The present uncertainties facing the peoples of the world, and the startling discoveries in science during the past few decades, have stimulated many to prognosticate about the future. Numerous and various forecasts have been made as to national groupings, forms of government, celestial transportation, sources of food, new building materials, and modes of living. Some predict communization of the world, others that there will be internal revolutions against communism and fascism, bringing about the return of freedom of speech and action to all people.

William J. Hale forecast the gradual regroupings of nations into four units, each of which would embrace peoples of more or less the same biological traits, but which would not be influenced by common languages and customs. The groupings would be based on physical, chemical, and biological considerations in areas which never lack self-sufficiency of any type. The smaller nations, technologically unsuited to a future in a strictly chemical world, would have to be grouped with the greater powers, which through two centuries have shown an innate ability to advance against all opposition.

The line may not yet be forming for the first trip to the planets, but the Hayden Planetarium of the American Museum of Natural History is accepting reservations for the first interplanetary flights. The rough timetable assumes rocket ships that will reach the moon in 9½ hours, Mars in 75 days, and Jupiter in 666 days. This may lead to new terms in timetables when a trip is almost two years in duration. The dining compartments will necessarily be enormous in size, even if food concentrates are used, and even if it be assumed that people will require less food under gravity-free conditions. Perhaps there will be celestially anchored hot-dog stands along the way.

Some rocket engineers have boldly predicted space flights within the next decade. Many, many decades seem more likely before rocket

[1] Based on the address of the retiring president, delivered at the annual meeting of the American Association for the Advancement of Science, December 28, 1951, Philadelphia, Pa. Reprinted by permission from Science, vol. 115, No. 2981, February 15, 1952.

ships will be built that will accelerate to the 25,000 miles per hour required to escape from the earth's gravity. Moreover, it is still to be determined what will happen to body functions under gravity-free conditions, and how human beings may be protected in an oxygenized, pressurized ship when the body has no weight and one can lift a sledge hammer quite as easily as a pencil. These illusions are no more astounding in our day than those of one hundred years ago when, in John T. Trowbridge's *Darius Green and His Flying Machine*,

> Darius was clearly of the opinion
> That the air is also man's dominion,

and J. H. Yates wrote,

> I have seen so much on my pilgrimages through my three-score years and ten
> That I wouldn't be surprised to see a railroad in the air,
> Or a Yankee in a flyin' ship a-goin' most anywhere.

Predictions of this sort do not fall within the purview of the chemist, but there is a rapidly growing number of science-fiction writers who are creating fanciful plots that may someday come true.

My remarks will be based on projecting the chemical discoveries of the past to logical achievements in the future. One hundred years ago all materials used by man were derived directly from natural sources—plants, animals, and minerals. The chemist has, through the past six decades, so perfected his knowledge of the intricacies of molecules through physical and chemical methods that he is now able to determine the patterns in which the atoms are combined in nature's substances. Indeed he is able to assemble atoms according to his own design and thus produce many of these same substances by synthesis. Moreover, he has discovered how to create new, better, and cheaper compounds based on a knowledge of natural products.

One of the first industries transformed by chemistry was dye manufacturing, an industry that is now 99 percent synthetic. In a second field, drugs and medicinals are over 75 percent of synthetic origin. Natural gums and resins at present account for only 5 percent of the 2.3 million pounds of plastics produced in the United States last year. More than half the 500 million gallons of paint used annually are based on synthetic products. Over 50 percent of today's rubber is synthetic, and over 20 percent of the textiles. The field of synthetic detergents has had a phenomenal growth, until more than one billion pounds are produced annually. This figure is still well below the amount of soap consumed.

During World War I we became conscious of shortages of raw and finished materials, especially chemicals; of shortages of certain foods and of the necessity for substitutes. During World War II, and now during the rearmament period, the shortages are primarily in raw materials. We normally consider that the United States has abundant

resources, yet the Government lists 167 strategic items that must be imported. Stockpiling by the Government of materials essential to both war and peace, but not indigenous to the United States or found here in less than the required quantities, has resulted in artificial price increases.

Let us consider for a moment our mineral supplies. The most widely distributed metals are iron, aluminum, magnesium, and titanium. They are available in amounts sufficient to supply the world's needs for hundreds of years. Aluminum and its alloys will continue to replace steel and other metals in even larger measure than in recent years. Magnesium, a very light metal, has found many uses, especially in alloys, but certain of its properties would appear to limit its extensive industrial application. Titanium, about which much has been heard in recent months, is fourth in abundance of all metals, and its ores are widespread over the world. It is truly the metal with an attractive future. Only half as heavy as steel, it is, in a pure state, ductile, very significantly heat- and chemical-resistant, and readily forms valuable alloys. It does not corrode even in sea water. For jet engines it is ideal. Its applications would be exceedingly numerous were it not for the cost. Titanium dioxide, a common derivative, which can be obtained readily from the native ore, is familiar as a superior white pigment for outdoor house paints and in finely divided form as a delustrant for rayon and nylon. The cheap production of pure titanium metal, however, has baffled the efforts of chemists and metallurgists for years. The annual supply of the metal has been only a few hundred tons, and it has sold at a price of $10 to $20 or more per pound, thus restricting its use to items where properties are all important and cost is a small factor. But now the Government is supporting the construction of plants that will provide an annual production of several thousand tons to be used primarily for military purposes. The cost of production, even on the larger scale contemplated, is likely to bring the price down to not less than $5.00 a pound, a figure much too high for general industrial application. One of the liveliest chemical problems today is the attempt to discover a cheaper way of obtaining pure titanium metal from its ores. When solved, several of the metals now considered so essential for certain steels and alloys will be in less demand.

Proved mineral deposits of all ores of less common metals, such as copper, lead, zinc, manganese, chromium, tungsten, tin, and others, would appear to have a limited life. There is, however, still much territory on earth that has not been prospected, and there still exists the possibility of mineral deposits being found deep in the earth or under lakes and seas. It has been reported that under the lakes in central Finland rich bodies of ore have recently been discovered. Per-

haps the future supplies are under water or in the frozen regions of the Poles.

There is a fantastically large source of chemicals hardly touched at present in sea water. The amounts of chemicals in sea water have from time to time been published, but I venture to repeat them. A cubic mile of sea water contains 143,000,000 tons of sodium chloride, more than 300,000 tons of bromine, and over 5,000,000 tons of magnesium. A host of other metals are present in lesser amounts. When it is considered that there are over 300,000,000 cubic miles of sea water, the potential supply of metals and salts is staggering. At present, sea water is a source of salt in some countries and an economic source of magnesium and bromine in the United States. The future chemist and engineer will discover a practical method of recovering many of the other minerals for commercial use. Paraphrasing Longfellow—

> Would'st thou, so the chemist questioned,
> Learn the secret of the seas?
> Only those who're trained in science
> Divine the possibilities.

The use of petroleum and natural gas for fuels, and more recently as raw materials for strategic organic chemicals, has been stupendous. During the past 25 years, the consumption of petroleum has increased, on the average, 4 percent a year, and of natural gas 10 percent a year. The present demand for petroleum has reached a level of 2 billion barrels a year. The demand for natural gas is 7 billion cubic feet annually, 10 percent of which is consumed in the chemical industry.

As of January 1951, proved reserves of petroleum had been established which, on the basis of present annual consumption, would last for 15 years and those of natural gas 26 to 27 years. More significant, however, is the fact that in spite of the continuous increased consumption of these products the 1951 reserves substantially exceeded those of 1950. Exhaustion of supplies has been predicted periodically for three decades, but still new reserves continue to be discovered, although with greater difficulty and at increased expense. Even if the supply in the United States decreases more rapidly than elsewhere, the reserves in foreign lands will be adequate for a long time. From 1859 to 1951, almost a century, about 41 billion barrels of oil have been produced. All this would not fill a space 1.6 cubic miles in volume. This is insignificant in relation to the total volume of oil likely still to be found in the world.

But even when the petroleum is exhausted, huge reserves of coal, oil shale, and lignite are available. By appropriate processing, the study of which is well advanced if not yet perfected, these may be converted into gasoline and related products. On the basis of present consumption, coal, oil shale, and lignite reserves would last 700 or 800

years, but allowing for difficulties of recovery and for increased demand it would appear conservative to estimate they will last for at least 200 to 300 years. I am willing to prophesy that when the time of exhaustion arrives scientists will have found substitutes.

Petroleum, originally a source merely of kerosene, then of gasoline and lubricating oil, has become, along with natural gas, the raw material for a host of aliphatic and aromatic chemicals upon which many of our chemical industries are founded. The magnitude can be realized best by citing that 1.25 billion pounds of butadiene, obtained by an appropriate cracking process from petroleum, are used annually for 825,000 tons of synthetic rubber. From 3½ billion pounds of ethylene, propylene, butylene, and isobutylene, 16 billion pounds of derivatives are made each year. Just a decade or two ago the chemical industry relied upon coal tar, the volatile liquids obtained when coal is coked, for many of its raw materials. But with increased use of petroleum for power, and of natural gas for heating, less coal is being coked and the supply of chemicals from the coal tar is much smaller than the demand. Industry has now turned to petroleum for a substantial proportion of its chemicals for the synthesis of dyes, drugs, plastics, and fibers.

Rapid mechanization has made search for substances to produce energy as well as heat one of our prime objectives. A hundred years ago, it was wood, and now fossil fuels have the attention of a multitude of technologists. It is difficult to conceive of modern life without power and heat. In spite of the discovery from year to year of more reserves of energy-containing materials, the time before these are exhausted is at most a matter of a few hundred years and then a new source of energy must be available.

A perpetual supply of energy comes from the sun. How vast it is compared to the energy-supplying materials on earth may be realized by a comparison presented in an article by Eugene Ayres. Suppose that all the coal, lignite, peat, tar sands, crude petroleum, natural gas, and oil shale that we are likely to produce in the future on the basis of the most optimistic estimates were collected. Suppose that all the timber of the world were cut into cordwood. Moreover, suppose that all the uranium and thorium that are likely ever to be discovered were purified and made ready for nuclear fission. Suppose now that this fuel were distributed over the face of the earth, that the sun were suddenly extinguished, and that the fuel were ignited to give energy at the rate at which we are accustomed to receive it from the sun—the combustible fuel would be gone in three days. Nuclear reactions would last a few hours. The energy that actually reaches the earth from the sun is over 30,000 times that of all the fuel and water power now used. There is absolutely nothing

that can be a competitor of the sun. It is fortunate that we shall continue to have plenty of solar energy, which, directly or indirectly, serves to keep the world an attractive place in which to live.

Of the annual land vegetation, only 14 percent is consumed as food, fuel, lumber, paper, and chemicals. The balance of 86 percent is returned to the earth to maintain essential biological balance. With our ever-increasing population, it is doubtful whether the fuel use of vegetation can be increased to any very great extent.

Sooner or later the inexhaustible supply of energy from the sun will be used to supplement, or in large measure to replace, energy-containing materials on earth. Only limited progress has so far been made. Of the scientists' approaches for collecting the sun's energy several have shown some promise. A popular study has been that of the single-celled alga *Chlorella pyrenoidosa.* This plant multiplies at a rate that appears to be limited only by the carbon dioxide content of the water. Carbon dioxide in the air amounts to 0.03 percent. It has been found that algae in pans of water 6 inches deep are capable of absorbing up to 2 percent of the total solar energy falling on a given area as compared with less than 0.1 percent for average agriculture. A yield of 15 dry tons per acre has been realized, which is nearly five times that of the best land growth, and scientists believe that this yield can be trebled. The Carnegie Institution has recently reported what is claimed to be the first large-scale experiments with *Chlorella.* Whether these algae may be used directly for cattle or human food, or whether they may be converted more profitably into chemicals or fuel is a problem for the future. To provide 1 billion barrels of motor fuel from algae would require an area of 35,000 square miles, assuming 35 dry tons of algae per acre could be obtained.

Photosynthesis, the process by which all vegetation is created, is not well understood. In essence, the plant converts the low-energy compounds, carbon dioxide and water, to carbohydrates and oxygen in the presence of chlorophyll. Attempts have been made to replace chlorophyll by synthetic dyes and inorganic chemicals. It has been reported that from certain experiments an amount of energy is absorbed equivalent to that absorbed in the presence of chlorophyll.

The use of glass, sometimes with reflectors, to collect the heat from the sun shows promise of becoming practical. Energy absorption seven times as efficient as the most optimistic agricultural proposals has been claimed. Apparatus is now in use for the heating of water by the sun.

Phosphors are chemicals that absorb radiant energy and radiate it after a certain length of time. Such chemicals might be employed to absorb energy from the sun during the day and for illuminating pur-

poses at night. Even though inefficient in this process of absorption and emission, the amount of the sun's available energy is so great that this procedure is not beyond the realm of practical possibility.

New sources of energy, however important they may be, are not an immediate problem but one for future generations of chemists and engineers. With our present adequate raw materials, let us explore what discoveries may be expected. "Synthetic polymers" is a term used by the chemist for the giant molecules he has learned how to manufacture from very simple ones. Such polymers possess very different physical properties and relatively inert chemical properties compared to the substances from which they are derived. Synthetic rubber, plastics, resins, and fibers fall into this category.

Today's synthetic rubber is the equivalent of natural rubber when fabricated into tires for passenger automobiles. Many improvements in the processing of synthetic rubber for tires have been made in the past decade, the most interesting of which has been recent—the incorporation of a substantial amount of petroleum in the mix. The resulting tires are claimed to have no inferior qualities, and some superior ones, to those that are oil-free. Moreover, they can be made more cheaply, and a substantial amount of raw rubber is conserved. A synthetic rubber suitable for heavy-duty tires on trucks, busses, and other large vehicles has yet to be found. Present synthetic rubber tires when used for this purpose are susceptible to a heat build-up that leads to excessive degradation. The eventual discovery of a synthetic rubber for this purpose is merely a matter of time. Moreover, special rubbers, capable of withstanding the cold of the Arctic and the heat of the equatorial desert regions without losing the required elasticity, and those which are oil-resistant and suited for low-temperature utilization, will be added to the list.

Dozens of various kinds of plastics are now sold commercially. These vary from the clear and transparent, especially suitable for ornamental purposes or for airplane windshields, to very tough, chemical- and heat-resistant plastics for use as gaskets in chemical operations involving corrosive materials. There are resins and plastics for parts of chemical equipment; for coatings of wire to be used in the construction of small motors operating at high temperatures to produce the power of an ordinary larger motor; for the waterproofing of fabrics; for finishes of wood, metals, and even stoneware. Plastics are available for all types of bristles, and others are suitable for replacement of metals even where strength is a primary factor. The future will see transparent plastics that will not discolor and with surfaces that will not craze or scratch readily; finishes for wood and metals that will remain durable for long periods of time in the presence of sunlight and salt air; and flexible, waterproof and moistureproof film of any desired strength.

Cotton, silk, and wool have been the fibers used almost exclusively for fabrics until a few decades ago. Rayon and acetate silk were then introduced. These are both chemical modifications of cellulose, derived usually from cotton or wood. In spite of the fact that they lack many of the desirable properties of the natural fibers, particularly wet-strength and recoverability of the original shape upon drying, these fibers have been widely accepted and have supplemented or in part replaced cotton and silk. Acetate fabric possesses a luxurious "feel" and drapes in soft, lustrous folds. Acetate blends remarkably well with other fibers. Just recently it has been announced that a rayon has been made in which the basic structure has been so modified that the resulting product has the wet-strength exhibited by natural fibers. If this is authentic, one of the greatest steps forward in rayon manufacture since its inception will have been achieved.

About 15 years ago nylon, a strictly synthetic fiber, made by combining very simple molecules into a complex one similar to those nature furnishes us, made its appearance. Chiefly because of its rapid-drying properties, its durability, and its resistance to fungi and insects, it has found many applications for which natural fibers are not suitable. Natural silk, for which nylon is a substitute, has never recovered its prewar status. The brilliant researches in Japan extending over a period of 40 years, when the silkworm was nurtured and pampered until he produced an egg-shaped instead of peanut-shaped cocoon with a filament twice as long as formerly and of double strength, will be of no avail by the time the synthetic chemist has had a decade or more of additional experience. The uses for nylon have become so numerous that the demand cannot be met by present production facilities. Newer synthetic fibers have appeared on the market—for example, Orlon, Acrilan, Dynel, which resemble one another somewhat in properties and are all based on the same simple chemical, acrylonitrile. These fabrics are utilized particularly for seat covers, curtains, and filter cloths in industry. They are also suitable in the apparel field because of their smart appearance, long wear, and easy laundering. Still another synthetic fiber is Dacron, which resists wrinkling, water, and moths as does no other fiber. Suits made of Dacron go through rainstorms without losing their crease and can be cleaned with soap and water without losing the original shape after drying.

Rapid drying is effected because the threads do not absorb water and drying consists merely in the evaporation of surface moisture. But this nonabsorption of moisture leads to a certain amount of discomfort, particularly in hot weather. Consequently, closely woven fabrics for shirts and undergarments have in large measure been replaced by those with a sheer or open weave. To find a fiber that will

dry rapidly and at the same time permit moisture to penetrate is asking more than the chemist is likely to discover, since they are two incompatible properties. But these synthetic fibers must be improved in other ways, or new fibers found which have the desired properties, before natural fibers will be extensively replaced. The present synthetic fibers do not take dyes as effectively as natural fibers, and up to the present it has been impossible to manufacture fabrics with the attractive colors so frequently found in silk and wool. Synthetic fibers also have the annoying property of melting or changing color if the pressing iron is too hot. The "feel" of synthetic textiles has been improved, but the resiliency of wool or the warm, soft "feel" of silk has not yet been duplicated in the synthetics. When, however, synthetic fibers are blended with wool or rayon in various proportions, fabrics with many of the desirable properties of each of the components have been obtained.

Certain representatives of the petroleum industry, when called upon to make speeches in foreign lands on the progress of petroleum chemistry, have demonstrated the achievements by clothing themselves completely—suit, necktie, shirt, underclothing, and socks—with synthetic fibers, the primary chemicals for which are all derived from petroleum. For any traveler in foreign lands, the convenience of synthetic-fiber wearing apparel is superlative.

I predict the discovery of synthetic fibers which the public will prefer for most purposes to the natural fibers. An official of the wool industry made a statement recently that the demand for wool as a fabric will never be replaced. These words were spoken by one completely unfamiliar with the potentialities of chemical research. Just as the automobile replaced the wagon, synthetic fibers will replace the natural fibers. Half the wool now consumed in the United States will be replaced by synthetic fibers within 10 to 20 years, the time being dependent primarily on the restrictions which industry encounters in materials and money for plant construction. Synthetic fibers to replace cotton will also be discovered; these will be strong, durable, and moisture-absorbing, thus making them suitable and comfortable for wearing apparel. They will not, however, be rapid-drying.

The plastics to replace cotton will also serve to replace natural leather for shoe uppers. For years excellent leather substitutes, especially for seat coverings and bookbinding, have been available but not for shoes. Natural leather permits moisture to penetrate, and the feet remain dry except when it is unusually hot. The present artificial leathers do not have this property. As a consequence, when shoes of this material are worn the feet become moist and uncomfortable. With durable, moisture-absorbing plastics, the problem of synthetic shoe uppers will be solved.

Plant life is essential to human existence, and the chemist will contribute much in this field. By well-known processes of selection and plant breeding, the agriculturist has succeeded, during the 40 years that soybeans have been grown in this country, in increasing the oil content from 16 or 17 percent to 21 or 22 percent. Hybrid seed corn, which is now widely used by farmers, results in an increase in crop yield sometimes as high as 50 percent, essentially without any additional requirements in the soil. The inference from these achievements is that proper chemical treatment of plants could result in fundamental modification of their metabolism. By standard agricultural development methods the future will see food crops in which the size of the plant is dwarfed and the fruit, kernels, or ears of corn are of greater size. In this way, more plants can be grown in a given area and the subsequent crop will be larger.

Another means of providing a greater crop from a given acreage is by plant-growth stimulants—chemicals that accelerate the growth and maturation of plants. Several are known, and chemists will discover new and better ones, with the eventual result that two crops of the same or different plants may be grown during the normal season where now only one crop is possible. Perhaps during these experiments we may find substances that will not merely speed up the growth of a plant but cause its fruit to be larger—for example, pears, apples, or oranges the size of grapefruit. If this seems fantastic, just consider the coconut-milk factor recently discovered in academic experiments. On its addition to a basal nutrient agar medium, mature plant cells are caused to subdivide; for example, cylindrical slices of carrot will grow rapidly.

Plant physiology is still in its infancy, and it must be better understood before rapid advancement in the cultivation and control of plants can reach a maximum. Experiments performed in Germany during the past 10 years permit one to envisage remarkable achievements in the future. In the flowers of the forsythia, those early yellow blooms which decorate gardens in many parts of the country in the early spring, it has been observed that the pollen of one flower never fertilizes the stigma of the same flower, nor does it fertilize a flower of the same type whether the flower is on the same or another bush. Formation of seed occurs in flowers where the pollen comes from long stamens and is accepted by flowers with long stigmas. Similarly, pollen from flowers with short stamens fertilizes flowers with short stigmas. Other combinations result in nonfertilization. A chemical study of pollen from long and short stamens has revealed that, although closely related chemicals are in each, they are actually different. With this discovery, a procedure was developed whereby fertilization of these flowers could be made to occur by chemical treatment where it would not have occurred naturally.

Not too remote from these experiments is that of spraying the blossoms of tomato plants with 2,4-D, a chemical commonly used for killing broad-leaved plants. This not only causes many more of the earlier blooms to mature into fruit, but the tomatoes formed are seedless. With this start, let us look forward to seedless raspberries, blackberries, cranberries, and perhaps many other kinds of fruits, such as watermelons, pears, and apples.

One of the banes of the farmer or the florist is the insect pests that either destroy or greatly reduce his crops. The varieties of insects and mites are many, and consequently different kinds of chemicals have been sought to eliminate them. DDT is effective in the killing of flies, mosquitoes, and many insects that attack plants, but it is not universally good. Several other insecticides are available, each with its special properties for use on a certain type of insect. Periodic spraying of crops, however, is not only expensive but inefficient, since it is impossible to reach all parts of the plant. The chemist must search for a more ideal insecticide. The ultimate will be a chemical, repellent to all insects and mites and innocuous to plants and to higher animals, a substance which when sprayed on the leaves will be absorbed and completely translocated by means of the plant juices. Why not seek also a combination of minerals and fertilizer required as plant food that can be absorbed through the leaves rather than to follow the traditional custom of fertilizing the soil with chemicals, a large proportion of which is washed away by the rain before plant absorption has occurred?

The farmer also requires chemicals to control weeds and to simplify his cultivation problems. Rapid advances have been made in this area, and many chemicals are known that are toxic to certain kinds of vegetation. Chemicals will sometime be available to sterilize the soil completely toward grasses and weeds but not toward the desired crop. Because of the similarity of many plants to each other, it may be necessary to provide a series of chemicals, each of which will effectively kill just one kind of several closely related plants. The layman will welcome the day when he can effectively kill the crabgrass in his bluegrass lawn.

Far more important information will eventually result from the study of plants. Each plant, with the aid of the sun's energy, converts carbon dioxide and water in presence of mineral salts into a wide variety of chemicals, such as starch, cellulose, protein, vegetable oils, chlorophyll, and many other complex organic molecules in smaller amounts. These reactions take place at ordinary temperatures under very mild conditions, commonly known as "biological conditions." In comparison, the chemist is a clumsy operator. He requires massive

equipment, often high temperatures and pressures, skillful engineering, and a number of operations to achieve what the plant does with a little sunlight and the simplest of chemicals. The chemist has discovered a few reactions that take place under very mild conditions and result in the formation of complex molecules from several simple ones. But he is a long way from understanding how nature operates. When, a few centuries hence, such reactions can be duplicated in the laboratory our present production methods for many organic chemicals, ingenious and skillful as they now appear, will look archaic.

Characteristic of each plant is its ability always to build up the same chemicals year after year. It has been observed, however, that if a plant is moved to a different climate the relative amounts of the chemicals present may often be modified. The day will come when a plant, after treatment with a certain chemical, will be inhibited from synthesizing one or more of the substances normally found within its structure or, on the other hand, the plant may be stimulated to create one or more of its chemicals in much larger amounts. Thus fodder crops might result from plants which now contain some toxic constituent, or plants which contain physiologically active medicinal substances may be induced to produce them in larger quantities.

The present food supply of the world, if properly distributed, would be adequate. With the steady increase in population, sooner or later all the arable land will be utilized, and even intensive farming of the soil through improved agricultural methods, plant stimulants, weed-controlling agents, pesticides, and other developments will not meet the world's food requirements. The resources of the sea will then be more intensively exploited than at present. Fish is a valuable food of high protein and rich vitamin content. It can be expanded to supplement meat supply. I envisage a more systematic fishing industry than at present—certain types of fish ranches—large fenced-off water areas in which fish are grown, fed, and annually harvested—analogous to cattle ranches. Sea farming will be a term comparable to land farming. Marine plants for food, fuel, or chemical use will be grown and harvested like land crops instead of the present system of collecting what happens to be washed ashore. When, with these extensions, the food supplies reach the limit the chemist will provide antifertility compounds which upon addition to the diet will assure a means of controlling the birth rate.

The diets of humans have been improved until now many ailments resulting from diet deficiencies are well understood and have largely been overcome either by balancing or supplementing the food intake. Concentrated or synthetic foods containing just the necessary constituents for human growth and development are feasible, but they will never be accepted by persons in good health as long as eating attractive

food is the most general and universally liked human activity. In spite of properly adjusted diets, the human race is susceptible to a long list of bacterial, virus, fungus, and degenerative diseases, some of which have thus far resisted the efforts of science.

Until half a century ago medicinal products for treatment of disease were confined chiefly to plant or animal extracts or principles discovered originally through the cut-and-try methods of the physicians of earlier ages. The chemist has now synthesized many of these principles and on the basis of this knowledge has been able to produce other products superior to the natural. Drugs that have not been derived from the basic information provided by nature have been fortuitous or have been discovered usually by serendipity, a combination of skillful observation and chance that leads so often during scientific research to unexpected achievements of basic or applied importance.

Even though a marvelous array of drugs is now available, and a vast storehouse of information has been collected, the laws of chemotherapy are still unrevealed and decades will pass before a rational chemical basis will be provided for discovery of new therapeutic agents. The knowledge of the living cell in which the chemical reactions are constantly occurring to provide the life process is still very meager. However, the elaborate series and combinations of reactions in the cell are gradually being untangled. The cell functions in health and disease will sooner or later be clarified.

While these more basic explorations are progressing, search for more effective drugs by present procedures will be intensified. New and better drugs for combatting bacterial diseases may be expected. I envisage the gradual replacement of the drugs which must be administered intravenously or intramuscularly by others of equal or greater potency which may be taken orally. Many of the most stubborn diseases of mankind are those caused by viruses, such as the common cold, poliomyelitis, spinal meningitis, influenza, virus pneumonia, mumps, and measles. Satisfactory drugs for their treatment are lacking. The retarded progress in this field in contrast to that made in the study of bacterial diseases is the result of the absence of suitable laboratory or animal assay methods for determining the effectiveness of any chemical agent upon a particular virus. Bacteria can be grown in the laboratory, but viruses propagate only within living bacteria or living cells. Research in the next decades will solve the vexing problem of finding viricides, and thus open a new chapter in medical therapy.

For the degenerative diseases, such as cancer, heart disease, or arteriosclerosis, it is unlikely that complete cures can be found, but the organic chemist will succeed in providing products that will eliminate susceptibility toward these diseases.

As the physiology of the cell becomes better known, and the relation of chemical structure to cell and tissue is revealed, chemically induced mutation of cells may become possible. Certain hormones and other drugs are now known which affect the physical being as well as the mental attitude of an individual. The future may bring to us a series of drugs that will permit deliberate molding of a person, mentally and physically. When this day arrives the problems of control of such chemicals will be of concern to all. They would present dire potentialities in the hands of an unscrupulous dictator.

What may we expect from atomic energy and radioactive substances? The ores of uranium and thorium are found in only limited quantities on this earth. The industrial applications of atomic energy are, therefore, likely to be limited to special situations, such as submarine propulsion or power units to be used in isolated spots, inaccessible to the ordinary energy-bearing materials. Radioactive substances will continue to find more and more utilization in elucidation of organic and physiological reactions, particularly metabolic degradations and transformations. Whereas biochemical studies will probably lead to compounds which may go far toward the prevention of cancer, the newer α-, β-, and γ-radiations from radioisotopes are likely to be found more effective for reducing or arresting growth of certain types of tumors than the older radium radiation. Promising results have been obtained by introducing such a substance as radioactive gold directly by mechanical means into certain tumors. In the diagnostic field many applications of radioactive substances may be anticipated. Thus it is now possible to demonstrate the presence of a tumor in the brain, and even to localize it accurately from outside the skull by means of certain radioactive iodine-tagged chemicals.

In 1780, Benjamin Franklin, in a letter to Joseph Priestley, wrote as follows:

> The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter. We may perhaps learn to deprive large masses of their gravity, and give them absolute levity, for the sake of easy transport. Agriculture may diminish its labor and double its produce; all diseases may be by sure means prevented or cured, not excepting even that of age, and our lives lengthened at pleasure even beyond the antediluvian standard. O that moral science were in a fair way of improvement, that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity.

Let us see what has happened during the 170 years since this was written. We do not know yet how to eliminate gravity so as to facilitate transport. In agriculture, however, Franklin's predictions have already come true. When this country was founded, it took nine people on the farm to feed themselves plus one city dweller. Today,

in contrast, one man on the farm feeds himself, four city people, and one person overseas.

There can be no complaint about the achievements in treatment of many diseases by use of various serums, vaccines, hormones, vitamins, antibiotics, antihistamines, and a host of others. The life expectancy of a child has increased from 50 years in 1900 to 68 years at the present time. With these results already recorded, Franklin's predictions, which relate to 830 years hence, will in large measure be correct.

Pictures of the past show log cabins, sailing frigates, oil lamps, caravans, and prairie schooners, crude utensils, hand weaving, and the man with the hoe cultivating the fields. Today life is mechanized, electrified, abundant, easy, because of the push-button era. In the future citizens will more effectively farm the land and the seas; obtain necessary minerals from the oceans; clothe themselves from coal and oil; keep themselves warm by using the stored energy of the sun; be cured of any ailments by a variety of drugs and medicinals; be happy, healthy, and kittenish at 100 years of age; and perhaps attend interplanetary football matches in the Rose Bowl.

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Phosphorus and Life[1]

By D. P. Hopkins, B. Sc., F. R. I. C.

Of the truly mineral elements—those found in the earth's crust of rock—phosphorus undoubtedly has the greatest biological significance. In the strictest sense of objectivity all elements that are essential for the growth and maintenance of living matter are equally important whether required in large or small amounts. However, the major role of phosphorus has compelled special attention since the first days of nutritional and agricultural science, and centuries before scientific interpretation was possible the vital importance of materials containing phosphorus was widely known.

The natural occurrence of elementary phosphorus is exceedingly rare and transient, for it combines spontaneously and vigorously with oxygen. Even the oxide that is formed, the pentoxide, has a very brief existence, for it rapidly absorbs water and combines with it to produce phosphoric acid. It is as simple or complex phosphates, which are the salts of phosphoric acid, that most of the world's supply of phosphorus is distributed. A proportion of the earth's phosphorus is continually passing out of the mineral reserve into living matter; similarly, phosphorus is continually passing out of living matter and re-entering the mineral reserve. These circulations take place within two cycles, a land cycle and a marine cycle. Although each of these cycles can be separately described, they are in fact interconnected; indeed, losses of phosphorus from one cycle become gains for the other.

The initial source of the world's phosphorus was the sun. Spectroscopic analysis shows that the sun's atmosphere is fairly high in phosphorus content. In the formation of the earth by the condensation of solar matter, much of the phosphorus then present was enveloped in the earth's outer shell of siliceous matter. All igneous rock contains phosphorus, mainly as apatite, a complex form of calcium phosphate. The first biological organization of matter took place in the seas and the marine cycle of phosphorus utilization long preceded the land cycle.

If the silicate rock surface of the earth imprisoned solar phosphorus, so, too, the large water surfaces must have acquired some supplies of

[1] Reprinted by permission from Discovery, vol. 13, No. 3, March 1952.

the element. In an aqueous solution phosphates would have maintained a simple chemical form much longer than phosphates fused in rock composed largely of other complex-forming minerals. It is possible, therefore, that the first unicellular living organisms of the sea were able to obtain their phosphorus requirements from this original solar supply. Even so, it would have been a limited source of phosphorus, in time becoming inadequate for the demands of expanding marine life. The principal store of phosphorus was in the land's igneous rock surface. Although apatite is insoluble in water, it is slowly and slightly dissolved by carbonic acid (formed when carbon dioxide dissolves in water). Rain water, thus acidified, steadily extracted minute amounts of phosphate from the apatite. There were then neither soils nor land plants to utilize any of this dilute solution of phosphate as it ran off into streams and sea-bound rivers. But in the seas the phosphate could be promptly utilized by marine plants.

Higher forms of sea life evolved. Then, as now, one form of life in the seas fed upon another. The same "quota" of phosphorus could support a succession of lives and thus be indefinitely retained within the biological sequences of the marine cycle. The initial assimilation of phosphate is largely made by algae, minute diatoms which multiply by self-division like yeasts; but their synthesis of phosphate and other simple nutrients in the sea's solution is dependent upon a supply of energy from sunlight (i. e., they are photosynthetic), and their floating existence is confined to the upper levels of the sea. In the mass these algae are known as plankton. Plankton is the food for zooplankton, larger and longer-living forms of very simple sea life. Young fish when hatched feed first upon the plankton and then upon the zooplankton; later, however, most sea fish feed carnivorously, upon other species and even upon their own species.

However, all sea life does not die by becoming the diet of other organisms; were this so, there would be no losses of biologically organized phosphorus from the marine cycle. A large proportion of sea plants and sea animals die naturally. Their remains sink to lower depths. The eventual decomposition of this organic matter returns the phosphorus (and other nutrients) to the sea. But most of this liberation takes place at depths beyond the sun's penetration; the simple nutrient-assimilating organisms are not present to remobilize this phosphate. There is, therefore, in the lower water levels of the seas a steady building up of phosphates and other nutrients. However, this phosphate is not accumulatively retained in the sea solution. Some of it is assimilated by crustacean and other bottom-living organisms; much of it is steadily precipitated to the sea floor; and in temperate regions there are regular inversions of the upper and lower layers of sea water which result in the further utilization of deep-sea phosphate for plankton growth.

The second of these three influences, precipitation, is largely caused by the release of calcium in the decomposition of marine organic residues. When calcium and phosphate ions meet, insoluble calcium phosphate is formed. This steadily precipitated phosphate enters the composition of *sedimentary rock;* again it eventually becomes a more complex mineral phosphate of the apatite class. Here there is an important connection between the marine and land cycles of phosphorus. Substantial areas of what is now the land surface of the world were once covered by seas; indeed, their rock and subsoils have a much longer past history as seabeds. There are, therefore, two kinds of complex mineral phosphate on land — the phosphates of igneous rock originating directly from solar phosphorus and the phosphates of sedimentary rock which have formerly passed through the marine cycle.

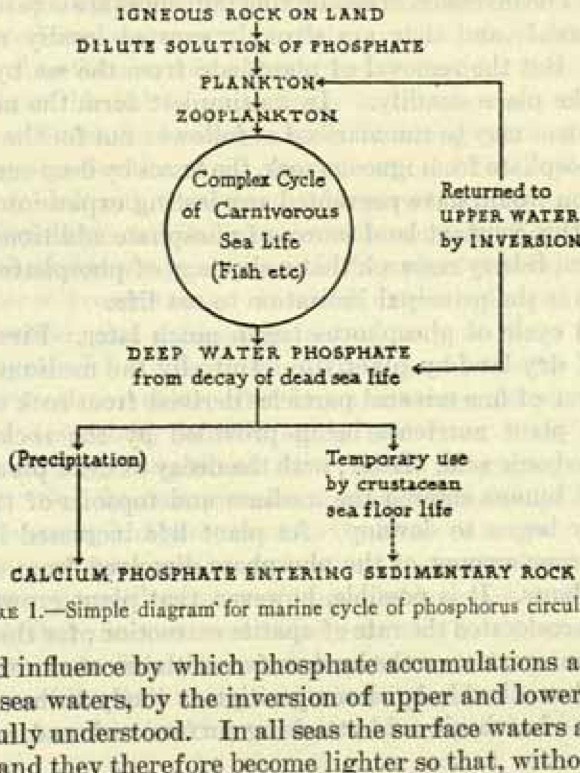

FIGURE 1.—Simple diagram for marine cycle of phosphorus circulation.

The third influence by which phosphate accumulations are removed from deep-sea waters, by the inversion of upper and lower sea layers, is not yet fully understood. In all seas the surface waters are warmed by the sun and they therefore become lighter so that, without some intervening disturbance, the colder and heavier water below cannot rise. In marine science the boundary between the upper part, which extends some 40 yards down, and the cold lower part is known as the thermocline. In temperate regions the autumn cooling of upper waters leads to a breakdown of the thermocline and there is a seasonal rising of the lower and nutrient-rich waters; but in tropical regions the surface waters remain permanently warmer and lighter and there is no sea-

sonal breakdown. This is the explanation of the comparative absence of good fishing grounds in the tropical parts of the world. But there are other factors that promote inversion in particular sea areas; a contoured shape of seabed coupled with the seasonal breakdown of the thermocline may create rising bottom currents which produce a more thorough and persistent mixing of the lower and surface waters. More than one complex theory of this hydrodynamic nature has been put forward to explain the exceptional amount of inversion that occurs at the Dogger Bank in the North Sea. But whatever the detailed explanations may be, all the deep-sea fishing grounds are places where an exceptional uprising of bottom water takes place. With it, of course, a supply of nutrients, particularly phosphate, is brought into the sunlit zone of plankton growth.

It is clear that only a limited recovery of deep-sea phosphate can be expected. The inversion or sea-mixing influences are occasional rather than perpetual; and they are strongly exerted locally rather than generally. But the removal of phosphate from the sea by precipitation can take place steadily. In its simplest form the marine cycle for phosphorus may be summarized as follows: but for the steady flow of fresh phosphate from igneous rock, the losses by deep-sea phosphate precipitation would have prevented any lasting expansion of sea life. Even with this constant land source of phosphate additions, it is clear from modern fishery research that a shortage of phosphate in the surface waters is the principal limitation to sea life.

The land cycle of phosphorus began much later. First came the invasion of dry land by plant life. Initially the medium of growth was the layer of fine mineral particles derived from rock weathering, the simple plant nutrients being provided by the rock-extracting power of carbonic acid. Later, with the decay of dead plants, organic matter and humus entered the medium and topsoils of the kind we know today began to develop. As plant life increased its land invasion a larger amount of the phosphate dissolved from apatite was taken by plants. It is possible, however, that plant growth and soil formation accelerated the rate of apatite extraction; for the accumulation of organic matter on the land surface with its concomitant production of carbon dioxide by decomposition is likely to have increased the amount of carbonic acid attacking surface rock and rock-derived subsoil.

In any case, some of the phosphorus needed for further plant growth was provided by the decomposition of previous plant material. The invasion of animal life enlarged and complicated the economy of the ROCK→PLANT→SOIL→PLANT cycle. Only a portion of the phosphorus taken by animals from plants was speedily returned to the soil. The reason for this is found in the twofold function of phos-

phorus in animal life. It is not only an essential constituent of all cell nuclei but also a major constituent (as calcium phosphate) of bone substance; it has, therefore, a dynamic "life process" function and a less dynamic structural function. Nearly 25 percent of the total mineral content of an animal body may be phosphorus, but as much as four-fifths of this amount is held as calcium phosphate in the skeleton. In the final decomposition of the animal body after death, the phosphorus in the flesh will be fairly quickly returned to the soil; but the decomposition of solid bones is exceedingly slow. So, in the SOIL→PLANT→ANIMAL→SOIL sequence, the final closing of the cycle involves, at any rate for as much as 80 percent of the animal-assimilated phosphorus, a serious time lag.

Did the expansion of plant and animal life on land with its increasing utilization of rock-derived and dissolved phosphate reduce the flow of land phosphate into the sea and the marine cycle? There would seem to have been always a sufficient release of soluble phosphate from the land to the sea, a fact that supports the idea that soil formation and plant life led to an increase in the previous rate of rock denudation. There is, however, little "washing out" of phosphate from soils by rain for the actual existence of soluble phosphate in soils is quite brief. Like other nutrients, phosphorus can be assimilated by plants only when it is available in the soil solution. But if phosphate in the soil solution is not quickly removed by plant uptake, it is precipitated by other soil constituents. Insoluble calcium phosphate is readily formed; however, this need not be a long or permanent withdrawal from the "system" for calcium phosphate can be equally readily redissolved by weak soil acids. But iron and aluminum phosphates are also formed (especially in acid soils) and from these compounds phosphate recovery is slight and slow. These processes are known as *soil fixation*. Soil fixation prevents a considerable proportion of the "biological currency" of phosphorus in the SOIL→PLANT→ANIMAL→SOIL sequence from re-entering the cycle when it returns to the soil. Instead, it enters the soil's reserve of unavailable or not easily available phosphate. There is some resemblance in this to the steady loss of deep-sea phosphate from the marine system. (It is possible that a tiny fraction of the fixed soil phosphate enters the marine cycle; for some of this accumulation in topsoils will pass downward by gradual and physical movement. In contacts with ground waters the fixed phosphates will be at least as extractable as the apatite of igneous rock. These ground waters, out of reach of most plant roots, making their way to streams and rivers, will carry some of the phosphate to the sea.)

The slow and almost timeless balance of the land cycle was greatly disturbed by farming. Agriculture meant the ever-increasing growth

of cereal plants for feeding man and his domestic animals upon the seeds or grain, those parts of the plant in which most of the soil-derived phosphorus is concentrated. As proportions of total mineral needs, man and animals require more phosphorus than plants (about 24 percent compared with 16 to 17 percent). The fact that seeds are concentration centers for the phosphorus in plants is a major reason for the development of cereal grains (wheat and rice) as primary foods for the animal kingdom. But as a result far more phosphorus was removed from soils than was returned. Early farming was nomadic, a steady movement from soils whose fertility had been extracted to virgin soils maintained in a state of mineral sufficiency by the cycles which circulate nitrogen, phosphorus, and other elements. Three devices were in time discovered: (1) Returning animal manures to soils; (2) fallowing, i. e., periodic and temporary returns to the natural cycles; (3) crop rotation. But none of these could indefinitely return a sufficient amount of phosphorus to soils as human populations increased and sharpened the demands for cereal foods.

In the seventeenth and eighteenth centuries the usefulness of bones as a fertilizer was gradually realized, particularly when it was found that their effectiveness was increased if they were first ground finely. But it was not until 1795 that the first suggestion was made that the principal virtue of bone material lay in its phosphorus content; nor did this become really understood until Liebig in 1840 published his theory of mineral plant nutrition. Nevertheless, bones were extensively used as a fertilizer before 1840, particularly in England. Thus in 1815 we find Liebig attacking England for her bone-importing activities: "England is robbing all other countries of their fertility. Already in her eagerness for bones, she has turned up the battlefields of Leipzig, Waterloo, and the Crimea; already from the Catacombs of Sicily she has carried away the skeletons of many successive generations . . ."

It was Liebig himself who indirectly solved the problem of bone supply. He suggested that treatment of bones with strong acid would give a more soluble phosphatic fertilizer. In England Lawes put this idea into practice, thus founding the superphosphate industry. Finding the supply of bones inadequate to meet the demand for superphosphate, Lawes experimented with phosphorus-containing minerals and found that an equally effective superphosphate could be based upon these mineral sources.

The existence of richly phosphatic mineral deposits in various parts of the world is not a fortuitous legacy from the earth's original formation by solar condensation. These deposits exist as a result of the marine-cycle movements of phosphorus. It is not fully understood why these exceptional concentrations of mineral phosphates

occur at certain places on the exposed sedimentary rock surface. Several explanations have been put forward and it is possible that no single explanation accounts for all the deposits. Sudden temperature changes in the sea once covering these sites may have caused enormous mass destruction of life among sea animals and organisms; heavy destruction of sea life through causes of this nature are not unknown today. Abnormally high precipitation of phosphate together with the deposition of bone phosphate would follow. Bottom-water currents in the sea may have set up chemical disturbances resulting in an intensified precipitation of deep-sea phosphate ions. Another explanation is that sea-floor currents and the local contour of the sea floor itself have segregated the precipitated calcium phosphate and prevented it from entering siliceous dilution in sedimentary rock itself. Whatever their true explanations may be, the fact remains that marine-cycle losses of phosphate have in various places accumulated in concentrated "rock phosphate" forms instead of penetrating siliceous rock as a minor diluent.

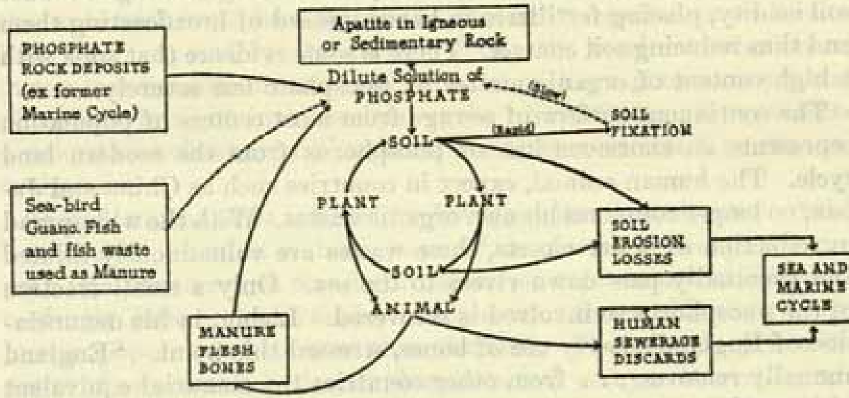

FIGURE 2.—Simple diagram for land cycle of phosphorus circulation.

The first mineral phosphates used by Lawes were from nodulated deposits (coprolites) in Suffolk and Cambridgeshire. Until 1900 various nodule deposits in England were worked, but in the period 1850–1900 many much richer phosphate rock deposits were found abroad, notably the huge beds of North Africa, America, and Russia. A large and widespread industry has arisen to produce superphosphate and other phosphatic fertilizers from these minerals deposited as a result of the marine cycle. By this means the agricultural acceleration of the land cycle is at least partially compensated, though as human numbers increase and demands for cereal crops intensify, more and more phosphatic fertilizer is required.

It is pertinent to consider how long this intervention of man can preserve a balance. The known world reserves of suitable rock phos-

phate are put at 26,000 million tons. A high estimate of world use of all phosphatic fertilizers is 25 million tons a year. But, with world population increasing rapidly and with the use of fertilizers still only partly established in some of the large crop-producing regions, a high estimate must be taken in making any long-term prediction. There would seem to be enough rock phosphate in known and workable deposits to last for another thousand years.

The phosphorus in fertilizers is just as exposed to the processes of soil fixation as is the soil's own supply of available phosphorus. Even in favorable conditions not more than 25 percent of the added fertilizer phosphorus enters current or subsequent crops. Despite considerable study by twentieth-century science, this problem remains unsolved. The discovery of a phosphatic fertilizer producible from mineral phosphate, which would (*a*) remain highly available to plants and (*b*) resist soil-fixing influences, would greatly reduce the world's annual consumption of mineral phosphate reserves. At present, however, the best that can be done is to prevent a minor proportion of the fixation loss by soil-management practices, e. g., liming to reduce soil acidity, placing fertilizers in bands instead of broadcasting them and thus reducing soil contact. There is some evidence that soils with a high content of organic matter fix phosphate less severely.

The continuous outflow of sewage from most centers of population represents an enormous loss of phosphorus from the modern land cycle. The human animal, expect in countries such as China and Japan, no longer conserves his own organic wastes. With the widespread introduction of water closets, these wastes are voluminously diluted and eventually pass down rivers to the sea. Only a small fraction of the phosphorus so involved is recovered. Liebig, in his denunciation of England's heavy use of bones, stressed this point. "England annually removes . . . from other countries the manurial equivalent of 3½ million men, whom she takes from us the means of supporting, and squanders down her sewers into the sea." It has been estimated that the phosphorus in the sewage from 5,000,000 people is equivalent to 17,000 tons of rock phosphate per year; Britain's current annual wastage must be at least the equivalent of 160,000 tons of rock phosphate (while she imports some 1,200,000 tons of mineral phosphatic fertilizer materials).

A more serious loss of phosphorus in the modern world is probably that caused through soil erosion. When millions of acres of topsoils are blown or washed away, several hundred pounds of phosphorus (available plus fixed) are lost with each acre. The annual loss of phosphorus by erosion in the United States was estimated in 1930 to be more than 2,000,000 tons. And we are still only on the verge of reversing the widespread erosion of soils even in those countries where the problem has been seriously and determinedly faced.

Both the loss by soil erosion and the loss by sewage outflow—man-created losses—are conserved by the marine cycle; whether conducted through sewers, washed away into rivers, or blown away in dust storms, most of the phosphorus thus removed eventually reaches the sea, where a great part of it will be assimilated by plankton.

A very minor but interesting link between the land and marine cycles has not yet been mentioned. Certain oceanic islands, rocky and uninhabited by man, and in almost rainless areas, are regularly used by sea birds (pelicans, albatrosses, etc.) during their breeding season. Their excreta and the bodies of young birds that die accumulate. Rain would wash out the phosphate but instead the sun dries and concentrates this material. As these birds feed entirely upon fish, their organic wastage is directly derived from the marine cycle's "phosphorus currency." This naturally dried material has long been known as guano. Guano islands were exploited as a source of manure by the Incas. In more recent times the most famous guano islands, off the Peruvian coast, have yielded 10,000 tons of guano a year. Guano collection is illegal during the four-months' closed season when the birds flock to the islands; similar protective regulations are said to have been imposed by the Incas. Today the total contribution of guano is insignificant compared with the millions of tons of mineral phosphate brought into the land cycle. Nevertheless, it represents a unique transference of phosphate and other nutrients from the sea to the land.

Is modern man to be indicted for his agricultural acceleration of the land cycle? An adult requires just over one pound of phosphorus per year as a maintenance standard. Many of the world's soils are exceedingly deficient in available phosphorus. Since 1800 the world's human population has more than doubled. The marine cycle's deposits of concentrated mineral phosphate took many millions of years to accumulate and they are being consumed at an exhaustion rate to be measured in centuries. Yet it is difficult to see how man, faced with so vast an increase in his numbers, could have done otherwise. If there is any indictment, it rests upon the charges of wastage, upon the huge losses in sewage and the even greater losses through unchecked soil erosion.

Both the loss by soil erosion and the loss by sewage of the [illegible] mineral wealth—are conquered(?) by the marine cycle; whether conducted through sewerage and [illegible] into rivers, or blown away by wind, most of the phosphorus thus removed eventually reaches the sea, where a great part of it would be assimilated by plankton.

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The Ice Age in the North American Arctic[1]

By Richard Foster Flint
Professor of Geology
Yale University

[With 4 plates]

SIGNIFICANCE OF GLACIAL AND INTERGLACIAL AGES

Arctic North America,[2] in common with the rest of the world, is now emerging from the latest of the series of glacial ages which, as a group, have characterized the last million years or more of geological time. During the glacial ages, each of which was a hundred thousand years or more in length, the mean temperatures at the earth's surface were markedly lower than today. In consequence the proportion of snowfall to rainfall increased, melting diminished, and the accumulated snow formed glaciers. These great ice masses spread outward, slowly flowing under their own weight, until they covered one-quarter to nearly one-third of the land area of the world, principally, of course, in high and middle latitudes. In North America and Greenland alone the area covered by ice amounted to 7 million square miles.

Between the cold glacial ages, warmer times intervened. The record of the soils formed in temperate latitudes during the warmer, interglacial ages shows that those ages were longer than the glacial ages—one of them probably lasted 300,000 years. The record of the fossil animals and plants entombed in the deposits of interglacial times establishes that one or more of those times was warmer than today; from this the inference follows that the interglacial ages probably witnessed a more extensive disappearance of ice from the arctic regions than is now the case. In fact, for the world as a whole the present is a time transitional from glacial to interglacial. The great ice sheets that formerly blanketed much of North America and Eurasia have disappeared, but more than 10 percent of the world's land area still remains covered by glacier ice.

The glacial and interglacial ages together constitute the Pleistocene epoch, the latest epoch in the scale of geological time. Although this

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[1] Reprinted by permission from Arctic, vol. 5, No. 3, October 1952.

[2] Throughout this paper "Arctic North America" is used in the broad sense and includes both arctic and subarctic regions.

epoch is also known as the "Ice Age," the latter term is not a good one; it is too simple. It does not imply that it includes the interglacial ages, whose combined length was greater than that of the combined glacial ages.

Most of the information on which we have formed our concepts of Pleistocene conditions comes from temperate regions. Knowledge of the former glaciation of arctic regions is scanty and is based in part on inferences from research carried on in lower latitudes. At present our reconstruction of glacial and interglacial events in the Arctic consists of broad generalizations, meagerly supported at one place or another by detailed data. As exploration and research fill in the wide blanks in our knowledge much will be learned that will modify our concepts concerning the extent of the former glaciers, their growth and decay, and the paths they made possible for large mammals and for early man emigrating from northeast Asia into North America.

EVIDENCE OF GLACIATION[3]

Today only a minor proportion of the arctic and subarctic regions is covered with glacier ice. But it is now well known that during the glacial ages a very large proportion of the land areas of these regions was overspread by glaciers, while the seas were largely covered with ice consisting of frozen sea water plus icebergs broken off from the glaciers along the coasts.

This knowledge is based on evidence of various kinds. Direct evidence of former sea ice is little known as yet, but it is unmistakable. In 1936 the Western Union Telegraph Co.'s ship *Lord Kelvin* made a cable-repairing voyage from Canada to Britain. On board was Dr. C. S. Piggot, who had invented a device for taking a 10-foot core sample of the soft sediments beneath the sea floor. A study of the series of cores he made from the region between Newfoundland and Ireland showed that the sea floor in that region is underlain by alternating layers of foraminiferal ooze and pebbly grit (Bradley et al., 1940). The single-celled Foraminifera contained in the ooze are characteristic of the warm surface waters of the Gulf Stream. The pebbly grit likewise contains some Foraminifera, but they are of types peculiar to colder northern waters.

There can be no reasonable doubt that the layers of pebbly grit were deposited by sea ice as it floated southward and melted during glacial times. The layers of foraminiferal ooze, on the other hand, were deposited under warmer conditions much like those of the present day. Hence there is firm ground for the belief that in the glacial ages the northern seas yielded sea ice that was far more abundant and that extended much farther south than at present.

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[3] Systematically discussed in Flint, 1947.

On the lands of Arctic North America the glacial ages left a more evident impress. In the alpine mountains of British Columbia and Alaska in the west, and of Labrador, Baffin and Ellesmere Islands, and Greenland in the east, the shattering action of frost, accompanying the glacial climates, sculptured typical jagged peaks and serrate ridges and, at slightly lower altitudes, excavated the capacious, half-bowllike corries that characterize the heads of most glaciated valleys. The larger valleys were converted into fiords and, in Alaska and British Columbia, where the rate of flow of the glaciers was rapid owing to abundant snowfall, some valleys were deepened at least 2,000 feet by glacial erosion. Now partly filled with sea water, these troughlike valleys are the familiar fiords characteristic of the mountainous coastal regions of high latitudes.

On the lowlands the slow grinding action of thick glaciers almost entirely removed the mantle of preglacial soil and subsoil, and grooved, scratched, polished, and generally smoothed the surface bedrock underneath. In places where the rock is cut by closely spaced fractures and other planes of weakness, the glaciers quarried out blocks of many sizes, creating roughened surfaces, as well as many rock basins that now contain lakes.

The depth of glacial erosion of the lowlands was small, as is indicated by the preservation of preglacial topographic features and of chemically altered bedrock that could only have been formed close to the surface during preglacial time. Most estimates place the layer of soil and rock removed by glacial action at a few tens of feet at most. The small figure is the result chiefly of the lowland character of the country; there were no deep valleys to channel and concentrate the flow of the ice, nor were there mountains to provide steep gradients.

Here and there throughout the lowland region, irregular deposits of earth and stones (the *glacial drift*) left on the surface, chiefly during the melting of the glaciers, created obstructions to the natural drainage, forming many lakes in addition to those occupying bedrock basins.

The glacial drift is generally thin and is distributed in patches. In the regions surrounding Hudson Bay and lying immediately east of the Mackenzie Great Lakes, where the ancient bedrock is strong and not easily eroded, bare, ice-smoothed outcrops are much in evidence and drift is scanty. Farther west, in the plains region, where the weaker bedrock yields more readily to erosion the covering of drift is more general. It is also thick in the central region between Hudson Bay and the Mackenzie River.

Much of the drift is a variety of *till*—a tough, compact nonstratified stony clay plastered bit by bit onto the ground from the load of rock fragments carried in the base of the slowly flowing glacier. The till

is usually only a few feet in thickness, although in the plains region it may be much thicker. In some areas where the till is comparatively thick the flow of the overriding ice has molded it into the whaleback hills known as *drumlins*. Commonly these occur in broad groups, the individual drumlins ranging in length up to 3 miles. Thus far drumlins have been reported principally from the region west of Hudson Bay, as far west as northern Saskatchewan. Undoubtedly further exploration will bring to light many more than are now known. The value of drumlin study lies in the fact that the long axes of these hills record the general direction of flow of the glacier ice at the time when they were built.

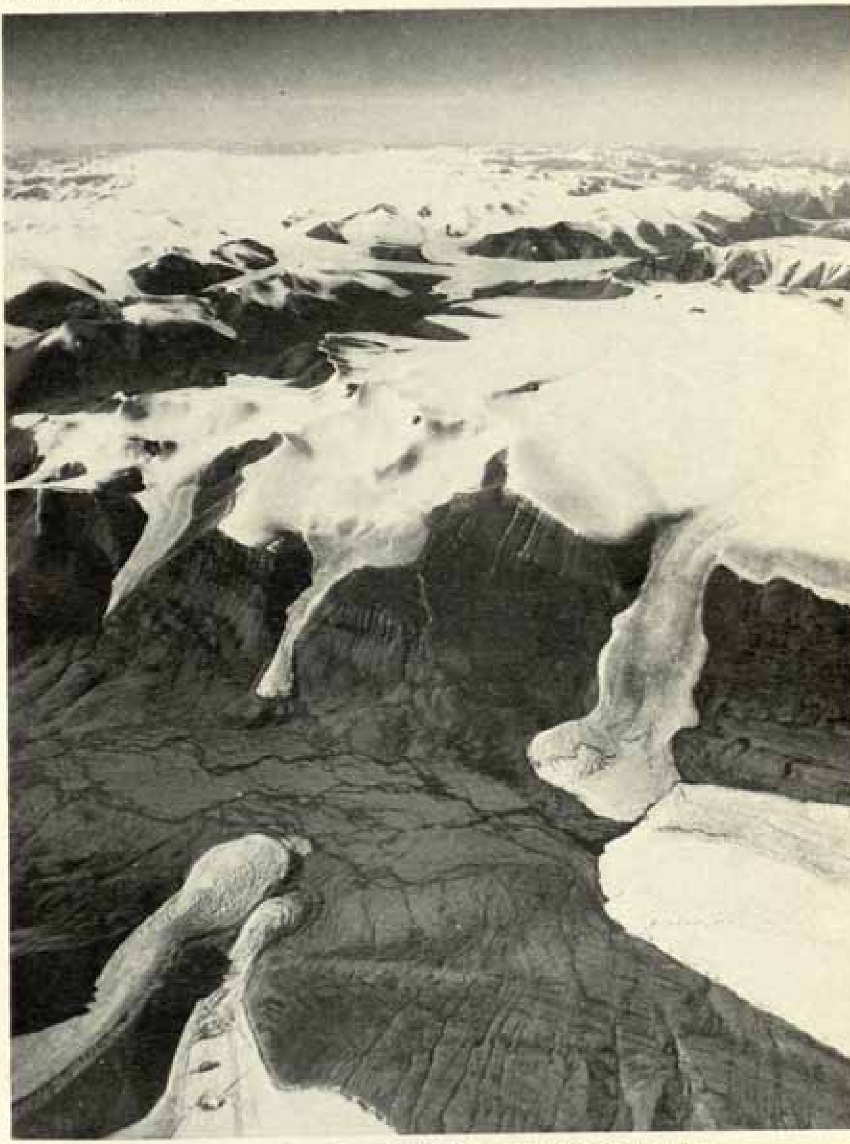
The *esker*, another type of drift accumulation, is also useful in reconstructing the movements of glaciers. Eskers are long and usually winding ridges, several tens of feet in height, and in some cases more than 100 miles in length. Some of them branch like streams, and all are built of stratified glacial sediments. They are believed to be the deposits made by streams of meltwater that flowed in tunnels beneath the ice or in channels in the surface of thin ice, in the marginal part of an ice sheet. They were built during the period of decay, just before the ice melted away, and are generally aligned at right angles to the trend of the glacier margin at the time they were built. Thus they may record successive positions of the edge of the ice sheet during its shrinkage. Eskers are numerous in Arctic North America, but as yet they have been mapped in two regions only: east of Great Slave and Great Bear Lakes (Wilson, 1939, 1945) and in central Quebec and Labrador.

End moraines—ridges of drift heaped along the margin of the ice sheet—occur here and there. Except in a few localities, however, no systematic attempt has been made to map them. When fully mapped these features, too, like the drumlins and eskers, will constitute a valuable clue to the successive positions of the retreating margin of the ice sheet.

DISTRIBUTION AND TYPES OF FORMER GLACIERS

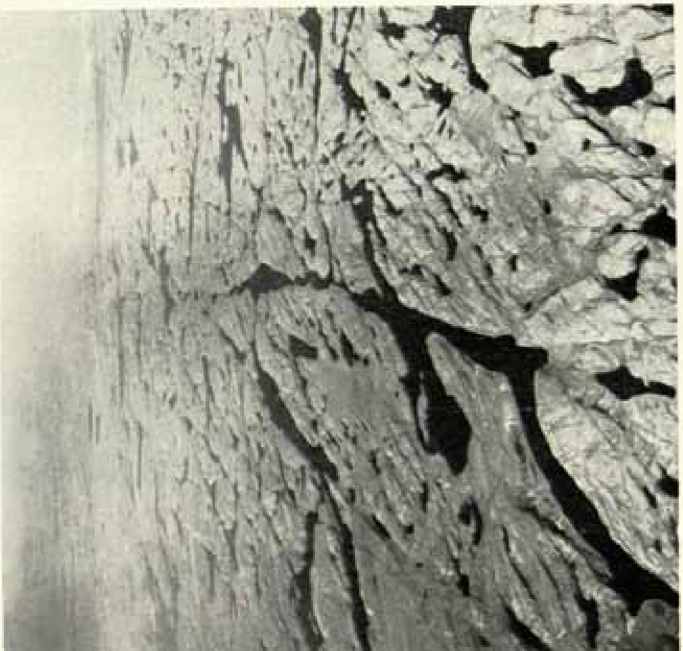
Plate 1, adapted from the glacial map of North America (Flint et al., 1945), shows the areas at present believed to have been covered by former glaciers in North America. Excepting in the region of the Arctic Ocean, the limits of the highland glaciated regions are fairly well known, though many details remain to be filled in. Of the vast lowland area west, north, and east of Hudson Bay, our knowledge is hardly even elementary.

The distribution and directions of flow recorded by the former glaciers show that the two great groups of highlands in Arctic North America—the western or Pacific and the eastern or Atlantic—were



SMALL ICE CAP, CONGER RANGE, ELLESMERE ISLAND

View looking west toward the United States Range. Photograph courtesy of R. C. A. F.



1. NEARLY BARE GLACIATED BEDROCK, RAE ISTHMUS, MELVILLE PENINSULA

View looking west.

2. DRUMLINS

View looking east on Barren Grounds near Artillery Lake.

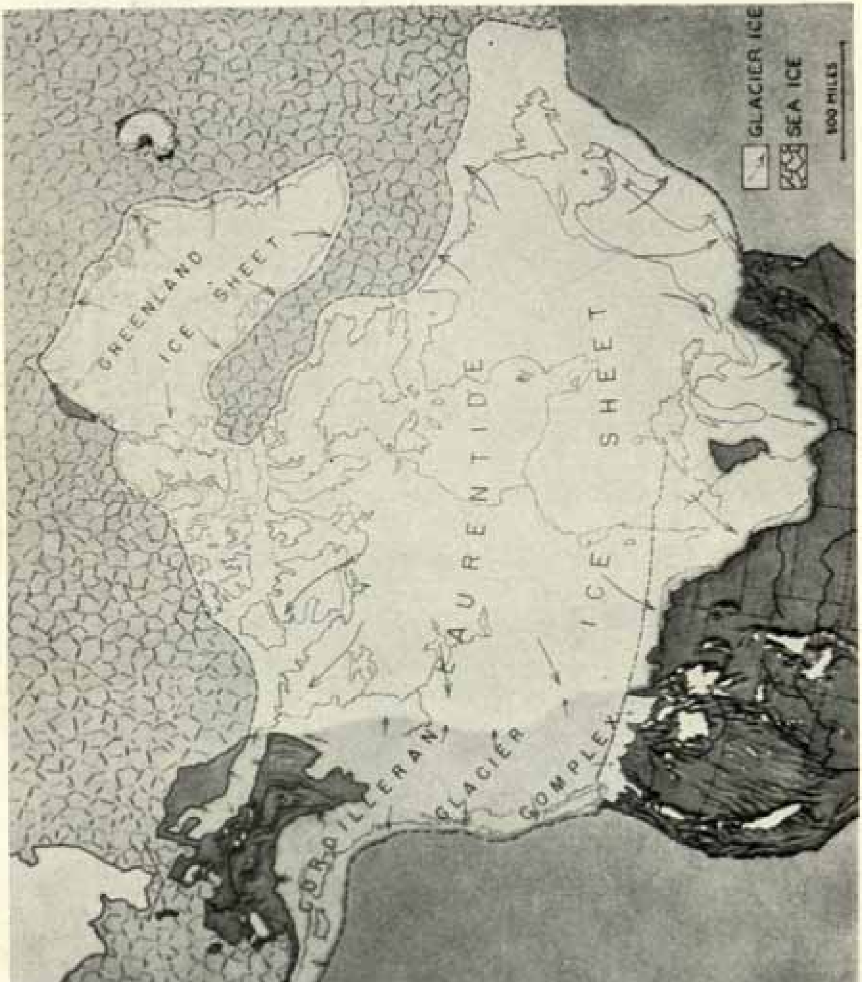
Photographs courtesy of R. C. A. F.

1. ESKER ON BARREN GROUNDS BETWEEN BACK RIVER AND CONTWOYTO LAKE

2. SUCCESSIVE SHORE LINES LIFTED ABOVE SEA LEVEL BY UPWARPING ACCOMPANYING DEGLACIATION

West coast of Hudson Bay at mouth of Shell Brook, south of Fort Severn.

Photographs courtesy of R. C. A. F.



GLACIATED AREAS IN NORTH AMERICA, GENERALIZED TO SHOW THE MAXIMUM AREA COVERED REGARDLESS OF DATE OF GLACIATION

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glaciated and that glaciers originated in these highlands. Data of the same kind show that the vast lowland region between these highland groups was also glaciated—evidently by a thick and extensive ice sheet. It was long believed that this ice sheet was built up by the accumulation of fallen snow on the lowlands themselves. However, I have put forward reasons for believing that the great lowland ice sheet grew up through the coalescence and expansion of glaciers from the Atlantic highlands (Flint, 1943, 1947; Demorest, 1943). According to this view the ice sheet was in a sense an immigrant into the lowland country rather than being indigenous. The manner in which the ice sheet developed is not entirely settled, nor can it be until much more has been learned about the glacial geology of the vast region surrounding Hudson Bay. The discussion that follows is based on the view that the broad ice sheet invaded the lowland from the east, with the reservation that this view is not yet fully proved and is therefore subject to whatever modifications may be made necessary by further study.

The Cordilleran Glacier Complex.—The Cordilleran or high-mountainous region of western North America, from Alaska to Mexico, is dotted with glaciers today. The colder climates of the glacial ages brought about so great an expansion of glaciers in this region that from southern Washington northwestward to the Bering Sea a complex of coalescent valley glaciers, piedmont glaciers, and ice sheets covered a combined area of more than 950,000 square miles.[4] On the west this ice entered the Pacific and probably formed a floating shelf similar to the shelf floating on the Ross Sea off the Antarctic Continent today. On the east the ice descended to the plains where, along a 1,700-mile front stretching from Glacier National Park in Montana to the mouth of the Mackenzie at the Arctic Ocean, it coalesced with the great lowland ice sheet.

The distribution of the Cordilleran glaciers was controlled then, as today, by two principal factors: high land and atmospheric moisture. These controls are clearly evident in Alaska. There the thickest and most extensive glaciers formed on the coastal mountains, which not only are the highest and most massive mountains in western North America but also stand directly in the path of warm moist air masses coming in from the Gulf of Alaska. The Brooks Range in Northern Alaska is lower and less massive, and faces the cold Arctic Ocean rather than the warm Gulf of Alaska. In that range the glaciers were correspondingly less extensive, thinner, and less active. Between the coastal mountains and the Brooks Range the lowlands drained by the Yukon River had no glaciers at all; this intermontane country, although cold, was too low and too dry to support them.

[4] For descriptions of the glaciation of representative districts see Kerr, 1934; Capps, 1932.

In southern Yukon and northern British Columbia, where coastal mountains are lower, enough moisture was carried across the coastal barrier to build up a thick ice sheet in the rough but lower country between the Coast Ranges on the west and the Rocky Mountains on the east.

The Laurentide Ice Sheet.—Most of North America east of the Rocky Mountains was overspread during the glacial ages by a vast, coalescent mass of ice to which the name Laurentide Ice Sheet has been given (G. M. Dawson, 1890, p. 162).[5] The area of this glacial carapace at its maximum probably exceeded 5 million square miles. Its exact eastern limits are not known because the ice extended to seaward of the present coast and the evidence is therefore submerged. To the north the vast glacier covered the southern and eastern islands of the Canadian Arctic Archipelago and overspread the network of narrow straits that separated them. Whether the most northerly and westerly islands were ever wholly buried beneath ice is not known, simply because the geology of much of the region has never been investigated.

The ice grew thick enough to overtop most or all of the highlands in northeastern North America, and may possibly have reached an extreme thickness of 10,000 feet, although this figure is a matter of conjecture.

Greenland Ice Sheet.[6]—Eastward across Baffin Bay and Davis Strait the Greenland Ice Sheet, during the glacial ages, was thicker and more extensive than it is today, as is clearly shown by the ubiquitous signs of glaciation both vertically above and outward beyond the existing ice sheet. It can hardly be doubted that the Greenland and Laurentide ice bodies were firmly coalescent across the narrow straits that separate northwest Greenland from Ellesmere Island. It is even possible that the two ice sheets, partly aground and partly afloat, were coalescent across Baffin Bay and Davis Strait.

Despite its great area, the Greenland Ice Sheet failed to cover the extreme northeastern tip of Greenland, just as it fails to do today. The explanation lies in lack of nourishment. In that region the precipitation is now very small, and during the glacial ages it must have been as small or smaller, literally starving the northeastern tip of the Greenland Ice Sheet.

GROWTH AND DISAPPEARANCE OF THE GLACIERS

The hypothesis that best fits the facts now known is that each of the glacial ages began with a world-wide gradual reduction of temperature. In consequence the proportion of snowfall to rainfall increased,

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[5] For good descriptions of some of the glacial features see Bell, 1890; J. W. Dawson, 1893; Tanner, 1944, pp. 173–253.

[6] Systematically discussed in Kayser, 1928.

and the melting of fallen snow during the summer diminished. All of this, quite understandably, resulted in the enlargement of glaciers existing in the higher mountains and in the appearance of many new glaciers in mountainous districts. There can be little doubt that in Arctic North America the first crop of glaciers took form in the two great mountain regions: the Alaska-Yukon region and the Greenland-Ellesmere Island-Baffin Island-Labrador-Quebec region.

The probable growth of the glaciers in the Alaska-Yukon region is not difficult to trace. Individual mountain glaciers enlarged, thickened, and coalesced. Many of them spread out beyond the bases of the mountains as piedmont glaciers. In southern Yukon and northern British Columbia the ice bodies flowing eastward from the Coast Ranges and those flowing westward from the Rocky Mountains coalesced over the rough but somewhat lower country between them, and the combined mass thickened and grew into an ice sheet that nearly overtopped the high mountains themselves. Geological evidence shows clearly that the ice, when near its maximum extent, flowed from the lower interior country westward *across* the higher coastal mountains to the Pacific.

The growth of the glacier ice in the eastern part of the continent is less clearly evident, but the probable course of events was similar. Through the use of what scanty direct evidence we have, and by analogy with better-known regions, we can conjecture that on each of the highlands along the northeastern border of the continent proper, and in Greenland, the new crop of glaciers expanded until they coalesced, as did those in the far west. Recent seismic measurements, by the Expéditions Polaires Françaises, of the bedrock surface beneath the Greenland Ice Sheet have suggested the possibility that the land mass of Greenland consists of three separate islands which have been buried beneath the Greenland Ice Sheet.

Glaciers descending the western slopes of the mountains of Ellesmere and Baffin Islands, and of Labrador and Quebec, formed a piedmont apron of ice that chilled the air above it and thus drew snowfall from the comparatively moist air masses that approached it from the south and southwest. The added snowfall increased the thickness of the ice, which thereby gradually became a topographic barrier to the southerly and southwesterly winds, as well as a cold-air barrier or polar front. Snowfall was thereby still further increased, which in turn thickened the ice and increased its outward spread.

The high cold front of the combined glacier crept slowly westward and southward, fed by moisture brought to it by the winds it intercepted. At the same time the ice thickened until it buried, or nearly buried, the highlands along the northeast coast on which the earliest glaciers had formed. The ice, now the full-fledged Laurentide Ice Sheet, flowed across the broad, shallow Hudson Bay depression and

up the long gentle slope of the plains country to the west. Its uphill course was made possible by its great thickness. Ultimately it met the piedmont glaciers flowing eastward from the Rocky Mountains and merged with them to form a continuous glacial mantle that stretched from the Labrador Sea to the Gulf of Alaska, broken only by high mountain peaks. The line along which the two ice masses merged shifted its position from time to time, but it was never far east of the Rocky Mountain front. This line lay along the general course of the Mackenzie and Liard Rivers, through the vicinities of Fort Nelson and Dawson Creek, and passed west of Calgary and Lethbridge, to the southern limit of the ice at the International Boundary. That rock debris was brought to this line by both glaciers is shown by exposures of overlapping glacial deposits, one layer containing Rocky Mountain stones, another containing stones brought from the region west of Hudson Bay, and still another layer containing a mixture of both.

The transport of stones to western Alberta from the country immediately west of Hudson Bay involved not only a journey of many hundreds of miles but also a vertical lift amounting to more than 4,000 feet. In order to accomplish the lift, the ice sheet must have had a thickness considerably in excess of this value. It is not probable, however, that the ice sheet, when at its maximum, was thickest at its geographical center and thinner elsewhere. The probability is that the ice was thickest at its eastern and southern marginal areas—the areas that intercepted the largest amounts of atmospheric moisture—and that elsewhere the ice was thinner. The glacial striations and other geologic evidence of direction of flow of the ice are still too scanty to justify definite conclusions, but such facts as we have are consistent with this concept.

If this was the case, then the flow of the spreading ice was most active in the southern peripheral zone and was least active in the vast interior and northern areas. Furthermore, most of the ice markings left on the bedrock and the localized accumulations of glacial drift deposited on the surface must have been made during the waning of the ice sheet; for the majority of the markings and accumulations made earlier would have been erased or reshaped by later movement.

Floating shelves of glacier ice, like the shelf off northern Ellesmere Island today, undoubtedly fringed many coasts. Beyond the shelves the sea ice was far more extensive and more nearly continuous than it is today. Pack ice filled not only the Arctic Ocean but also the Bering Sea and the Greenland and Labrador seas, and reached into the North Atlantic beyond the southern coasts of Greenland and Iceland.

The state of exploration of Arctic North America permits us as yet to sketch only the general outlines of the deglaciation—the shrinkage

of the glaciers from their former great extent. As recorded by a variety of features, chiefly in the glacial drift, the shrinkage seems to have been generally concentric, inward toward a "last stand" of the shrunken main body of the ice sheet in the regions of Hudson Bay and the Quebec-Labrador highlands. But wherever there were conspicuous highlands their cold and moist climates favored the persistence of glacier ice upon them. Thus southeastern Quebec, Labrador, and Baffin and Ellesmere Islands and their high-standing neighbors, as well as Greenland, continued to nourish glaciers of various kinds separate from the main residual ice body. Some of these separate glaciers, notably the Greenland Ice Sheet, persist today despite a somewhat unfavorable climate and conspicuous contemporary shrinkage.

EVIDENCE OF REPEATED GLACIAL AGES

Most of the evidence that glaciation was repeated comes from the temperate region, where the southern margins of the great glaciers piled up at least four overlapping layers of drift, each separated from the one below it by a zone of deep weathering-decomposition that indicates a lapse of perhaps hundreds of thousands of years. During each glacial age most of the arctic region lay beneath ice, and in the mountainous areas the intensity of glacial erosion favored the destruction of earlier-formed drifts. Hence, as yet, the Arctic has contributed little to our growing knowledge of the succession of glacial ages. In no arctic locality has clear evidence of more than two glacial ages yet come to light. If the Arctic alone were considered, this fact might be taken to mean that glaciers continued to cover much of the arctic region during the interglacial ages proved to exist in lower latitudes. But when the whole glaciated region is examined, such a condition is seen to be very improbable, for the fossil plants and animals contained in some of the interglacial deposits imply arctic climates as warm as, or warmer than, those of today. This in turn implies very widespread deglaciation.

Within the arctic region perhaps the best evidence of repeated glaciation is a series of exposures in the district south and west of James Bay (McLearn, 1927, pp. 30C–31C). Here, between two sheets of till, is a layer of peat, the compressed remains of a spruce-pine-birch-fir forest. Clearly there were two glaciations of this district and, although the length of the intervening time is not evident, it is probable that both glaciations are of very late date.

In the Carmacks district, Yukon, there are present two till sheets of which the younger contains firm, fresh stones while the stones in the older are thoroughly decomposed. A long interglacial process of soil formation is indicated (Bostock, 1936, p. 48).

In the sea cliffs of Herschel Island, in the Beaufort Sea west of the mouth of the Mackenzie River, extensive beds of soil and clay containing twigs and at least one log are exposed (O'Neill, 1924, p. 12). Again, near the mouth of the Ikpikpuk River, on the arctic coast of Alaska east of Point Barrow, spruce logs occur in the sediments of the coastal plain (Smith and Mertie, 1930, p. 254). Large logs are found in the superficial deposits of the Kuzitrin lowland north of Nome, Alaska (Collier et al., 1908, pp. 89, 91). Little is known about these deposits but, as their localities lie beyond the present poleward limit of trees, the material may be interglacial. We cannot state the inference more strongly than this, because the possibility that the twigs and logs were simply driftwood, perhaps from distant points of origin, has not been eliminated.

There is clear evidence of at least two glacial ages in the frozen ground in the Yukon River basin in central Alaska, although the region was never glaciated because it is low, dry, and subject to warm summers. This country is underlain by thick beds of silt, deposited mainly by the Yukon and other rivers. As it lies within the arctic belt of perennially frozen ground, most of the silt is frozen to depths reaching hundreds of feet. Mining operations have exposed extensive sections of the silt, overlain by thick mudflow deposits consisting of thawed silt, now refrozen. Such sections furnish evidence of an episode of deep thaw that intervened between two episodes of deep freezing (Taber, 1943). As freezing and thawing well below the surface take place slowly, a long interval of warmth is indicated. These events, however, have not yet been firmly dated.

In northern British Columbia and also on the east coast of Greenland the forms of major valleys seem to indicate a period of deep stream trenching that occurred between two periods of glaciation.

These are the scattered pieces of evidence of repeated glaciation derived from the arctic region. Many more will be discovered, but they are not likely to approach either in quantity or quality the records from the southern margin of the glaciated region.

A great variety of evidence has established the belief that since the latest of the glacial ages reached its peak several tens of thousands of years ago and began to wane, the climate has not become continuously milder. The record shows that in northern Europe and temperate North America, at least, climates attained a maximum of warmth and dryness roughly 5,000 years ago; since when, conditions have become appreciably cooler and wetter. It has been shown that some of the glaciers in western United States had dwindled away or disappeared entirely during the period of warmth and were later reborn. Arctic America is not likely to have undergone so drastic a change because of its cooler climate, but nevertheless it is likely that

all the arctic glaciers underwent at least some reduction in size during the warm period. Future research is likely to bring forth evidence that this reduction occurred.

GLACIAL LAKES

The great deglaciation that has been in very irregular progress throughout the last few tens of thousands of years was accompanied by the appearance of many temporary lakes, held in between glacier ice on one side and sloping ground on the other. Most of the lakes were localized in preglacial stream valleys, depressions that could be converted into basins by glacial erosion, or damming by ice, or both. Some of the most conspicuous preglacial valleys had developed along the contact between the igneous and metamorphic pre-Cambrian rocks of the Canadian Shield and the surrounding Paleozoic sedimentary rocks. Major lakes of today, such as Great Bear and Great Slave Lakes and Lake Winnipeg, consist of segments of these valleys converted into lake basins by glacial action. These, together with other lakes in the region west of Hudson Bay (notably Lake Athabaska and Wollaston, Reindeer, Cree, and Lesser Slave Lakes), show by the abundance of lake deposits and abandoned strandlines in the terrain surrounding them that they were considerably larger during the shrinkage of the ice sheet than they are at present.

The two larger lakes formed partly within the arctic region during the deglaciation have almost entirely disappeared. *Lake Agassiz* extended from latitude 46°N., in Minnesota, nearly to latitude 58°N., in northern Manitoba, and had an area equal to that of the existing Great Lakes combined. It was held in on the north and east by the edge of the ice sheet, and when this melted away the water drained off to Hudson Bay, leaving a few basins, Lakes Winnipeg and Winnipegosis, to contain residual pools. *Lake Ojibway-Barlow*, south of James Bay, was held in in the same manner. It stretched from the 76th meridian to the 88th, and when glacial melting destroyed its northern shore it drained away, leaving upon the bedrock surface a veneer of silt and clay to mark its former extent. This is the well-known "clay belt" which has made a wide region possible for agriculture, in contrast with the rocky country surrounding it.

THE POSTGLACIAL SEA AND RISE OF THE LAND

The greater part of the coastline of Arctic North America is fringed with superficial deposits of sand and silt, in places containing the fossil shells and bones of marine animals. Throughout great distances these deposits are fashioned into beaches, bars, and other shore features sweeping along the contour of gently sloping terrain. Shore and sea-floor deposits of this kind form a discontinuous belt that varies

greatly in width. Along steep coasts, such as those of Labrador and British Columbia, the deposits are narrow and very discontinuous, consisting of hardly more than local patches. Along gently sloping coasts, such as the coast of Hudson Bay, they increase to form a belt more than 150 miles wide, and in the Thelon River basin, northwest of Hudson Bay, the width of the belt exceeds 400 miles. The greatest height of the marine features above present sea level likewise varies from one part of the coast to another. This height commonly reaches 500 feet; and, at a few points, it has been observed to reach as much as 900 feet. In contrast, in northwestern Alaska it is not certain that marine deposits extend above the present level of the sea. In general the height increases with increasing proximity to the Hudson Bay region, which lies near the geographical center of the area covered by the former ice sheet.

In the few places where exposed sections of these deposits have been examined, they are seen to rest upon the glacial drift. Hence the marine sediments postdate the glaciation. The phenomenon of marine deposits overlying glacial drift is known also in southeastern Canada and New England, and is still better known along the Baltic Sea coasts of Sweden and Finland. The explanation now widely accepted is that the weight of an ice sheet causes the earth's crust beneath it to subside slowly. As the great glacier shrinks, the sea inundates the subsided crust, which is slowly rising (though with a considerable time lag) owing to reduction of the glacial load. At first the sea rests against shores of glacier ice. But as the ice sheet shrinks and as the crust rises, the shoreline is transferred to the ground vacated by the ice and is forced to retreat little by little. Thus are explained the marine cover and the successive shorelines at ever-decreasing levels. Evidently, then, during an earlier phase of the process of postglacial uplift, Hudson Bay was very much larger than it is now.

There are indications of various kinds that the upheaval is still in progress. Prominent among these are the occurrence at several localities of Eskimo dwellings, built near the shoreline, and fish traps, built between high and low tide, now 30 to 80 feet above sea level (cf. Bell, 1884, p. 37; Washburn, 1947, pp. 69–71). Calculations based on the probable amount of depression of the crust under the ice sheet, and on the uplift already accomplished, indicate that in the region of Hudson Bay some additional hundreds of feet of uplift are to be expected before the crustal equilibrium that prevailed before glaciation will have been restored. From this it follows that Hudson Bay will gradually become still smaller. In fact it is probable that by the time the movement has ended, the Bay will have become once more a broad plain drained by a master stream flowing north. There is

reason to believe that in preglacial time this master stream included the drainage of the Missouri River in North Dakota and Montana, but that that drainage was diverted toward the south by the expanding ice sheet.

The absence of highly elevated marine features from the western and northern coasts of Alaska results probably from the fact that western and northern Alaska were but scantily covered with ice, so that disturbance of crustal equilibrium there was small. Postglacial emergence of the Pacific coast of Alaska and British Columbia has been conspicuous; this is in keeping with the known thick cover of glacier ice in that coastal region.

CHRONOLOGY AND CAUSES OF GLACIATION

The North American Arctic yields very little direct information either on the actual dates of events in the glacial past or on the probable causes of the glacial climates. Our knowledge of these matters, still very scanty at best, comes chiefly from the glacial drift sheets in the temperate zones of North America and Europe. Until the use of the radiocarbon method of dating, developed by Libby (1952), it was assumed that the time elapsed since the shrinking ice sheet began to uncover the very young Mankato drift was 25,000 years. Radiocarbon measurements of wood from the Two Creeks peat, immediately underlying the Mankato drift, has shown that the age of the wood is only about 11,000 years (Flint and Deevey, 1951). As yet the radiocarbon method is directly applicable only to organic matter less than 30,000 years old. Therefore the degree of chemical alteration of each of the several drift sheets still furnishes the best chronology, inaccurate though it is. At present the lengths of the glacial ages can only be guessed at, but they are widely regarded as having been much shorter than the interglacial ages. The whole group of four glacial and three interglacial ages together is believed to have lasted roughly one million years.

Because the interglacial times are believed to have been longer than the glacial times, the Arctic has been largely free of a glacier-ice covering during the greater part of the Pleistocene epoch. However, whatever thin soils may have been developed over the surface of the bedrock during the ice-free interglacial ages were almost wholly swept away by the intervening glaciations.

The fluctuations in the mean annual temperatures of temperate latitudes during the Pleistocene epoch seem to have been no more than 10°C.—roughly 8° colder than now during the glacial ages and 2° warmer than now during the interglacial ages. The causes of these repeated fluctuations constitute a much-debated question to which various answers have been given. To me the cause appears to have been

twofold (Flint, 1947). The first factor was a conspicuous world-wide elevation of the lands in general and of many mountain ranges in particular, during the epoch immediately preceeding the Pleistocene and continuing into the Pleistocene epoch itself. This elevation in itself reduced surface temperatures in several ways, though alone it cannot explain repeated temperature fluctuation. The second factor is an assumed fluctuation in the rate at which radiant energy is emitted by the sun. Small present-day fluctuations are currently observed, but the larger fluctuations necessary to form glaciers on the highlands must be assumed. These two factors constitute a reasonable and, it seems, probable explanation of the glacial and interglacial ages, though the second factor is not at present capable of proof.

EFFECT OF GLACIATION ON LIFE

The present-day flora of the North American Arctic includes few endemic forms. There can be little doubt that glacial-age conditions in the glaciated regions almost wholly extinguished the plant cover, which was renewed after each glacial age by immigration from the nonglaciated territory. Probably the principal arctic refuge within which plants with sufficient hardihood survived the glacial ages lay in nonglaciated areas in central Alaska and the adjacent parts of the Yukon. In addition, repopulation of the arctic flora must have taken place to a considerable extent from the belt of country lying south of the southern limits of glaciation.

If, during the glacial times, there was a conspicuous belt of tundra at the southern margin of the ice sheet, there is little evidence of its former presence. Most of the comparatively few exposures of plant-bearing deposits immediately overlying the drift sheets yield floras, dominated by spruce and fir, such as characterize the subarctic forest of the present day. It seems likely, therefore, that the subarctic forest generally reached close to the margin of the ice sheet and that the intervening belt of tundra was narrow. Along the arctic coast between Point Barrow and the Mackenzie River, as already noted, there are suggestions of tree growth, presumably during some interglacial time (unless the wood in question is merely driftwood).

Evidence of the effect of the glacial ages on animal life in the far north is very slight, chiefly because there has been little systematic search for fossils. We can be quite sure that in the glacier-covered areas animal life was completely extinguished. The change was gradual, and took place through slow migration, generally toward the south, as each glacial age developed. During the interglacial ages the glaciated tracts were repopulated with at least some of their former inhabitants. In the arctic regions, as elsewhere, the Pleistocene record is one of repeated wholesale shifts of faunal assemblages rather than

one of conspicuous evolutionary changes in the animals themselves. On the other hand, cold-climate adaptations did appear in such Pleistocene mammals as the woolly mammoth and the musk ox—adaptations that are unknown in the fauna of the preceding Pliocene epoch.

The only extensive Pleistocene mammal fauna thus far collected in Arctic North America comes from the nonglaciated interior region of Alaska and western Yukon. Here, in frozen muck and silt, has been found a rich collection (Frick, 1930; Stock, 1942; Quackenbush, 1909), that includes mammal types both extinct and still living. Among the extinct forms are the short-faced bear (*Arctotherium yukonensis*), dire wolf (*Aenocyon dirus*), great cat (*Panthera atrox*), ground sloths (*Megalonyx* and *Nothrotherium*), camel (*Camelops*), great bison (*Bison crassicornis*), oviboids (*Symbos tyrrelli* and *Boötherium sargenti*), horse (*Equus alaskae*), woolly mammoth (*Mammonteus primigenius*), and mastodon (*Mammut americanum*). Forms still living include lion, peccary, reindeer, moose, bighorn sheep, saiga antelope, Rocky Mountain goat, and the musk ox. The deposits from which the bones are taken have been thought to be of interglacial age, but the assemblage of fossil animals implies such different habitats that both glacial and interglacial faunas are suggested. The ground sloths, peccary, camel, and lion suggest a warmer climate than do the woolly mammoth, musk ox, and reindeer.[7] A more extensive study of the deposits may reveal that they are of more than one Pleistocene date.

Elephant bones and ivory are widespread in northwestern Alaska, together with fossil horse, musk ox, and beaver (Smith and Mertie, 1930, p. 252). Fossil elephant remains, not generically identified, have been found in the Aleutian and Pribilof Islands (G. M. Dawson, 1894; Bell, 1898, p. 374). Teeth ascribed to the Columbian elephant have been found near Edmonton and on an island in James Bay (Bell, 1898, pp. 370, 372). Mastodon bones have been collected from the Moose River near Moose Factory on James Bay and from the district west of Lake Winnipegosis (Bell, 1898, pp. 383, 387; Hay, 1923, p. 166). Fossil musk ox, reindeer, and seal occur in the younger deposits of Ellesmere Island (Hay, 1923, p. 244).

These scattered bits of information hardly provide a firm basis for reconstructing a picture of the arctic plants and animals of the various Pleistocene ages. All we can say with probability is that during the glacial ages the transition zone between tundra and subarctic forest was pushed far south of the Great Lakes region and that during interglacial ages it reached somewhat farther north than it does at present. This particular zone is recorded not only by fossil plants but by the

[7] Even the Columbian elephant (*Mammuthus columbi*) has been reported from Alaska (Bell, 1898, p. 371). If correctly identified, this form would suggest a warmer-than-glacial climate.

distribution of the woolly mammoth, outstandingly an inhabitant of this zone. The various musk oxen generally preferred the open tundra; in contrast, the mastodon and moose inhabited the subarctic forest.

It is well known that many of the large mammals that inhabited northern North America during Pleistocene ages were immigrants from northern Asia via the Bering Strait bridge. The strait is both narrow and shallow. It could have become land at one or more times as a result of a moderate lowering of sea level, such as is known to have occurred during each glacial age when water was abstracted from the sea to build the great terrestrial glaciers. A slight warping of the earth's crust in the Alaska-Siberia region could also have converted this shallow strait into land. However the land bridge may have been made, there is little doubt that it existed and that over it moved a varied fauna into Arctic North America. The arctic region therefore was the corridor through which Asiatic mammals entered the New World.

In contrast with mammals on the lands, the vertebrate life in North American Arctic waters does not seem to have undergone conspicuous changes, probably because temperatures were fairly low during the interglacial as well as the glacial ages. The chief differences thus far noted consist of slight changes in postglacial faunal assemblages. These changes are attributable to increased salinity of the sea water, as dilution with glacial meltwater diminished, and to decreased depth, as continuing crustal uplift elevated the sea floors (Richards, 1937).

Among the mammals that crossed from Asia into North America via the Bering Strait bridge was man. He came in several, perhaps many, groups, over a considerable period of time. Very likely he followed some of the migrating game animals as a hunter.

Just where, or through how long a time, the diffusion of people from Asia into Arctic North America took place, is not known. It has been established that man was well settled in southern North America at the time when the Mankato expansion of the Laurentide Ice Sheet reached its maximum, roughly 10,000 years age. But how long he had been there is still a question. When that question is answered, and when the climatic and ecological circumstances of the whole immigration become known, the arctic region will undoubtedly assume a new and important perspective in the history of man in America.

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The 1944 Eruption of Usu, in Hokkaido, Japan[1]

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[With 6 plates]

Usu Volcano, which had been in a dormant state since 1910, again became active at the end of 1943 and in the following 2 years gave birth to a new composite volcanic dome, or mountain, now called Syowa Sinzan. This dome is one of the rare examples of a volcano whose growth and history have been traced by eyewitnesses from the very beginning of its birth. It is, moreover, unique in the mode of its formation, quite different from Parícutin Volcano in Mexico, for example, also born in 1943, which is an ordinary basaltic cone with lava flows.

The seat of the new mountain was once, like Parícutin, a cornfield, called Kumantubo. It is now covered by numerous boulders and blocks of lava and presents a dismal scene. An upheaval of the ground fissured the cultivated lands at the eastern foot of Mount Usu in the early months of 1944. This was followed by more rapid uplift in the gently sloping and partly cultivated ground adjoining this area on the north early in April. Late in June, while this upheaval was still in progress, volcanic explosions began in the central part of the rising mass which, during the succeeding three months, formed successively seven small craterlets by the ejection of small quantities of pyroclastic materials. About the middle of November the ground in and about the craterlets began to be pushed up en masse by the protrusion of a column of red-hot viscous lava to form several huge lava masses separated by narrow crevices. In the ensuing 10

[1] Revised from a report that originally appeared in Bulletin Volcanologique, ser. 2 vol. 11, 1951.

months this protrusion grew into a massive dome rising above the previously elevated ground.

The final result of this new activity of Usu was a double volcanic dome. The first dome, formed by the upheaval of the old ground, is about 200 meters wide and 1,000 meters in diameter and has terracelike forehills. The second dome, about 150 meters above the first dome and 300 meters in diameter at its base, is formed by the protrusion of a column of primitive viscous lava.

Ever since the discovery of laccoliths by G. K. Gilbert in the Henry Mountains in the United States, the possibility of a local upheaval of the earth's surface has been suggested. Several cases of remarkable upheavals of land about a crater of eruption have actually been observed. Such a case was the eruption of Usu in 1910, when a land mass 3 kilometers long and three-fourths kilometer wide at the northern foot of the volcano, on the shore of Lake Toya, was raised a maxium of 155 meters. The present activity of the same volcano supplies another and more striking instance, proving that a land mass can be domed by the force of the slow rise of an underlying viscous volcanic magma.

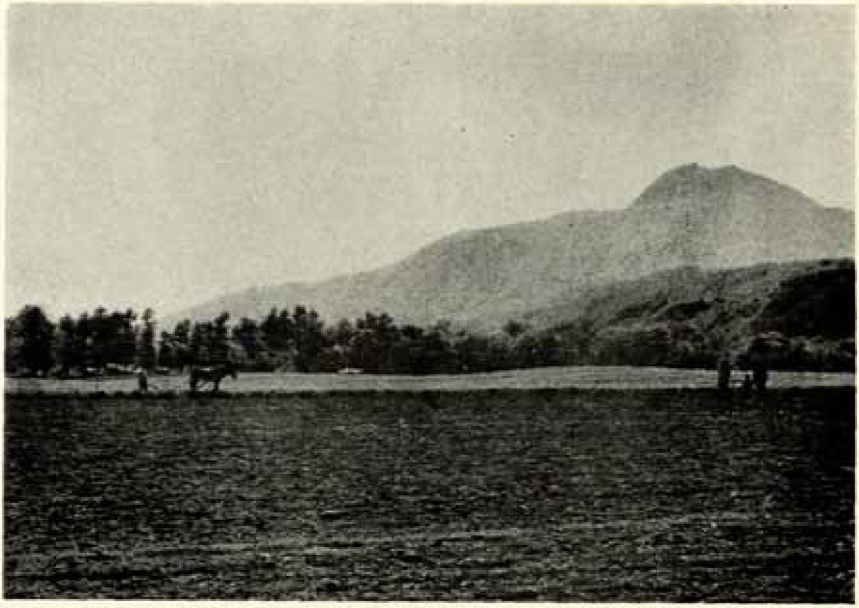
The renewed activity of Usu offered a good opportunity for the study of the mechanism of the birth of volcanoes in which a felsic magma (dacite) participated. Because the country was in the midst of war, the volcanic activity was not investigated by a large, well-organized expedition, but its main events were observed at intervals by persons from several research institutes, including the Earthquake Research Institute and the Geophysical Institute, Tokyo University; the Central Meteorological Observatory; the Geophysical Institute and Petrological Institute, Tohoku University; and the Geological Institute, Hokkaido University.

PREVIOUS ERUPTIONS

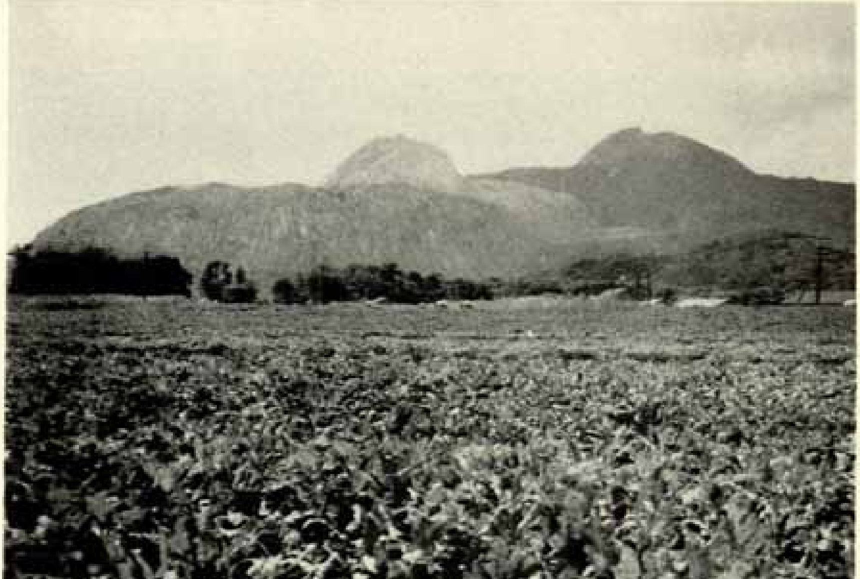
Usu Volcano is situated in the southern part of Hokkaido, nearly at the north end of the Nasu volcanic zone, which traverses the central part of the main island, Honshu, to the middle of the north island, Hokkaido.

According to ancient chronicles, Usu erupted four times prior to 1854—in July 1662, December 1768, November 1822, and March 1853. All these eruptions took place on the upper part of the southern slope of the somma, or large depression crater on the summit of the volcano. A later striking eruption took place at the northern foot of Usu in July–August 1910. No other information concerning the volcanic or seismic activities of Usu Volcano is available for the years since then.

But Usu Volcano had a long history previous to the events recorded in the chronicles. On the basis of studies by Z. Harada and S. Sasaki,

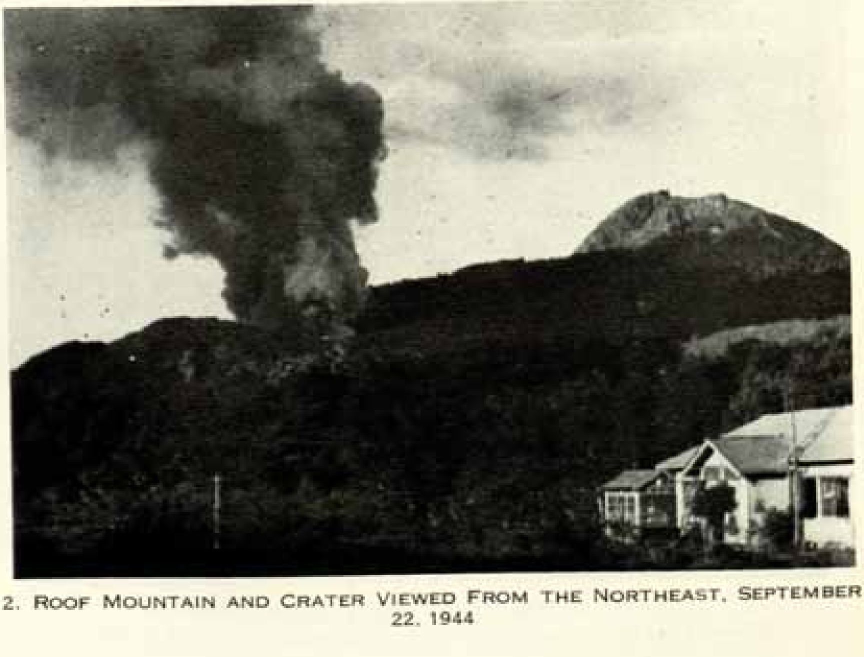


1. KUMANTUBO AND O-USU DOME SEEN FROM NISIKOHAN BEFORE THE PRESENT ACTIVITY



2. SYOWA SINZAN AND O-USU DOME SEEN FROM NISIKOHAN AFTER THE COMPLETION OF THE NEW MOUNTAIN

1. MUD ERUPTION ON JUNE 30, 1944



2. ROOF MOUNTAIN AND CRATER VIEWED FROM THE NORTHEAST, SEPTEMBER 22, 1944

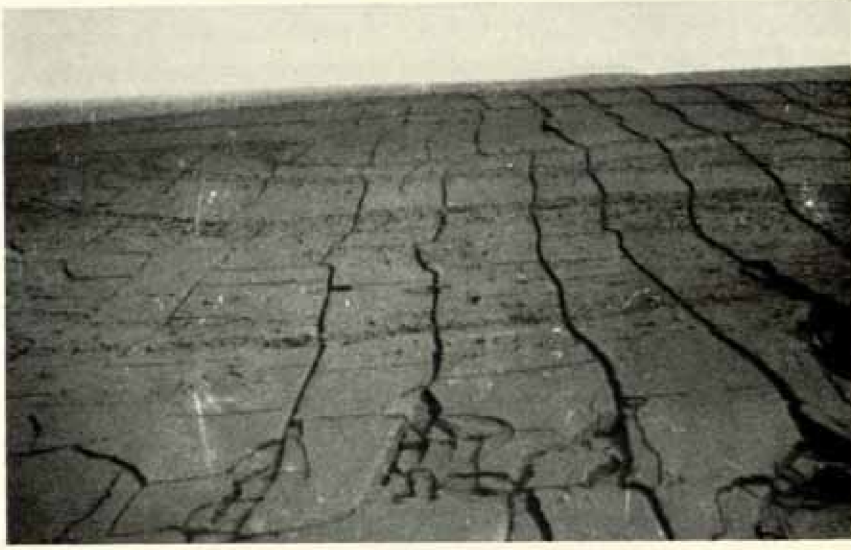
1. THE VIOLENT EXPLOSION ON JULY 3, 1944

2. CRATER AT THE STAGE OF PAROXYSMAL ERUPTION
Viewed from the eastern summit of the Usu Somma, on August 5, 1944.

1. DEVELOPMENT OF THE ROOF MOUNTAIN
Viewed from the north, 500 meters distant, on August 10, 1944.

2. THE NEWLY FORMED MOUNTAIN
Viewed from the south on October 15, 1948.

ROOF MOUNTAIN, OCTOBER 5, 1944



1. CRACKS ON THE RISING AREA (HUKABA), OCTOBER 5, 1944

2. WARPINGS AND FOLDINGS OF SMALL SIZE SEEN IN A GULLY FORMED ON THE FLANK OF THE FRONT MOUNTAIN

the succession of events in the geological history of the area about Usu may be summarized as follows: (1) Effusion of rhyolitic lavas from volcanoes in Miocene and pre-Miocene times; (2) deposition of the Toyoura formation, consisting mainly of green tuff and tuff breccia in Miocene times; (3) effusion of andesite lavas during Pliocene times; (4) deposition of the Rusutu formation (gravel beds, and volcanic ash and pumice) in early Diluvial; (5) uplift of the land in Diluvial times; (6) depression of the Toya caldera in late Diluvial times; (7) formation of the two volcanoes Toya-Nakazima and Usu since the end of the Diluvial, or early Recent.

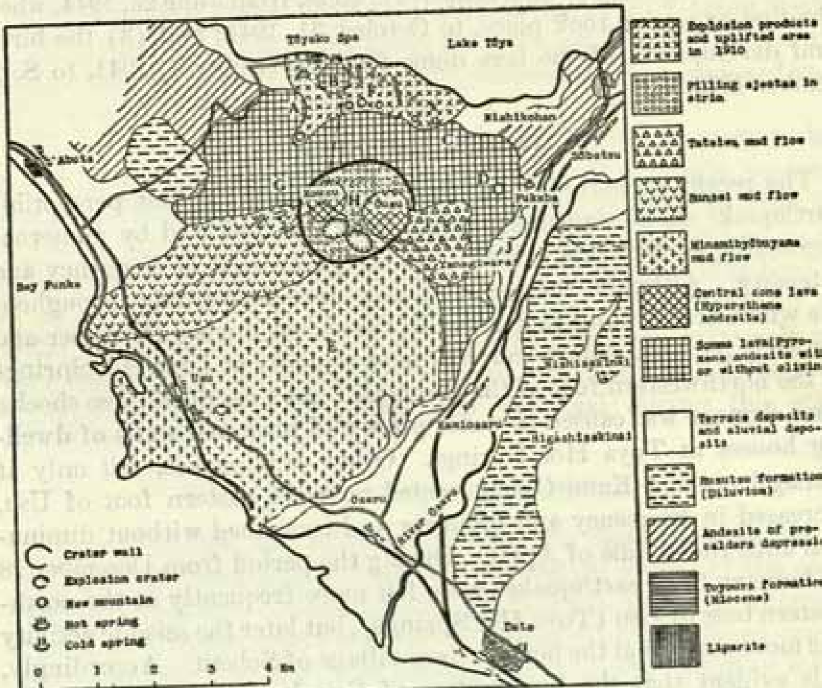


FIGURE 1.—Geologic map of the Usu Volcano prior to the recent activity. Villages: Sobetu (Sobetsu), Hukaba (Fukaba), Yanagihara (Yanagiwara), Kami-Osaru (Kamiosaru), Usu, and Toya Hot Springs (Toyako Spa).

Usu Volcano itself may be considered to have been formed in the following sequence of events: (1) Formation of the main cone and the somma of augite hypersthene andesite lavas and fragmental ejecta; (2) growth of two central cones of hypersthene dacite lava, O-Usu and Ko-Usu, in the somma; (3) an explosion at the foot of O-Usu, accompanied by a mud flow down the southern flank of the main cone; (4) an explosion at the foot of Ko-Usu in 1822, with a mud stream flowing down the southwestern side of the mountain; (5) an explosion at the base of O-Usu in 1853, in which part of the dome was blasted away; (6) a remarkable eruption at the north foot of the mountain in

1910, during which the ground was elevated and 45 new craterlets were developed; (7) the eruption in 1943–45, with the birth of a new mountain, Syowa Sinzan.

The newest activity of Usu began on the evening of December 28, 1943, with a series of severe earthquakes at the northwestern foot of the mountain, and essentially ended in September 1945 upon the completion of the growth of the newly formed mountain. The development of the recent eruption falls into three stages of activity; (1) The pre-eruption stage, from December 28, 1943, when the first earthquake was felt, to June 22, 1944; (2) stage of paroxysmal eruptions, with the formation of small eruptive craters, from June 23, 1944, when the first explosion took place, to October 31, 1944; and (3) the birth and development of the lava dome from November 1, 1944, to September 1945.

PRE-ERUPTION STAGE

The recent catastrophic activity started with the first perceptible earthquake on December 28, 1943. This was followed by numerous succeeding earthquakes, which for 3 days increased in frequency and intensity. Although these earthquakes were perceptible throughout the whole area around Usu Volcano, the shocks during December and the early part of January were felt most strongly at Toya Hot Springs at the northwestern foot of the mountain. As a result of these shocks, some damage was caused to water pipes and plastered walls of dwelling houses at Toya Hot Springs. Other earthquakes, felt only at Yanagihara and Kami-Osaru located near the eastern foot of Usu, increased in frequency and intensity and continued without diminution until the middle of April. During the period from December 28 to January 5 the earthquakes were felt more frequently at the northwestern base of Usu (Toya Hot Springs), but later the seismic activity was more marked at the northeastern village of Sobetu. Accordingly, it is evident that the hypocenters of the shocks shifted from the northwestern or central part of Usu to its eastern foot. By comparing the perceptible areas it was apparent that the earthquakes originating in the first area were deeper than those at the later place. And rumblings accompanying the earthquakes were most strongly heard at the northwestern skirt of the mountain during the initial seismic activity but were more frequently heard in Yanagihara and Kami-Osaru after the hypocenters had shifted toward the eastern foot of Usu.

Soon after most of the earthquakes were localized at the eastern side of Usu, a most remarkable phenomenon occurred. The ground about the epicenter of the shocks began to rise rapidly. The roads, railways, irrigation canals, and the Osaru River and its tributaries

here run from north to south. As a result of the upheaval of the ground that now took place the roads and other passages were cut off by cracks and dislocations in the ground, rendering the area impassable. The underground waters, too, were considerably disturbed. Villagers in the disturbed area no longer had water for drinking and irrigation, while in the adjoining villages the wells and fountains overflowed.

From March to the middle of April the rising area stretched along the Kami-Osaru–Yanagihara road for a distance of 4 kilometers. The greatest rise, as determined by leveling, was 16 meters, or at a rate of 30 centimeters per day. Just at this stage the locus of rising shifted about a kilometer toward the north from Yanagihara to Hukaba and the adjoining cornfield at Kumantubo, where numerous cracks of various size and disposition were formed.

As soon as the rising area had shifted northward, the earthquakes, which are believed to have had an extremely shallow origin, occurred directly below Hukaba. After the middle of June more than 100 shocks per day were experienced there and reached 250 shocks on the day preceding the first paroxysmal explosion, June 23. It is needless to say that during this early stage of activity, which had now endured for 6 months, the inhabitants of the area were extremely uneasy, wondering when volcanic explosions would occur and where the craters would open. The maximum upheaval during this stage reached a height of 50 meters.

STAGE OF PAROXYSMAL ERUPTION

On June 23, 1944, the eruptive column of the first explosion was observed, rising noiselessly from the northwestern corner of the cornfield at Kumantubo. This explosion gradually increased in intensity, hurling mud, ashes, and blocks of rock from a newly formed crater. Simultaneously a mud stream flowed from the crater, pouring into a nearby depression to form a pond of mud and hot water. After several hours of recurring mud flows the eruption came to an end, leaving a calm pool of hot, muddy water in the bottom of the crater. After a few hours of quiescence, steam again began to rise and activity was resumed with the spouting of muddy water. The activity continued variable; at its height blocks were thrown as high as 800 meters.

A strong explosion of similar type occurred on the morning of June 27, when a second vent opened near the first. Activity in the first crater gradually diminished, the muddy explosion shifting to the new vent.

The eruptive activity bore a striking resemblance to the phenomenon of a geyser. It appears that these muddy eruptions were not caused by the pressure of gases emitted by the fresh lava but by the pressure of steam generated by the heat of the new magma. Since

there is no need here to describe the mechanism of geysers, it will suffice to suggest the source of the water of these mud eruptions. According to the inhabitants of Hukaba, a group of springs formerly existed at the village, the water of which was used in the hatching ponds for salmon and trout, because of its constant temperature and abundant supply throughout the year. There was also a fountain that supplied drinking water to the farmers in the cornfield. Both indicate an ample source of underground water in the area.

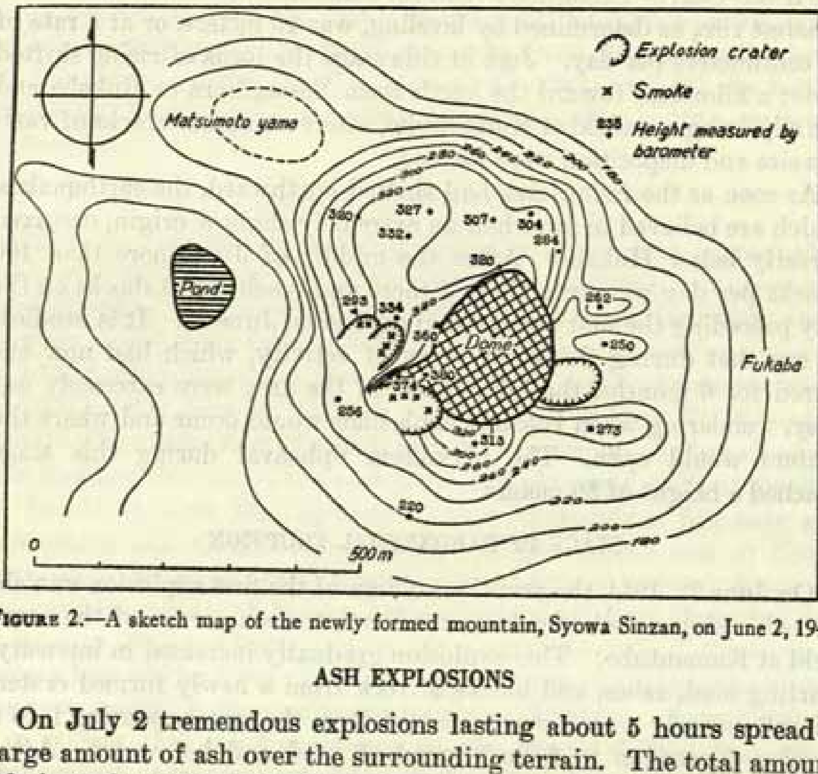


FIGURE 2.—A sketch map of the newly formed mountain, Syowa Sinzan, on June 2, 1946

ASH EXPLOSIONS

On July 2 tremendous explosions lasting about 5 hours spread a large amount of ash over the surrounding terrain. The total amount of ejecta for these explosions was estimated at 2,000,000 metric tons and the energy expended at 1.4×10^{20} ergs. This paroxysmal explosion was, both in volume of ejectamenta and in intensity, more furious than the numerous explosions that succeeded it. Another severe explosion occurred the next morning, ejecting material estimated at 100,000 metric tons over a large area toward the southwest side of Usu. But no new crater was opened by these two explosions. After these marked outbursts, further strong explosions did not occur until July 10, although columns of steam were intermittently observed from Sobetu.

The abundant ash which fell upon the area did much damage to the corn and potato fields, and the inhabitants of Hukaba were compelled to abandon their homes and take refuge in other parts, carrying their household effects with them.

After the early eruptive outbreaks of July, moderate and violent paroxysmal eruptions occurred successively for more than 3 months until October 31. The main explosions were dated as follows: July 11 and 15, August 1, 5, and 26, September 9, 23, and 27, October 1, 16, and 31. On July 11, a new large crater (the third crater) was opened, and thereafter the issuing vapor increased remarkably. The fourth crater was formed on August 26, the fifth one on September 9, the sixth and seventh ones in October. All the craters were arranged in an arc opening to the north. The seven craters opened close to one another; the earlier ones were buried under the detritus and ash of the later explosions, and after September 1944 they hardly retained

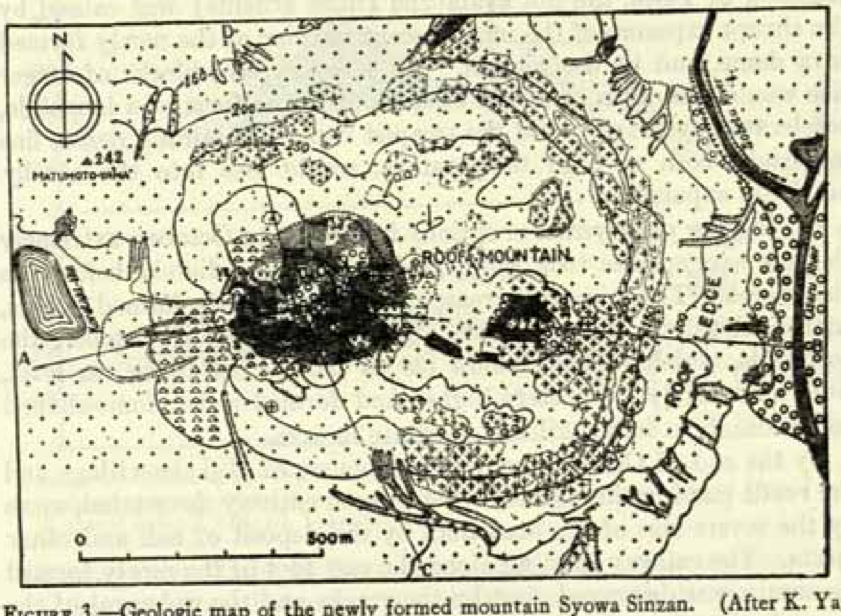


FIGURE 3.—Geologic map of the newly formed mountain Syowa Sinzan. (After K. Yagi and J. Z. Okamoto.)

their original forms. No incandescent bombs and blocks were found, but the blocks, ash, and mud ejected in later eruptions had a higher temperature than the earlier ones of June and July. Several of the craters were dry, indicating a temperature higher than boiling water; others when active always contained hot water.

During August and September, when paroxysmal eruptions occurred, blasts loaded with heavy ash occasionally descended on Nisikohan village, 1 kilometer north of the craters, breaking windowpanes and even occasionally blowing off the roofs of houses. Fortunately, these ash avalanches were not sufficiently hot to ignite wooden materials, but only in this respect did they differ from a "nuée ardente" (hot avalanche). It seems that the genesis of the hot avalanches is mechanically related to the existence of the "belonite" of the "crypto-

dome" of solid lava, as yet unrevealed, and that the phenomenon depended on the direction initally taken by the ejected materials. A plug or cover closing a crater vent prevents juvenile gas from free exit into the air. Accumulated gas sometimes tries to escape from the plug's marginal foot, and accordingly ejected materials may be shot out obliquely. Or the gas may move the plug or the cover by its strong pressure, and squeeze through some newly formed weak zone along the marginal side of the plug. In such cases the initial direction of ejected materials is not vertical, but oblique. There was such an inclined vent in the Ansei crater of Komagatake Volcano, where ash avalanches occurred in 1942. In other cases, as in the 1902 eruption of Pelée, the hot avalanche (nuée ardente) was caused by the abrupt exposure of the incandescent interior of the newly formed lava dome, and its destruction. As a result, lava blocks of larger size would roll down along the steep slope in the form of a landslide, accelerated by gravity, and the escaped vapor, containing dense, fine materials, both at high temperature, would rise into the air by adiabatic expansion.

During the paroxysmal eruptions from July to October, extremely shallow earthquakes took place at Hukaba, immediately below the rising area. The epicentral areas, including the newly formed craters, continued to rise without cease. Toward the end of October, the cornfields, which formerly were 130 to 180 meters above sea level, were now nearly 100 meters higher and formed a flat dome-shaped mountain about half a kilometer square in area.

By the end of October the dwelling houses of Hukaba village and the roads passing through the village were entirely devastated, more by the severe rise of the area than by the deposit of ash and other ejecta. The railway running along the east foot of the newly formed mountain was destroyed, first by the cracks and the upheaval of the ground, then later by a lateral movement from the active center. As a result, the roads and railways were compelled to move 60 meters and 20 meters toward the east. The Sobetu River, running parallel to the railway, was dammed by the upheaval of the river bed to form a temporary lake 1 kilometer long. Owing to the changes in the courses of the running water on and around the rising area, mud streams carrying ash, soil, and detritus, especially after a heavy rain, came down from unexpected directions and ravaged the downstream area.

BIRTH AND DEVELOPMENT OF THE LAVA DOME

Early in November the paroxysmal eruptions ceased, and soon one could see from Nisikohan a black mass close to the site of the craters. By the middle of December this appeared from Sobetu like a peak of pyramidal shape. Ten months after the first

precursor earthquake, the lava at last appeared, extruding as a solid from the earth's surface. It grew more and more as shown in figure 4, its development accompanied by numerous earthquakes and marked deformation of the topography. According to seismometric observations these earthquakes differed greatly from those previously observed. According to observations by Mimatsu, postmaster of Sobetu village, a black conical tower, about 25 meters in height, could first be distinctly made out on January 10, 1945, during the few days when it stood revealed from the enveloping white smoke. Its top part inclined to the north at the end of January but soon tilted to the south.

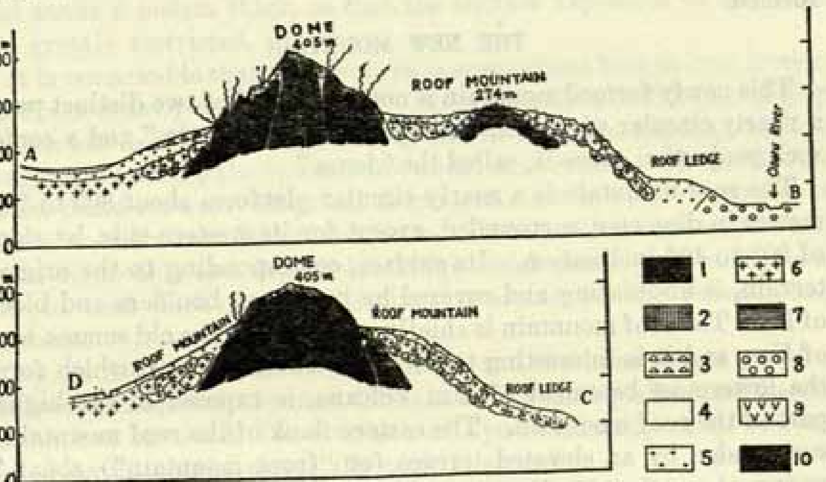


FIGURE 4.—Profile of the new mountain, Syowa Sinzan. 1. Fresh lava; 2 burnt clayish rocks; 3, volcanic ejecta; 4, mud; 5, volcanic ashes; 6, somma lava of Usu; 7. clay; 8, gravel beds; 9, tuff; 10, Takinoue lava.

Glowing lava could be first observed in the crack opened at its northern foot on February 11. As the cone grew larger, spots of red-hot lava could be seen. Especially at night several bright red spots on the sides of the dome gave a wonderful sight to inhabitants of Sobetu village.

Thus the solid lava continued to rise about a meter a day, with marked trepidation during the early stage of development. In May a branch lava mass appeared at its west side. At the southwest side of the dome, a reddish glovelike mass of rock about 50 meters high stood separated from the main body by a fissure at a place where many solfataras vigorously ejected gases. It was called "Sangoiwa" (meaning coral rock) from its form and color. The dome did not grow uniformly as a single mass, but differentially or independently in divided bodies. The division of its top part may have resulted from fissure planes opened in the cap rocks by heavy friction after it was solidified. This new dome is within the arc of the seven craters with the periphery of the dome in contact with the craters.

Owing to the severe explosions, thick tuffaceous debris, clayey material, and other ejecta accumulated on the surface of the upheaved area covering the greater part of the dome's surface. Where lava was exposed the color of its incandescence indicated a temperature of at least 1,000° C.

Numerous severe earthquakes in the pre-eruption stage took place at depths ranging from 3 to 7 kilometers under the southern side of the Usu volcano, but with the development of the eruption, the depth of origin of the earthquakes came progressively nearer the earth's surface at the small area where the craterlets opened and the lava dome formed.

THE NEW MOUNTAIN

This newly formed mountain is now composed of two distinct parts: a nearly circular platform, called the "roof mountain," and a conical rock projection above it, called the "dome."

The roof mountain is a nearly circular platform about 800 to 1,000 meters in diameter, surrounded, except for its western side, by slopes of 20° to 40° inclination. Its surface, corresponding to the original terrain, is undulating and covered by numerous boulders and blocks of lava. The roof mountain is chiefly composed of the old somma lavas of Usu, and it is interesting to note that Takinoue lava, which forms the lowermost basement of Usu Volcano, is exposed in the highest part of the roof mountain. The eastern flank of the roof mountain is surrounded by an elevated terrace (or "front mountain") about 70 meters above the old alluvial plain of the Osaru and Sobetu Rivers. Toward the middle of July 1944, when the paroxysmal eruption was at its height, it was noticed that the ground around the base of the new mountain began to rise abnormally. It developed rapidly and the horizontal displacements in the radial direction were accelerated as the lava dome grew. In May 1945, a hill in the form of a ring or a half-ring, the "front mountain," was formed at the margin of the roof mountain. Judged from morphological investigations, the "front mountain" is built up more completely at its eastern part, which includes the former ricefields of soft material, than at the other part, which is formed of firm materials such as the Usu lava flows and the Takinoue lava. Obviously, the hill of ring form was built by pressure acting laterally from the center of disturbance, the intrusion and protrusion of viscous lava, and resulted in an abnormal upheaval nearly 20 meters high, but still retaining the original surface of the ground. At gullies formed in the front mountain, we can observe the warping, folding, and the thrusts of small size caused in this manner.

The dome of extrusive lava is situated a little west of the center of the roof mountain and is about 150 meters higher, its summit being 405 meters above sea level. Its eastern side is an abrupt precipice with

huge slabs of lava surrounding a central core, like the scales of a lily corm about the central bulb. The thick layers covering the surface of the dome have numerous concentric cracks, emphasizing its shell-like structure. The surface shows many parallel striations caused by the intense friction experienced during the upheaval of the dome.

The greater part of the dome is covered by thick layers of clayey materials, which are mostly burnt into a reddish-brown bricklike sub-tance by the heat emanating from the lava. Tuffaceous beds are also common. The presence of gravels on many parts of the dome deserves special mention; even the very summit is crowned with beds of gravels and sands 2 meters thick, so that the surface exposures of new lava are greatly restricted.

It is remarkable that the new lava is everywhere broken into irregular fragments by numerous cracks, suggesting that it did not solidify in situ but had consolidated during its rise from the depths, and was fragmented during the upward movement of the mass. On the surface of the dome are many elliptical or irregular crevices several meters in diameter, with incandescent interiors. These crevices emit vapors and gases vigorously and deposit beautiful bluish-green, yellowish-green, purple, and dark-gray sublimation products on the surrounding surfaces.

By the end of 1945 the roof mountain and the dome ceased growing and were completely formed. Then, too, the earthquakes and the deformations subsided. The eruption of Syowa Sinzan, which had endured for 22 months, essentially came to an end.

Since the completion of the new mountain, no further remarkable change has been experienced. A small explosion occurred on May 2, 1948, forming a new craterlet. The smoke that issued from the new mountain diminished gradually, and in August 1946 we could climb up on the dome. Sulfataras around the dome became less active, but several fumaroles with vapor temperature of 95.5° were formed at the south side of the roof mountain. Temperature of the new lava, however, seems to be not much lower than at its first appearance. Ishikawa measured the temperature of the dull red lava exposed at the west foot of the dome in November 1950 at 780° C.

Small depressions were gradually formed at several places on the roof mountain. Loose materials on steep slopes of the roof mountain sometimes fell down to its foot. And after the cessation of volcanic activity, water began to well out from the side of the front mountain, near the site of the old springs at Hukaba. Its temperature measured about 15° C. in November 1950. A pond that formed in a depression near Matumotoyama in June 1944 has evaporated.

No noticeable earthquake in the area has been felt since October 1945, but weak tremors were recorded 29 times in 1951 on a seismograph placed at Sobetu village by the Sapporo Meteorological Observatory.

PETROLOGIC NOTE

The new lava is a hypersthene dacite with sporadic phenocrysts of andesine and hypersthene in a fine-grained groundmass. In spite of a silica content as high as 69.7 percent, phenocrystic quartz is absent, and its place is represented by the abundant presence of quartz and cristobalite grains in the groundmass.

It is noteworthy that the new lava closely resembles the lavas of the central cones O-Usu and Ko-Usu, in mineralogical as well as chemical composition, though there is a long time interval between the formation of these domes. These dome lavas are, however, entirely different from the more mafic somma lava of Usu Volcano, a basaltic andesite with silica content as low as 53 percent. Lavas of intermediate composition are lacking completely in this volcano.

It is unknown how the felsitic dome lavas were derived from the original mafic magma. It is evident that there has been no differentiation within this felsitic portion of the magma reservoir throughout this long period since the formation of Ko-Usu dome. This is striking when compared with Parícutin Volcano lavas, which show a noticeable change in chemical and mineralogical composition within the course of only a few years.

The preceding description shows that the recent eruption of Usu has many striking features, such as series of severe earthquakes, marked topographical deformation, violent explosions, and extrusion of solidified mass of juvenile lava. Such remarkable characteristics, quite unusual in many other volcanoes, are common in this volcano. as is clear from the inspection of previous eruptions.

Snails and Their Relations to the Soil[1]

By Harley J. Van Cleave

Department of Zoology, University of Illinois, Urbana

[With 1 plate]

THE CHANGING EARTH

Popularly, streams and lakes or ponds are very commonly thought of as relatively permanent features of the earth's countenance, even though physiography teaches that they are but temporary aspects in a series of successional changes between water and dry land. By erosion, soils are washed into lakes and ponds from the surrounding land. Ultimately, the shallow water at the margin with its fixed vegetation encroaches upon the open waters which, at the same time, are becoming shallower through the accumulation of silt at the bottom of the lake. If these processes continue, the lake is gradually transformed into a marsh or swamp land and there results an intermediate stage between the purely aquatic habitat and dry land. Snails of many species thrive in the shallow waters at the margin of a lake or swamp where vegetation is abundant enough to provide them with a constant food supply. They live their relatively limited life span, and after death the empty shells accumulate in the ooze at the bottom of the pond. The lake bottom thus becomes an admixture of soil and organic debris, washed in from the surrounding land, and the resistant remains of the organisms that once lived in the lake. Ultimately, in the processes of nature or by will of man, the lake may revert to dry land. Then the content of the old lake bottom is exposed for easy inspection and the shells which have been accumulating for ages are exposed to view. The interpretation of these deposits of limy shells involves an understanding of the varied conditions under which snails live and likewise consideration of the agencies responsible for their accumulation in the soil, where their influence on agriculture has long been recognized. Regarding the significance of lime in agriculture, Truog (1938) has said, "It is not too much to say that it must be considered the very backbone of profitable crop production, soil con-

[1] Reprinted by permission from the Biologist, vol. 34, Nos. 1–2, September–December 1951.

servation, and permanent agriculture in the humid regions of this country."

IMPORTANCE OF LIVING SNAILS

Biologically, snails have many important relationships in addition to their effect upon their physical environment. They have long been recognized as important elements in food chains. Living chiefly on vegetation, they in turn become food for fishes and a great variety of other animals and thus in an endless cycle they keep much of the organic material of which their bodies are composed passing from one incarnation to another and at the same time much of the material from their dead bodies and their wastes are continuously bridging the gap, back and forth, within the bodies of plants and animals.

In their capacity as necessary hosts for the digenetic trematodes, which live as parasites in all the classes of vertebrates, snails have peculiar biological significance.

It is an indisputable fact that food wastes passing through their digestive tracts have significant effect upon the organic content of the soil and of the water in which snails live, but there have been no quantitative studies paralleling the classical work of Charles Darwin on the effects of earthworms in the production of vegetable mold. Interesting as these aspects of relations between snails and their environment may be, they will be omitted from the present discussion and attention will be restricted to the role played by snails through the addition of lime to the soil.

RELATIONS TO SURROUNDINGS

While some species of snails have very broad tolerance of conditions under which they will live, there are many species which are sharply limited by their physical surroundings or by their necessity for association with particular types of living things. Thus, among the water-dwelling snails, some of the forms of the old genus *Physa* which breathe through a lung sac can prosper in water that is heavily poluted by sewage (*Physa anatina*) and at times become abundant even in sewage-treatment plants (Brown, 1937). Other forms of the same genus (e. g., *Physa gyrina hildrethina*) occur only in pools, while still other closely related forms (*Physa gyrina gyrina*) are characteristic inhabitants of more swiftly moving streams. Among the snails that dwell on the land, there is even more pronounced limitation to the conditions under which many species will live (Baker, 1939). One species (*Discus patulus*) is invariably associated with woodlands in which beech and maple trees are growing. This species is considered as an invariable associate of what ecologists term the beech-maple forest. It is not that *Discus* feeds upon either beech or maple, but the

conditions of soil and of climate favorable to these trees are at the same time the set of conditions demanded by *Discus*. There are many other snails which are usual associates of particular kinds of plants and animals because the latter provide the natural food for the snails. One of the commonest woodland snails of central Illinois is *Mesodon thyroidus* which will feed upon a wide variety of vegetation but becomes particularly thrifty and abundant where woods nettles grow in profusion (Foster, 1937). Some land snails have feeding habits wholly different from that just mentioned. For example, *Haplotrema concavum* is carnivorous and lives largely upon the flesh of other snails. Physical surroundings are less important in the life of the last-mentioned species, just so long as a supply of snails is available to serve as food.

Many land snails are indicators of the physical conditions under which they live (Baker, 1921). Their soft bodies are best served by relatively high atmospheric moisture so that moist ravines sheltered from the direct rays of the sun are particularly favored habitats and many species become especially active at night and during rains. Some of the land snails (as, for example, some species of the genus *Succinea*) are so exacting in their demands for moisture that they live a truly amphibious existence, remaining only a portion of the time out of water and always close enough to water to be able to return to it if they become too dry. Even when snails live in exposed situations, such as in open fields and along railroad embankments, or under desert conditions, they tend to conserve their moisture by crawling under objects lying on the soil, or even live in the roots of the vegetation. Further, many land snails are able to cut down evaporation from their bodies, when inactive, by secreting a tough membrane, the epiphragm, effectually sealing over the aperture of the shell.

Whether in the water or on dry land, the shells of dead snails often resist destruction for a long period of time and under proper conditions they accumulate in extensive deposits (pl. 1). By the study of these deposits, which often represent forms of bygone geological age, the student familiar with the habits of living snails is often able to analyze the conditions under which each species probably existed. In fact, at times it has been possible for the special student (Baker, 1937) to postulate the general temperature range and something of the ecological conditions of the environment under which the animals which produced the dead shells lived, even though that might have been at some remote time, several thousand years in the past. With a considerable degree of confidence, Frank C. Baker (1937) postulated the climatic conditions and the ecological associations for some of the molluscan faunas of the ice age. In his studies

of shells of the Pleistocene age, he found among Illinois deposits some species which are identical with forms dwelling in the same area today but he also found some shells representing species the only living varieties of which are today found at latitudes considerably farther north. A knowledge of the habits and living conditions of present-day forms has been helpful in interpretation of the conditions under which similar forms of past ages probably existed.

When the Chicago Drainage Canal was constructed, Baker (1930a) was able to study the evidence of the molluscan life in old glacial Lake Chicago, the forerunner of Lake Michigan, and could demonstrate fluctuations in lake level, changes from swampy to lake conditions, and from deep to shallow water.

The glacial advances and retreats of the Pleistocene Epoch profoundly affected all life, including the terrestrial as well as the fresh-water Mollusca (Baker, 1930b). Following an advance of the ice sheet, all life was killed or was driven southward, causing a commingling of arctic, subarctic, and temperate life south of the border of the continental ice sheet. During the warmer interglacial intervals, this life again returned to the territory left bare by the retreating ice just as rapidly as the vegetation essential to its existence became established. In the series of repeated invasions by the glaciers, there were successive decimations and repopulations in the same area. The reoccupied territory, left bare by the retreating ice, was usually entirely different from that previously existing. Such radical changes had profound influence upon the kind of plants and animals that could become successfully established in the area. Changed climatic factors also contributed to the altered conditions for life. Under the combined action of these factors, some species became exterminated while others were stimulated to undergo variations which led to the production of new species. For the glaciated part of the United States, it is estimated that 74 percent of the mammals of preglacial times are extinct. It should be remembered that 1 to 5 million years are estimated as the period in which this was accomplished. Of the fresh-water, gill-bearing snails, 13.8 percent are extinct; of the fresh-water pulmonates, 8.3 percent, and of land snails, 11.1 percent. By way of summary for the entire area, about 7.8 percent of all animal species became extinct.

In acid waters, snails and mussels are almost wholly lacking and the small numbers of unthrifty individuals which are encountered in either natural or artifically produced acid waters have either extremely thin shells or, if the acidity is due to recent pollution, the limy material is eaten away wherever the organic covering has been broken by natural abrasion or by accident.

LIME SUPPLY

Mollusks are so intimately dependent upon a lime supply for the fabrication of their limy shells that among fresh-water forms some of the poorest molluscan faunas are encountered in the areas poor in limestone but rich in granite. This correlation is so close that collectors of land shells have long recognized limestone cliffs and outcrops as particularly favorable collecting sites for living land snails and streams flowing through limestone or through soils rich in lime as particularly productive of snails and mussels.

Snails, living and dying in the same place, little influence the lime supply, for the limy material which they use is sooner or later returned to the soil again, and the lime cycle is repeated over and over within and without the shells of the living snails. When the shells disintegrate, the lime which had been temporarily entrapped is again returned to the general store. No quantitative studies have been made to determine if there is any dissipation of the available lime supply in this cyclic utilization of lime by the living organisms.

The late T. D. Foster (1937) recorded for a flood-plain forest along the Sangamon River in Illinois the presence of 2,630 individuals of one species of land snail (*Mesodon thyroidus*) per acre. Though there are about a score of species of snails present in this same area, the one species is the most abundant and relatively the most important so far as production and utilization of lime is concerned. On the basis of weights which Foster calculated, about 169 pounds of *Mesodon thyroidus* are present on each acre of the woodland studied. Of this weight, about 140 pounds are of snail flesh and about 29 pounds are of dry shell. This does not represent the entire annual accumulation but rather the amount present at one time in the shells of living snails as determined by sampling methods. Because of the cyclic fluctuations in abundance of all types of organisms, figures of this sort have but relative value, for at another time either greater or less abundance might be demonstrated (Foster and Van Cleave, 1937). However, the presence of the snails is an indicator of available lime supply and in turn their shells after death return lime to the soil as potential material for use by other organisms.

To a much smaller degree, the shells of zonitoids, pupids, and other minute snails living in grasslands utilize the available lime and return it to the soil, although quantitative studies on the losses in the transfer and by action of ground water have never been determined.

SHELLS NOT STATIONARY

In referring to the intimate relationship between the molluscan fauna and their physical and biotic environment, attention should be

directed to the the fact that deposits of shells are found in environments different from those in which they originated. There are many factors responsible for this fact, but the chief of them may be grouped under two headings: (1) translocation of the dead shells and (2) physiographical changes of the earth's surface.

TRANSLOCATION

Water, wind, ice, and human agency are the chief factors in translocation and accumulation of dead shells in areas other than those in which they originated on the bodies of living snails. Both recent and remote geological times have contributed to the stock of shells now found in the soil and, through the agencies for translocation, shells from past ages may become elements in the construction of soils at the present time where they may be mixed indiscriminately with shells recently produced.

Water.—Many limestone deposits include fossil shells of snails and clams of long-past geological ages along with the remains of multitudes of other organisms having limy skeletons, such as the corals, certain types of Protozoa, and echinoderms. These components of the sedimentary limestones provide deposits of lime utilized by modern mollusks in the production of their shells. These same limestone deposits are utilized commercially in the production of limestone for agricultural purposes. Here the shells of snails, clams, protozoans, and corals of geologically ancient oceans provide a renewed source of lime on lands where weathering, leaching, and cropping have depleted the natural supplies. Much of the lime now available in fresh water thus comes from the geologically old lime deposits, largely of marine origin. Ground water, flowing over and through the limestone, dissolves the lime and makes it available for the aquatic animals in fresh water.

Another type of translocation by water is that in which running water carries dead shells and lays them down in a new location either at the bottom of a lake or pond or along the margins of streams. If the water carries much abrasive material the shells may be ground fine and mixed with the mud and sediment, though often they are uninjured. When the course of the stream is changed, through natural or human agency, or when the bed of a lake or swamp is drained, the accumulated shells are exposed as marl deposits and attract more attention than they could while covered with water.

Surface waters on rolling lands often tend to wash dead land shells into gullies or against obstacles such as the stems and roots of grasses where definite windrows accumulate awaiting decomposition or further translocation by other agencies. In fact, an examination of gullies and hillsides often reveals to the collector dead shells which

ACCUMULATION OF DEAD SNAILS ALONG THE ILLINOIS RIVER

Sooner or later the lime of the shells will be returned to the soil.

have been washed down from higher grounds where colonies of living snails may be located.

Wind.—Winds are likewise effective agents in transporting dead shells. The evidences in support of this statement come largely from past geological times. Fine sands and shells from some prehistoric dustbowl were carried great distances by the winds and were then laid down in the characteristic deposits called loess. These formations, rich in fossil snail shells, are highly desirable agricultural lands.

Ice.—The fauna of the loess probably lived under conditions practically the same as those prevailing today. Many of the larger species where inhabitants of forested areas along river bluffs. Some of the smaller species doubtless lived in open woods or thickets, or even on the open prairies as they do today. In southern Illinois, the loess deposits are entirely different from those in the northern part of the State with respect to the molluscan fauna. In the southern loesses, there are large land shells abundantly represented although these are almost wholly lacking from the loess of northern Illinois and their place is taken by minute species. A part of this variation is probably due to climatic differences, similar to and even exaggerated above those existing today. Loess deposits in northern Illinois probably began soon after the retreat of the ice and under such conditions that the climate would have been considerably colder than at present. Geologists seem convinced that isotherms were displaced southward during considerable part of the period while loess was being deposited. Under these conditions it would be highly probable that temperature conditions in central and southern Illinois at that time were more nearly what we find now in central or southern Michigan and Wisconsin.

Human agency.—Shell heaps of enormous size have often been formed by human agency. Pre-Columbian Indians, especially along the coast, used shellfish for food and some tribes produced very extensive beds of shells at their camp sites. Even in the Central States, primitive Indians left extensive accumulations of snail shells in some places (Baker, 1936), probably having utilized the snails as food. In like manner, shells and shell artifacts are scattered through the mounds produced by the race of mound builders, though not in the quantities characteristic of the kitchen middens.

On top of natural deposits of shells, there are frequently found shells the presence of which would entail extreme changes in temperature and in the extent of the oceans if they were natural deposits. In dredge cuts in northern Illinois, there have been found fairly good samples of shells that have never been known to live anywhere except in Florida and many of these are strictly marine species. The only logical explanation of this condition is that Indians left them at camp

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The Ecology, Evolution, and Distribution of the Vertebrates

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The geological history and the accompanying evolution of the vertebrates are the products of the interaction of a large number of various factors the final results of which are seen in the diversity, distribution, and interrelationships of the several classes that we see at the present time. These factors are both geological, in the broad sense, and biological. The geological factors may be briefly summarized as follows:

Ever since the first appearance of the vertebrates, conditions on the land areas have undergone constant and continual change. Warm lands have become cool or even cold, while cold lands have become warm, especially in the Northern Hemisphere, as, for instance, in areas affected by the advance and retreat of glaciers. Well-watered lands have become arid and arid lands fertile. Seasonal and diurnal variations in temperature and humidity have increased or decreased. Mountains have arisen, greatly affecting conditions in their immediate vicinity, especially on their leeward sides, and other mountains have been eroded down. Land areas have been partially submerged, resulting in separate land masses or islands of various sizes, and isolated lands have been joined. Isolation by the dismemberment of an extensive land area, or the appearance of other barriers, provides an opportunity for such terrestrial animals as may still be able to find adequate support to form new centers of evolution and to develop new subtypes, while the joining of previously separated land masses, as, for instance, North and South America, or North America and Asia during the Pleistocene, permits the exchange of faunas, with resulting competition.

These changes are continuous. The well-known floral and faunal changes in North America as a result of the advance and retreat of the great glaciers are a familiar example. Even within historic times we have records of far-reaching changes, especially in North Africa, the Near East, and India, and comparable changes are now

proceeding rapidly in Central and South America and parts of Africa as a result of human activities.

Provided that they still remain extensive enough to support vertebrate life, land waters—lakes and rivers—are far less variable in the conditions necessary for that life than the dry land, especially in tropical and temperate regions. The temperature range is less, seasonal variation is much smaller, and diurnal variation negligible. Humidity is constant, although there may be considerable diversity in the amount and character of the dissolved salts and gases.

Of the biological factors influencing the development and evolution of the vertebrates the most important is food. The food of all terrestrial vertebrates, including those of the land waters, is both animal and vegetable. The vegetable food consists of plants, predominantly the leaves, seeds, fruits, and twigs of green plants, though all other parts of green plants and all other plants are eaten, and in addition plant detritus with its accompanying saprophytes, algae or fungi.

Of terrestrial animals both on land and in shallow fresh water by far the most abundant both in species and in numbers are the insects, which as a group are mainly feeders on plants or on detritus, though many are predaceous or parasitic. The insects are supplemented by the chiefly carnivorous spiders and their allies and, especially in water, by the mollusks, which are largely plant or detritus feeders. The other invertebrate groups play a relatively unimportant part on land.

Plants, insects, spiders, and mollusks occur wherever there is an adequate supply of water, permanent, temporary, or even irregular, and under all conditions of temperature and humidity except permanent frost. All are known since the earliest evidences of a terrestrial fauna. Although the plants and insects have varied greatly from time to time, and at present vary greatly from place to place, all plants and all insects in the present discussion may be considered as single units from the point of view of their availability as food for vertebrates.

In the sea the extreme importance of diatoms and some allied plants and of the planktonic animals that feed upon them, especially such crustaceans as copepods and mysids and such mollusks as pteropods, has long been recognized, as has the importance of detritus, especially in the abysses. But it has not been generally recognized that the vertebrate food chain on land is similarly based upon green plants and arthropods supplemented by mollusks and to a lesser degree by other invertebrates, with detritus playing an important, though here a relatively minor, part.

The essential parallelism between the food chain in the sea and the food chain on land is obscured by the fact that by far the greatest

part of the vegetation of the sea is microscopic, too small for any vertebrates to consume directly. The coastal algae and marine flowering plants such as eelgrass are eaten by manatees, dugongs, some sea turtles such as the green turtle, and a large lizard, but these are quite insignificant when considered in relation to the marine vertebrates as a whole.

On land the green plants are large—large enough to be consumed directly by vertebrates of any size without the intervention of intermediaries. The earliest vertebrates appear to have been almost wholly, perhaps entirely, carnivorous, parallel with the present vertebrates of the sea, and the fresh-water fishes have remained almost wholly carnivorous. In the strictly terrestrial classes, the reptiles, birds, and mammals, plant-feeding types soon appeared. These remained relatively few in the reptiles, although some of the vegetarians attained gigantic size, but soon became numerous in the warm-blooded birds and especially the mammals so that today the dominant, and also the largest, terrestrial mammals are plant feeders, and very many of the birds, including all the largest, are vegetarians, at least as adults, though many are throughout their lives.

As important as the amount and type of available food are the physical conditions that must be met in order to make use of it. For animals as a whole the maintenance of an adequate supply of water within the body is the chief physical requirement. For aquatic animals there is no difficulty here, though certain physiological adjustments must be made for the varying amounts of salts in solution. Amphibious animals living either in water or in a humid atmosphere are almost as independent of the necessity for water control as the aquatic. Strictly terrestrial animals, especially those living in dry regions, must develop special mechanisms for the conservation of water within their bodies, replenishing the water usually by intermittent drinking.

The next most important factor affecting vertebrate life is illumination, necessary for certain physiological processes, heat, and vision. In the completely dark depths of the sea the fishes either possess luminous organs or feed on luminous creatures. It is possible that the widespread luminosity among all types of marine animals may be related to the fulfillment of certain light requirements in the absence of light from the sun.

The oxygen requirements of vertebrates appear to be of minor significance in their effect on evolution. Oxygen occurs abundantly in water as well as in the air and is taken up by means of gills or internal lungs, or through the skin.

All terrestrial vertebrates must be capable of active locomotion in a medium much lighter than their bodies. This is usually effected by

two pairs of strong articulated limbs terminated by movable digits, though in some cases, as in snakes, in other ways.

It is generally agreed that animal life originated in water, whether in marshes, estuaries, or the sea is unimportant. But what is important is that the basic evolutionary pattern was aquatic and that this pattern has been carried over with modifications onto the land, the animals most perfectly adjusted to strictly terrestrial conditions being vertebrates, arthropods, and mollusks (gastropods), representatives of the three dominant and most diversified groups of aquatic animals.

Against this background vertebrate life must develop, hold its own, or perish. Most important for the continued existence of animal types through geological and other changes is their ability to produce new forms capable of meeting new conditions—that is, their capacity for evolution. The evolutionary history of any animal type is dependent upon three coordinate factors: First, the inherent ability to produce variants or mutants, either micromutants differing but little from the parent stock, or macromutants differing more or less widely from the parent stock; second, the existence of an adequate physiological balance in the mutants that are produced; and third, the ability of such mutants as may appear to find a habitat where the food supply is adequate, the physical and chemical surroundings are suitable, and there is no insurmountable competition.

In the course of constant geological and other changes new habitats appear from time to time, and established habitats become unsuited for the existing fauna. The ecological vacua thus created may be filled by modifications of the local fauna, or by immigrants from outside that possess or develop adaptations suited to the new conditions. Thus the large grazing and browsing mammals of the South American Pliocene and Pleistocene have given way to a great number of highly diversified rodents, and the ecological niche occupied by the great marine reptiles of the past has been preempted by the present mammalian cetaceans.

Each vertebrate class has the potentiality of developing new forms capable of occupying a considerable range of habitats. Thus each class includes a considerable number of peripheral or fringe forms arranged irregularly about a generalized central type. The five vertebrate classes, fishes, amphibians, reptiles, birds, and mammals, including their peripheral types, may be briefly characterized as follows:

CHARACTERISTICS OF VERTEBRATE CLASSES

FISHES

The fishes were the first vertebrates to appear as fossils, in the Silurian. Fishes are all aquatic, though a number, both fresh-water

and marine, can live for a considerable time out of water, and some fresh-water fishes, as the common eel, occasionally or regularly pass overland from one body of water to another at night. In contrast to amphibians, fishes are both fresh-water and marine, many groups being represented both in the sea and in lakes, ponds, and streams. Many fishes, as salmon, shad, and sturgeon, live in the sea but run up streams to spawn. These also have relatives living permanently in fresh water. A few fishes, as the common eel, some gobies, and some galaxiids, live in fresh water but spawn in the sea. Many marine fishes freely enter fresh water, as do some porpoises, the white whale, and some seals, and some will breed there if cut off from the sea, as for instance the shark and the sawfish in Lake Nicaragua. Some fresh-water fishes freely enter brackish or even salt water regularly or occasionally, like the northern trout and the pike. Some fishes, like the sticklebacks, are especially characteristic of brackish water.

Fishes are predominantly carnivorous, the smaller fresh-water species feeding mostly on aquatic insects with such other invertebrates as may be available, the larger on other fishes with an occasional amphibian or land vertebrate. In the larger bodies of fresh water a very few feed on plankton, especially when young. A few fishes feed largely on detritus, some are omnivorous, and a very few are vegetarian. A small number, as *Myxine* and some very small catfishes, are parasitic, and in the ceratioid fishes the diminutive and defective males are attached to the females as external parasites. These are the only parasites among the vertebrates.

Fishes may be scaled, completely or partly, or naked. Some have large, usually scattered, dermal scutes.

The limbs are modified into paired fins of which the posterior pair may be situated anywhere between the anus and throat, modified as a sucker, or absent; rarely both pairs are absent as in the snakes and some lizards.

Breathing is almost entirely by covered gills, but three fresh-water types, in South America, Africa, and Australia, have functional lungs and a number develop internal structures that function as lungs in addition to gills. A number of fishes will drown if deprived of access to air. An air bladder is commonly present.

The body temperature is not controlled but approaches that of the surroundings. Some fishes become torpid and feed but little during the winter. Others bury themselves in the mud at the bottom of ponds. One in Alaska and Siberia (*Dallia*) remains frozen in solid ice through the cold season. A number of tropical fishes estivate in the mud in the bottom of dried-up bodies of water, usually in a mud cocoon like some amphibians. Fresh-water fishes are much lessensitive to temperature changes than marine fishes.

Like amphibians, fishes are not dependent on bright illumination and many live in the oceanic abysses far below the maximum depth of penetration of sunlight. A considerable number live in the dark depths of deep lakes, such as Lakes Baikal and Tanganyika, and in the dimly lighted deeps of other lakes. As in the case of amphibians, some fishes are found only in caves and in deep underground waters. Most fresh-water fishes avoid bright light, and many are active mainly at night. Many marine fishes are luminous, usually developing special light organs, but this is not true of any fresh-water fishes, although a tree frog and a lizard are luminous.

A number of fishes in several widely different groups are provided with electric organs.

Most fishes produce eggs that are fertilized outside the body, but a number are viviparous with internal fertilization. The eggs, always soft and usually with a gelatinous covering or in a gelatinous matrix, sometimes in a horny capsule, are laid in strings or masses, or scattered individually. Many fresh-water fishes prepare more or less elaborate nests which are usually tended by the males, more rarely by the females or by both sexes. In a number of species in widely different groups the males carry the eggs about in their mouths until they hatch, as do some amphibians. In one South American catfish the eggs are carried about embedded in the skin of the under side of the female, parallel to the case of the Surinam toad (*Pipa*). In a few fishes the young are tended, but not fed, for some time by the male, more rarely by the female. None of the fresh-water fishes pass through a widely different larval stage such as is characteristic of many marine fishes. The common eel (*Anguilla*) has such a stage, but it is passed in the sea and the form of the adult is acquired by the little eels before they enter fresh water.

AMPHIBIANS

The amphibians were the second group of vertebrates to appear as fossils, in the Carboniferous. At the present time they are represented by three groups, the caecilians, the salamanders, and the frogs and toads. Amphibians live in swamps, marshes, bogs, ditches, ponds, the quiet backwaters of lakes and rivers, and in humid regions usually near permanent or temporary water. Some, including the largest, are wholly aquatic. Others are largely or entirely terrestrial, living on moist land, in damp woods, or under stones or logs in damp areas, being active chiefly at night or during rains when the humidity is highest. Many toads live in relatively dry regions, but these are active mainly at night when the temperature drops and the humidity rises. Some amphibians are chiefly subterranean, appearing at the surface only under certain conditions, often at long intervals, and

others are wholly subterranean. A few salamanders are confined to caves or to underground waters. Nearly all terrestrial amphibians are strictly aquatic in their early stages.

In marked contrast to the other vertebrates, the amphibians are strictly confined to fresh water, only a single Indian frog frequenting somewhat brackish water.

As adults most amphibians feed on insects, some adding other invertebrates, but the large frogs and toads often eat small mammals or birds, some of them other frogs. Some amphibians feed largely or wholly on vegetable detritus, and nearly all feed on algae and detritus in the larval stages, reversing the cycle of such birds as sparrows which are insectivorous when young, seed eaters as adults.

All amphibians are naked, with a moist skin, least moist in some of the toads. They breathe by means of external or covered gills or by internal lungs, many by gills in the early stages and by lungs later, and also through the skin. Some may, as adults, retain the larval form, breathing by gills, or acquire an alternative form, breathing by lungs.

Most amphibians have four functional limbs terminated by separate digits, which may be subequal, or the hinder pair much enlarged and used for jumping or swimming, or absent. In some the limbs may be greatly reduced, and in one group they are wholly absent.

The body temperature is uncontrolled, and is approximately that of the surroundings. In temperate regions the frogs, toads, and salamanders hibernate, usually in water. In very dry regions some frogs and toads estivate deep in the soil, encasing themselves in a hard cocoon of earth mixed with mucus.

Amphibians are not dependent on bright illumination, and most of them are nocturnal, or at least avoid the sunlight. A few (as *Hyla micans*) secrete luminous mucus.

Except for touch, the senses are poorly developed, although some frogs and toads have good eyesight, and the fact that many are highly vocal indicates good hearing.

Most amphibians lay eggs which are fertilized either outside the body, in some cases long after deposition, or internally. The eggs are soft with a gelatinous covering or in a gelatinous matrix and are deposited individually or in masses or strings, usually in water or in situations where the young will fall or be washed into water, rarely in moist situations on land. A few species make more or less elaborate nests. In other species the eggs are carried about on the back of the female or in the mouth or wrapped about the body of the male until they hatch. The young are not tended after hatching. A few salamanders and two African frogs are viviparous.

Except for the viviparous species all amphibians pass through a superficially fishlike limbless larval stage, with vertical fins but no fin rays, in water. In some wholly terrestrial frogs the eggs are laid

on land and the larval stage is greatly abbreviated, the eggs giving forth perfect, though very small, frogs.

REPTILES

The reptiles were the third class of vertebrates to appear as fossils, in the late Carboniferous. At the present time they are represented by only four groups, rhynchocephalians (*Hatteria* or *Sphenodon*, confined to New Zealand), crocodilians, turtles, and snakes and lizards. Most reptiles are strictly terrestrial with their activities confined wholly to dry land, especially in hot or more or less arid regions, but the crocodilians, many turtles, and some snakes are amphibious, feeding largely or wholly in water though laying their eggs on land. The sea snakes are wholly aquatic. A few lizards and some snakes frequent the banks of streams or other bodies of water and enter the water freely though they do not feed in it. In warm regions a few blind and legless lizards are subterranean. No reptiles live in the dark recesses of extensive caves.

The great majority of reptiles are carnivorous, the smaller ones feeding mainly on insects, the larger ones on vertebrates, especially mammals and fish. Some of the snakes have highly specialized feeding habits, as the egg-, slug-, or snake-eating snakes, and the venomous snakes. The only other vertebrates with a venomous bite comparable to that of the venomous snakes are certain shrews among the mammals. The green turtle, the land tortoises, the large iguanas in tropical America, Madagascar, and Fiji, and a few other lizards are vegetarians; but the green turtle, up to a length of about 10 inches, is carnivorous. One iguana in the Galápagos Islands feeds on submerged seaweeds. Some turtles are more or less omnivorous.

All reptiles are completely covered with scales or plates. The skin is dry.

Most reptiles have two pairs of functional limbs adapted to walking, running, swimming, or climbing, but in some the anterior or posterior pairs, or both pairs, may be absent. The limbs when present usually end in a group of functional digits which in climbing lizards may be long. In some turtles, particularly the sea turtles, the limbs may be modified as paddles, the forelimbs being much larger than the hind limbs and the chief organs of locomotion, as in the penguins among the birds. Some lizards and snakes, like flying squirrels, *Galeopitheous*, and a few other mammals, are modified for gliding through the air, but without modification of the limbs.

The body temperature of reptiles is uncontrolled, approximating that of the surroundings. Some snakes, lizards, and turtles and the American and Chinese alligators hibernate during the winter, most of the turtles and the alligators in water.

Reptiles are highly dependent on abundant light, all of them for heat, and those with heavy skeletons, like most turtles, or with heavy dermal scutes, like the crocodiles, for skeleton formation. Most reptiles are strictly diurnal and are especially active in bright sunlight, but the geckos are mainly nocturnal. The poisonous snakes hunt their food mostly at night, but many, if not most, of them, like our rattlesnakes and copperheads, sun themselves by day. In one lizard from Trinidad the males have a row of luminous organs along each side, recalling certain luminous fishes.

The senses as a rule are not highly developed, but in lizards and turtles sight is usually good, and in snakes and some lizards there is an acute sense of smell.

Most reptiles lay eggs with either a tough and flexible or a hard and rigid shell. These may be scattered individually, deposited in batches in a hole and covered up, or, as in the case of the crocodilians, placed in a compost heap to be hatched by the heat of decomposition as is done by some megapodes among the birds. The eggs are usually abandoned, but are sometimes tended. The female python coils about her eggs and incubates them, her body temperature rising during the period in incubation. But few reptiles tend their eggs and these generally lose interest in the young when they appear. Some snakes and a few lizards are viviparous. Sea snakes give birth to their young in the water. Fertilization in the reptiles is always internal.

All reptiles breathe by means of internal lungs. Some sea turtles have supplementary anal breathing.

BIRDS

The first known birds, exhibiting many reptilian features, are from the Jurassic. All birds nest on land, and most birds are terrestrial, the most widely distributed of all terrestrial vertebrates, found on many islets and even on some good-sized islands, as some of the Aleutians, where no other vertebrates occur. Many birds are amphibious, obtaining all their food in fresh or salt water, or in both, as the mergansers, loons, grebes, many kingfishers, and others, particularly the sea birds. A few birds are oceanic, visiting land only to breed, as do the sea turtles and the fur seals.

The earliest known birds, which were relatively large and possessed teeth, a long jointed tail, and other reptilian features, were presumably carnivorous. At present the dominant and by far the largest group of birds is that of the perching birds or Passeres which includes at least half of all the known species. As in the case of the modern rodents, the dominant mammals, they are all small, or at least none are very large. They are primarily insectivorous, but many are more or less omnivorous and others are plant feeders, at least as

adults. Included in the Passeres are the finches and sparrows and their relatives, forming the largest and most highly specialized group. The sparrows and finches, like the other perching birds, feed their young on insects but as adults are vegetarians, mainly seed eaters. This is the reverse of the conditions seen in most amphibians which are alga and detritus feeders when young, insectivorous as adults. Other perching birds as adults are vegetarian, omnivorous, or insectivorous. As seeds are to be found everywhere at all seasons the sparrows and their relatives are the most generally and widely distributed of all terrestrial birds. They are able to exist under the most severe conditions if sufficient food and water in usable form is available, and therefore are not so strongly migratory as most other birds.

All sea birds are carnivorous, feeding on crustaceans, fish, and squid. The gulls are mainly scavengers; some feed more or less extensively on large insects, especially grasshoppers and cicadas. Shore birds feed on crustaceans, insects, and small fish, some at certain seasons eating berries. Most of the smaller land birds feed wholly or mainly on insects. All the very large birds, the ostriches, rheas, emus, and cassowaries, are vegetarian, as are the parrots, pigeons, swans, geese, and many ducks, as well as a number of species in other groups. Gallinaceous birds are chiefly vegetarian, though most of them eat insects, especially when young. Vultures eat carrion, and some birds, like the ravens and crows, are omnivorous. Predatory birds feed chiefly on mammals, fish, reptiles, and other birds. Many birds, as woodpeckers and hummingbirds, have highly specialized feeding habits, and others, like the hoatzin, will eat only a certain kind of food. Very few birds store food, and these only casually. Birds are much more likely to gather shiny, brightly colored, or otherwise attractive objects, a habit shared with certain rodents.

All birds are completely, or almost completely, feathered, with the legs scaled. The beak suggests that of the turtles. Some, as the vultures and a number of gallinaceous and struthious birds, have the head and neck naked. The skin is dry.

All birds have two pairs of limbs of which the posterior pair is always well developed, at least in the young, adapted for perching, clinging, climbing, running, swimming, or grasping prey, with usually four, sometimes only three or two, clawed digits, three or all four of which may be connected by a web. The anterior pair is usually modified to form wings which in most birds serve for aerial transport, though in individual species in many different groups they are reduced in size and useless for flight, and in such birds as ostriches, rheas, emus, cassowaries, and kiwis, which have greatly enlarged and powerful legs like kangaroos, leaping rodents, and frogs, they are very greatly reduced, especially in the three last. In the penguins the anterior

pair is modified to form paddles parallel to those of the seals, cetaceans, manatees, and sea turtles. In agreement with the sea turtles but in contrast to all other aquatic birds the forelimbs of the penguins provide the chief motive power in swimming.

In contrast to the uniform flapping flight of bats the flight of birds is highly diversified. The large sea birds are gliders, which seems to have been true of most of the flying reptiles of the past. Most vultures, most eagles, many hawks, and some other large birds spend much of their time soaring. Many birds alternately flap and sail. Most small birds progress by continuous flapping in direct, or, less commonly, undulating flight. In some birds the flight is feeble and they are reluctant to take wing, though a few of these, as some rails, undertake surprisingly long migrations.

The power of flight enables birds to live or to take refuge in trees secure from most predators except other birds; to escape enemies by taking to the air; and to take advantage of the concentrated life in the warm light summer season in the far northern or southern regions, retreating toward, to, or even through the Tropics in the dark winter. It also enables tropical birds to wander about from one feeding ground to another in a distant area. Although strictly diurnal in their usual activities, many small birds migrate by night. Many of the larger birds, as geese and swans, migrate by day or night. In contrast, the bats, though capable of sustained flight, fly only by night except to cool themselves in hot weather, and few are known to migrate.

All birds maintain a controlled high body temperature, higher than that of mammals, and are continually active throughout their lives except during sleep. A very few birds have vicarious or even fairly long torpid periods simulating hibernation, but none estivate.

All birds breathe by internal lungs and all have more or less extensive internal air sacks.

In all birds sight is the dominant sense, in some, as in owls and goatsuckers, supplemented by acute hearing. In owls, which have the most highly developed ears, the plumage is very soft, possibly so as not to interfere with auditory perception, in addition to concealing their presence. Thus birds are dependent on adequate illumination. Their visual range is broad, including the longer wavelengths, not visible to us, by means of which they find their way through fog, and possibly in the case of crepuscular birds, the shorter, to us invisible, wavelengths commonly used by insects. No birds are blind. Although some take refuge or nest in caves, holes, or burrows, their essential activities are always carried on outside.

The breeding habits of birds are singularly uniform. Most birds nest in trees or on the ground, singly or in colonies, sometimes making a community nest, but many lay their eggs in holes or burrows. The

eggs of all birds are provided with a rigid calcareous shell. Nearly all birds incubate their eggs. The young are hatched in widely different stages of development in the different types, and are usually tended and fed for some time by both parents or by the female, in a few only by the male. A few birds, as the megapodes, deposit their eggs in compost heaps as do alligators and crocodiles, or in warm sand, like the sea turtles, and leave them to be incubated by the heat of decomposition or of the sun.

MAMMALS

The first definitely known mammals, showing certain resemblances to reptiles, are from the Jurassic. Although mammals are primarily terrestrial, living on or above the surface of the ground, a number, such as water rats, muskrats, beavers, otters, the hippopotamus, and the platypus, are amphibious, the seals are aquatic but bear their young on land or on ice floes, and the cetaceans are wholly aquatic, bearing their young in the water. A few mammals, such as the moles, marsupial moles, mole rats and some other rodents, are largely or almost wholly subterranean.

The earliest known mammals were small and presumably insectivorous, and many of the later types such as the present-day insectivores and bats were and are primarily insectivorous, with the larger carnivores feeding chiefly on vertebrates.

At present, by far the largest mammalian group is that including the rodents, very nearly all of which are exclusively, or almost exclusively, vegetarian. With these should be considered the ecologically similar but very much smaller group including the rabbits, hares, and pikas. Most of the very large terrestrial mammals such as the elephants, rhinoceroses, hippopotamus, tapirs, horses, the giant panda, the great apes, kangaroos, and manatees, and all the hoofed animals except for a few omnivorous pigs are exclusively vegetarian. These large vegetarians are very delicately adjusted to their environment. They require a constant and abundant supply of food and water under a limited range of physical conditions, and are very sensitive to environmental changes greater than those that can be met by limited migrations. A large number of rodents and the pikas store food to tide them over unfavorable seasons, and many rodents hibernate. Some rodents and some lemurs estivate. These characteristics, together with their much smaller size and vastly superior reproductive powers, give the rodents a great advantage over the larger herbivores. Strictly vegetarian and more or less omnivorous species are found in greater or less numbers in all the other mammalian groups except the seals and cetaceans.

All mammals are covered with hair, or at least have traces of hair, although the elephants, rhinoceroses, some pigs, and manatees and

dugongs, and the cetaceans have the hair covering greatly reduced, in the last two vestigial or absent in the adults. In many rodents and in the echidnas the hairs may be transformed into spines. In the pangolins they are grouped into broad scalelike structures. Some mammals have bony plates in the skin which in a few, as the armadillos, may form a complete bony dorsal covering. The skin is more or less moist because of the occurrence of sweat glands.

In some shrews a pair of salivary glands is transformed into a pair of poison glands from which ducts lead to the lower incisors, recalling the poison apparatus of the venomous snakes.

Most mammals have two pairs of functional limbs terminating in separate digits. The limbs may be subequal, or either pair may be enlarged or reduced. In the seals the limbs are modified into paddles without separate external digits, and in the cetaceans and manatees the forelimbs are paddle-shaped, the hind limbs absent.

The bats have the forelimbs developed as wings and all of them are capable of sustained and long-continued flight. Most of the bats are rather small and insectivorous, but some, including the largest, eat fruit, and a very few feed on other bats, birds, fish, or the blood of mammals and birds. A number of mammals in widely different groups, as the flying squirrels, flying phalangers, and *Galeopithecus*, have the skin of the body greatly extended laterally forming a parachute by means of which they are able to make long glides through the air, like the gliding lizards and gliding snakes.

In most mammals the body temperature is constant and high, commonly well above that of the surrounding air, at least at night. But the temperature of the monotremes fluctuates in response to that of the surroundings. Some mammals, as some rodents, some bats, and some northern bears, hibernate with reduced body temperature, or at least become torpid, in very cold weather. Some mammals estivate in dry hot weather.

A few bats migrate south in autumn, and a few large mammals such as the bison withdraw southward in winter, at least in some areas. In winter many mammals wander widely in search of food.

In the mammals all the senses—sight, hearing, smell, and touch—are highly developed, though very unequally in the different groups.

Mammals are not dependent on bright sunlight, which most of them avoid. Some live in caves, holes, or burrows, but feed in the open. A few, largely blind, are subterranean.

All mammals except the egg-laying platypus and echidnas are viviparous. They are divided into the placentals, in which a placenta is present and the young at birth are at least fairly well developed, and the marsupials, in which there is usually no placenta and the young are born in an extremely undeveloped condition; in

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the marsupials a pouch is usually present into which the very small young find their way, attaching themselves to one of the mammae. In some bandicoots, as *Perameles*, a placenta is present, although the young are born in as undeveloped a condition as in the other marsupials.

ANALYSES

In the preceding reviews of the features of the several vertebrate classes it is evident in each case that some of the features are distinctive and diagnostic, fundamental attributes of the classes, while others represent specializations in various directions, attributes of what may be called fringe or peripheral types. The fundamental characters of the vertebrate classes seem to be the following:

Fishes.—Aquatic animal feeders of fresh or saline waters subsisting mainly on insects and other invertebrates, especially crustaceans; with a covering of scales, naked, or with dermal scutes; body temperature uncontrolled, approximating that of the surrounding water; breathing by gills, sometimes supplemented by lunglike structures or, rarely, lungs; not dependent on bright illumination; oviparous, the fertilization usually external, the eggs soft, usually with a gelatinous covering or in a gelatinous matrix, sometimes in a tough capsule, attached, less commonly scattered or pelagic; commonly with a larval stage widely different from the adult; a few are viviparous.

Amphibians.—Amphibious animals of exclusively fresh waters or very humid regions; animal feeders subsisting chiefly on insects, though some are detritus feeders, especially in the larval stages; naked, with a moist skin; body temperature uncontrolled, approximating that of the surroundings; breathing by external or covered gills or by lungs, or by both at different stages, and also through the skin; not dependent on bright illumination, and largely nocturnal; oviparous, the eggs fertilized externally, soft, usually in water, with a gelatinous covering or in a gelatinous matrix; mostly with a fishlike larval stage breathing with gills in water, later more or less terrestrial, breathing with lungs; in a few the young are born with the adult form.

Reptiles.—Terrestrial animal feeders subsisting mainly on insects, the largest on vertebrates; with a complete body covering of scales; the skin is dry; body temperature uncontrolled, approximating that of the surroundings; breathing by internal lungs; highly dependent on bright illumination, especially from the two ends of the spectrum, chiefly diurnal, but the geckos mainly nocturnal and the venomous snakes feeding mostly at night; oviparous, with internal fertilization, the eggs with a tough or hard and rigid shell; some are viviparous; young at birth resembling the adults.

Birds.—Predominantly terrestrial animal feeders, subsisting chiefly on insects, but many are vegetarians, at least as adults; with a body

covering of feathers (modified scales) and scales (on the legs); the skin is dry; body temperature controlled and constant, high—higher than in the mammals; breathing by internal lungs, and with extensive internal air sacks; highly dependent on adequate illumination, especially in the visual band of the spectrum; mostly diurnal, a few crepuscular, none truly nocturnal; oviparous, with internal fertilization, the eggs always with a hard and rigid shell; the young are hatched in various stages of development.

Mammals.—Terrestrial animal or vegetable feeders, or omnivorous; with a body covering of hair; with sweat glands in the skin; body temperature controlled and constant, nearly always higher than the surroundings, at least at night, but in the monotremes variable and in many types reduced during hibernation; breathing by internal lungs; independent of bright illumination; diurnal or nocturnal; viviparous, except for the oviparous monotremes, with internal fertilization, the young born in various stages of development and fed for a varying length of time by a secretion from the body of the mother.

The basic ecological features of the vertebrate classes may be graphically expressed in the form of a key, as follows:

KEY TO THE BASIC ECOLOGICAL FEATURES OF THE VERTEBRATE CLASSES

a^1. Dependent on a constant and abundant supply of external water; aquatic or amphibious; independent of bright illumination; cold blooded (Ichthyopsida).

- b^1. Strictly aquatic in fresh or saline waters of relatively large size ____ **Fishes**
- b^2. Aquatic in strictly fresh waters of small dimensions or temporary, or if of large dimensions more or less choked with vegetation, at least when young; as adults mostly emergent in regions of high humidity ____ **Amphibians**

a^2. Independent of a constant and abundant supply of external water; terrestrial.

- b^1. Highly dependent on sunlight (Sauropsida).
  - c^1. Cold-blooded but active and requiring a relatively large amount of heat provided by sunlight; terrestrial ____ **Reptiles**
  - c^2. Warm-blooded, independent of heat from the sun; terrestrial, with the power of flight ____ **Birds**
- b^2. Largely independent of sunlight; warm-blooded ____ **Mammals**

In order to illustrate the preceding key it is desirable to designate definite types that may be tentatively regarded as generalized representatives of the several classes. These types will serve to indicate in each class an approximation to the basic or fundamental complex as contrasted with the fringe or peripheral forms. Just what the best representative of each class would be is, of course, a matter of personal opinion. The following are suggested.

Fishes: Bowfin (*Amia*).
Amphibians: Salamanders and their relatives (Urodela).
Reptiles: Lizards (Lacertilia).
Birds: Tinamous (Tinamidae).
Mammals: Insectivores (Insectivora, especially the Tenrecoidea).

Under the present highly diversified conditions on the earth the mammals, the most adaptable of the vertebrates, are the dominant type. The mammals are independent of external water, bright illumination, and heat from the sun; they have an insulating covering of hair (or blubber) and sweat glands; all the senses are highly developed; they have powerful limbs adapted for walking, running, jumping, climbing, swimming, or flying, and strong jaws with diversified teeth. Mammals are viviparous, the female in most cases raising the young in a nest or den and always feeding them with a secretion from her body. In the marsupials the young are born in a very undeveloped condition and find their own way to the mother's pouch where they attach themselves to a nipple; there is therefore no necessity for a resting period for the females while producing young. The marsupials are thus especially well adapted to survive in areas subject to drought or other adverse conditions when the daily feeding range of the individuals must be greatly increased. The rodents are small, and most of them very prolific. This enables them to withstand adverse conditions, for they can become restricted to very small areas and when conditions improve promptly spread out again. The young of the hoofed mammals, the cetaceans, and some others are born essentially as small adults so that they are able from the first to accompany the mother, or the herd, in its wanderings.

Quite as successful as the mammals are the birds. Ecologically the birds are complementary to the mammals rather than competitors. Birds and mammals agree in being warm-blooded with an insulating coating of feathers or hair; in being independent of a continuous supply of external moisture; in having usually more or less helpless young that require feeding and tending; and in being largely plant feeders, at least as adults. Birds differ from mammals in their dependence on strong illumination, in possessing the power of flight (shared, however, with the bats), in being oviparous, in feeding the young, though with material collected by the adults instead of with a secretion from the mother, and in being toothless, which somewhat limits their feeding range as compared, for instance, with rodents, the dominant mammals.

Whereas mammals are predominantly ground feeders with a few arboreal, aerial, and aquatic types, birds feed mainly in bushes and trees though many feed on the ground or in water, and some are aerial feeders. Except for the large herbivorous types mammals are mainly nocturnal, birds wholly diurnal or crepuscular. The bats consume the

same food as certain birds, and both often hunt together in the evening. But except for the large fruit bats, which have good eyes, the bats are guided by hearing and not by sight and are active on very dark nights when the so-called nocturnal birds are wholly inactive.

The power of flight enables the birds to populate, permanently or temporarily, many regions where mammals are few or absent such as swamps, marshes, offshore rocks and islands, and in the summer the rich marshy tundras of the far north. In such regions they are often incredibly abundant. The necessity for incubating their eggs for a considerable time forces most birds to scatter in more or less widely separated pairs during the breeding eason, though they may be highly gregarious at other seasons. But in areas where there are few or no other creatures that would feed on the eggs or young, such as inaccessible marshes or swamps, on isolated rocks and islands, on steep cliffs or gravel banks, or on the Arctic tundra, birds, especially the larger birds, often live in colonies which frequently are of immense size. Some of the smaller tree-living birds also nest in colonies usually in specialized nests, as the apartment nests of some weaverbirds or the long pendent nests of the oropendolas. Some birds nest under the protection of bees or termites, and a number in widely different groups make no nests but deposit their eggs in the nests of other birds.

The geological history of birds appears to be parallel with that of the mammals, and the geographical distribution of the two classes is roughly similar. Both groups show a high degree of adaptation to present conditions with many plant feeders. In both groups there are few ancient types still persisting.

Reptiles differ from mammals and birds in being cold-blooded. They agree with birds in having a dry skin and in being highly dependent on sunlight. More dependent on sunlight than birds, nearly all live in very sunny regions, especially more or less arid regions. Nearly all reptiles lay eggs as do the birds, but the young emerge from the eggs completely developed, except sexually, and are not tended or fed by the parents. Nearly all modern reptiles are carnivorous, largely insect feeders, like most birds, at least when young. Except for being cold-blooded the reptiles in the broader aspects of their ecology are more similar to the birds than to any other vertebrates. Morphologically they have been united with birds under the term Sauropsida. But some reptiles are viviparous and some are wholly aquatic, like the sea snakes. Some have horny beaks like birds, others uniform or more or less diversified teeth. In the past a number had the power of flight, their wings being essentially like those of the mammalian bats, not like those of birds.

Whereas since the Eocene the mammals and birds have undergone continuous and great diversification with adaptations for the con-

stantly changing conditions and are today the dominant terrestrial vertebrates, the history of the reptiles has been quite different. In the Mesozoic the reptiles were in a high degree of development and specialization, and highly diversified. There were, among others, gigantic, chiefly herbivorous dinosaurs, great marine reptiles of various kinds, and several types of flying reptiles, together with the more familiar crocodiles, turtles, and snakes. The development of the reptiles reached a culmination in the Cretaceous, but toward the end of that period most of them disappeared. Up to the end of the Cretaceous there were 19 orders of reptiles, but since the earliest Tertiary, when there were a very few reminders of the exceedingly rich Mesozoic fauna, only four of these have persisted, the Rhynchocephalia, represented only by *Sphenodon* or *Hatteria*, the tuatara of New Zealand, the crocodilians, confined to tropical and subtropical regions, the turtles, and the Squamata, including the lizards and snakes.

The world-wide and practically simultaneous disappearance of most of the reptiles, including all the giant terrestrial herbivorous and carnivorous dinosaurs, the flying pterodactyls, and the large ichthyosaurs, plesiosaurs, and mososaurs, was followed by the evolution and development from mammalian stock of a great variety of types occupying the former habitats of all the terrestrial reptiles, with the cetaceans replacing the marine types. Presumably the place of the flying reptiles was taken by certain birds.

Any satisfactory explanation of the causes of the disappearance of the dominant reptiles and their rapid replacement by mammals must be applicable equally to all the continents and to all the oceans as well. In view of the dependence of practically all modern reptiles, especially those with heavy calcareous skeletons or dermal scutes such as the hard-shelled turtles and the crocodilians, on abundant sunlight, and the independence of sunlight characteristic of the largely nocturnal mammals, it would seem that a radical change in the amount or character of the sun's radiations reaching the earth may well have been the chief factor in the disappearance of the reptiles leading to the dominance of mammals.

During the Cretaceous there was extensive inundation of the land areas by the sea, the continents were much isolated, and the climate presumably was warm and uniform. At the end of the Cretaceous there seems to have been a great upheaval of the land in both the northern and southern hemispheres. This was accompanied by local and intermittent volcanic activity throughout the Eocene in the Rocky Mountain region, Central America, the East and West Indies, and southern Europe. Any marked increase in the land area would mean a corresponding increase in dust in the atmosphere, inorganic dust from arid areas, and pollen and organic dust from heavily vegetated

regions. Volcanic activity would also produce a large amount of atmospheric dust.

Of interest in regard to the latter is the information on the eruption of Krakatoa between Sumatra and Java on May 26–28, 1883. In this eruption the ejected column of stones, ashes, and dust was estimated to have reached a height of 17 miles or more. The finer particles were diffused over a large part of the earth, and were carried over North and South America, Europe, Asia, South Africa, and Australia. In the Old World they spread from Scandinavia to the Cape of Good Hope. And this is the record of only a single isolated eruption.

With increase in land areas and intermittent volcanic eruptions the illumination of the surface of the earth would be considerably altered. Whereas the extensive inundation of the land areas during the Cretaceous would presumably clear the atmosphere, giving rise to conditions especially favorable to reptiles, increase in land areas, especially in connection with volcanic activity, would make conditions unfavorable for reptiles while at the same time permitting the rapid increase and diversification of mammals.

In their present distribution the land reptiles fall into two main groups. The strictly terrestrial forms, such as the lizards and most snakes, follow largely the distributional pattern of the mammals except that they do not range so far north or south and, possibly because of their greater age, there are among them more striking cases of discontinuous distribution resulting from extirpation over a large portion of the original range. In the mammals examples of discontinuous distribution are the camels, originally North American but now represented only by two wild species in South America, two domesticated species in South America, and two in Asia, one of which has been introduced into Africa; the tapirs, once widespread but now restricted to tropical America and the Malay Peninsula, Sumatra, and Borneo; and the fresh-water dolphins of South America, India, and China. In the Pleistocene many mammals spread from Asia into North America, but apparently the connection between these continents was too far north to serve as a highway for any reptiles. Some examples of discontinuous distribution in the reptiles are: The Gila monsters (Helodermatidae), Texas, Arizona, Mexico, and Borneo; the large herbivorous iguanas, tropical America, Madagascar, and Fiji; the pythons, Old World and western Mexico; and the burrowing *Amphisbaena*, South America and Africa. The true land tortoises (*Testudo*) are found in all tropical and warm temperate regions except Australia.

The amphibious reptiles, the crocodilians and fresh-water turtles, present a more generalized picture owing to the fact that aquatic habitats are much less variable than terrestrial, the chief differential

here being extratropical changes in temperature. True crocodiles, appearing first in the Cretaceous, still occur throughout the Tropics. The gavials and alligators appear in the Miocene; the gavials are now confined to southern Asia, the alligators (with the caymans) to America, with one alligator in southern China. Among the fresh-water turtles the soft-shelled type, appearing first in the Cretaceous, still occurs in Asia, Africa, and America, as far north as Canada; the Pelomedusidae are found in Africa and South America; and the snake-necked turtles in South America, Australia, and New Guinea.

The amphibians occupy a very specialized habitat, essentially as constant as the aquatic and much less variable than the terrestrial. They differ from fishes, with which they are sometimes united under the term Ichthyopsida, in being intolerant of salt water and as adults living largely out of water in humid regions. Their very restricted habitat seems to have limited their possibilities for evolution. No fossil caecilians are known. Caecilians are now confined to South America, the East Indies, and Ceylon, their distribution recalling that of the tapirs. Frogs of the modern type appeared in the Jurassic and salamanders in the Miocene. Frogs and toads occur everywhere except in the extreme north, though toads are absent from Australia and Madagascar. Frogs are especially well represented in South America, but poorly represented in North America. The South American frogs have many affinities with those of Africa, while others are allied to those of Australia.

The salamanders and their relatives, on the other hand, are almost wholly confined to the temperate regions of the Northern Hemisphere, especially North America, to which a dozen or more genera, including the curious *Siren* and *Amphiuma*, are confined. Their distribution recalls that of the North American fresh-water fishes, especially the ganoids. Numerous instances of discontinuous distribution suggest that the present distribution of the amphibians is in large part a restriction of a once more or less world-wide distribution that was attained very long ago. Examples are, the Pipidae, the most aquatic of the frogs, found in South America and Africa; the tailed or ribbed frogs (Liopelmidae), found in New Zealand and from northern California to British Columbia; the Cryptobranchidae, represented by the hellbender (*Cryptobranchus*) in eastern North America and by the giant salamander (*Megalobatrachus*) in Japan and China; and the Necturidae, represented by several species in eastern North America and one in the caves of southwestern Austria.

The fresh-water fishes occupy a habitat which in tropical and subtropical regions is the least subject to change of any. So they might be expected to present the greatest faunal uniformity, and to include the largest number of very ancient types still persisting. In the

temperate regions of the Northern Hemisphere, however, the waters are now all cold, at least in winter. Especially is this true in North America where the Mississippi drains an area with a more or less severe winter climate, and the present fishes are almost wholly of types not represented in South America or in other tropical regions.

The close affinities of the fish fauna of South America with those of Africa and the Indian region are most logically explained by assuming that all three are local modifications of a very ancient and generally distributed fauna persisting under conditions that have here changed but little since the Paleozoic. In their distribution the fresh-water fishes show many cases of apparently anomalous distribution that can be explained only by restriction of a formerly widespread range. For example, the lungfishes are now confined to Africa, South America, and Australia; the family Polyodontidae is represented only in the Mississippi Valley (*Polyodon*) and in the large Chinese rivers (*Psephurus*); the shovel-nosed sturgeons (*Scaphirhynchus*) are confined to the Mississippi area and central Asia; the North American catfishes (Ameiuridae) are confined to North America except for a single species in China; the suckers (Catostomidae) are wholly North American except for two species in eastern Asia; and the mud minnows (*Umbra*) are confined to North America except for a single species in the Danube Valley in Europe.

Another type of relict distribution is represented by those fishes of which only those that have adapted themselves to life in underground waters still persist. Among these are *Lucifuga* (Brotulidae) of the caves of Cuba and the Amblyopsidae with four genera and seven species in the subterranean waters of the eastern half of the Mississippi Valley, and one genus with two species of normally appearing fishes in the coastal swamps from Virginia to Georgia.

The gar pikes (*Lepidosteus*) known from as far back as the Tertiary in America and Europe still occur in North and Central America and Cuba, and another very ancient type, the bowfin (*Amia*) lives in North America.

Considering animals as a whole, the vertebrates represent a relatively small, closely knit group of large or very large types with exceptional power of adaption to changing conditions, most highly developed in the mammals and birds, the two classes that were the last to appear and that have departed most widely from the original vertebrate stock, though in such a way as to be complementary to each other rather than direct competitors. The present distribution of the vertebrates appears to be mainly the end result of a series of evolutionary adaptations to changing conditions in each class, within their ecological limitations, the most ecologically limited classes, and also the oldest, the fishes and amphibians, still retaining the closest approach to vertebrate distribution in the Tertiary.

Grasshopper Glacier of Montana and Its Relation to Long-distance Flights of Grasshoppers

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[With 8 plates]

Insects probably occur in situations more diverse than those occupied by any other living creatures. Some of these situations, such as the water of tree holes and of hotsprings, the oil of petroleum pools, and the surface of woodland snow in midwinter, are natural habitats where it is perfectly normal to find particular species of insects at one or more periods of their seasonal development. Other substances, including the resin of coniferous trees, may trap insects that accidently become caught in the course of their normal movements. A somewhat different situation is represented by snow, frozen and solidified into ice, which under very special circumstances contains the bodies of insects that apparently did not go to the vicinity by their own choice but that nevertheless were preserved under entirely natural circumstances. Thus, in several places at high elevations large ice masses or glaciers contain grasshopper remains of uncertain age solidly frozen at considerable depths. The best known of these frozen accumulations of grasshoppers is in Grasshopper Glacier, located in Montana near the northeastern corner of Yellowstone National Park.

Grasshopper Glacier has been known for more than 55 years, and to entomologists (who are always looking for insects in strange places) and nonscientists alike the name of this glacier has aroused considerable interest. Unfortunately, few trained observers have visited Grasshopper Glacier, and there has been relatively little factual information about either the age of the glacier itself or the sources of the frozen insect remains. Recent observations have attracted further attention to the glacier and have contributed some significant facts on the grasshoppers which, at irregular intervals, fall upon the upper surface of the ice. For these reasons, it is timely to assemble what is known about Grasshopper Glacier. One

species of grasshopper, *Melanoplus mexicanus mexicanus* (Saussure), has been identified as occurring frozen in the ice in large numbers, and so the historical and biological details pertinent to its relation to the glacier have been given. A related grasshopper, *Melanoplus rugglesi* Gurney, was found numerous in 1949, alive on the snowfield of the glacier. Because it was probably brought by air currents all the way from Oregon or Nevada, where it is a rather remarkable and at the same time an important migratory species, the story of this grasshopper is also told here in some detail. As background for the supposed long flights of *Melanoplus rugglesi*, records of extensive movements by other grasshopper species are reviewed, especially one flight of *Schistocerca gregaria* (Forskål) from Morocco to Portugal, for which the supporting circumstantial evidence is particularly well documented. Those records are related to our subject because they round out the picture, demonstrating that flights as long as that from Oregon to Grasshopper Glacier have actually taken place.

LOCATION AND APPEARANCE

Grasshopper Glacier is situated in the Beartooth Range of Park County, Mont., about 30 miles due west of Red Lodge and about 12 miles north of Cooke, an old mining town through which tourists now pass on their way from Red Lodge to Yellowstone National Park (fig. 1). Though several small glaciers containing grasshoppers evidently occur in the same range, Grasshopper Glacier is the one most often visited. It is in the Beartooth Primitive Area, which is mainly within the boundaries of the Custer National Forest and is one of the most rugged and scenic areas in the United States left virtually untouched by man. Granite Peak, the highest in Montana, rising to nearly 13,000 feet, is only a few miles from the glacier, and the glacier itself is nearly 11,000 feet above sea level.

Grasshopper Glacier is located in an old glacial cirque, which forms a natural amphitheater just over the divide of the Beartooth Mountain Front, and faces northward. West Rosebud Creek arises at the foot of the glacier and flows northeasterly as a tributary of the Yellowstone River. For several decades visitors have come by horseback from Cooke to Goose Lake, which is about a mile and a half to 2 miles southwest of the glacier. From there they hike over a rough path to the top of the divide, which is just above the glacier, about a half mile beyond, spread before them amid a wild grandeur which approaches the majestic proportions of the Swiss Alps. In the 1930's the American Nature Association conducted horseback parties to the area, and for years Yellowstone National Park guidebooks have briefly described the glacier as one of the natural wonders to be seen on special side trips outside of the Park. Since World

War II, many persons have come to Goose Lake by jeep.[1] Because of the high altitude and frequent storms, July and August are the best months to visit Grasshopper Glacier.

In 1940 the glacier was a mile or more in width and extended almost as far back, to the north slope of the mountain. There is some size fluctuation from year to year, but during the past several decades there has been an evident reduction in size. The lower ex-

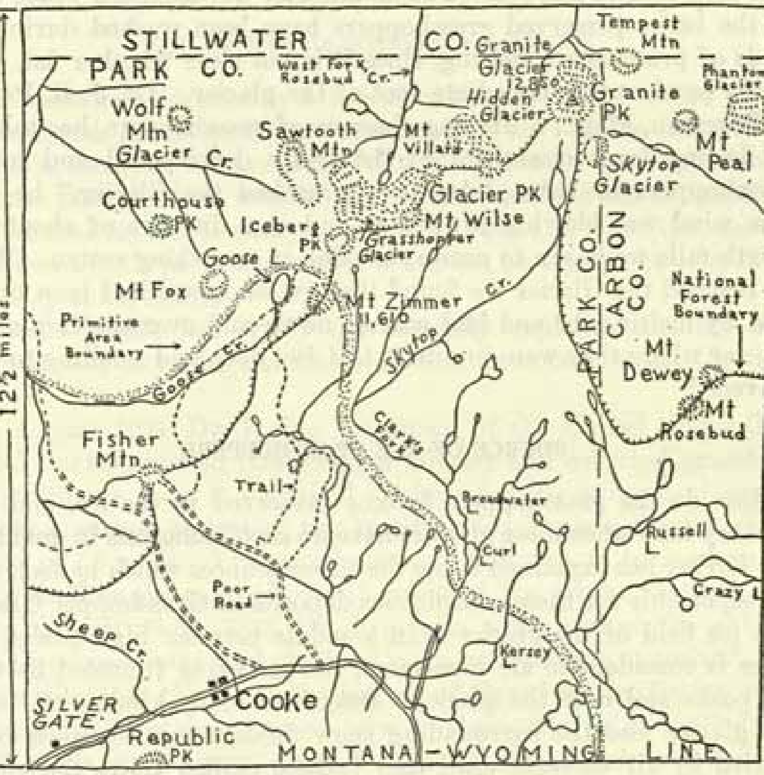

FIGURE 1.—Cooke, Mont., and surrounding area, showing location of Grasshopper Glacier in Custer National Forest. (Adapted from U. S. Forest Service map of Gallatin National Forest and environs, 1947.)

tremity of the glacier is variously shaped where melting occurs, but toward the northwestern end there is usually a vertical ice cliff, which was described in 1940 as 50 feet high. Folded and crumpled layers of ice, correlated with various snowfalls, are evident on this "face." Grasshoppers seem to be embedded from top to bottom of the glacier, and above, when the snow is gone, they have been found frozen in the surface ice. Dark bands in the ice are popularly thought

[1] F. C. Curtiss, supervisor of the Custer National Forest, estimates (letter of Sept. 22, 1952) that at least a dozen organized parties visit the area each year, in addition to perhaps 25 persons who do so as individuals or in small parties. Many who go to the area do not actually reach the glacier itself, and relatively few see the grasshoppers.

to consist entirely of grasshoppers, but they usually comprise dirt and various morainic debris in addition to grasshoppers. At the bottom of the face of the glacier, which overhangs a small lake, the grasshoppers are still mixed with the dirt and other debris where melting occurs. Lovering (1929, p. 41, pl. 13), in an important paper on the geology of the area, states that birds and fish "feed eagerly" upon the bodies of the grasshoppers as the ice releases them. He may have had reference to fish located some distance downstream, where some of the better-preserved grasshoppers have been washed during periods of pronounced melting, since it is not clear whether fish occur in the pond at the immediate foot of the glacier. Dr. J. R. Parker, of Bozeman, Mont., a lifelong observer of grasshoppers, has told me of finding large quantities of the badly decomposed and broken grasshoppers in 1931. "As we approached the Glacier," he says, "the wind was blowing toward us and at a distance of about one-fourth mile we began to notice the odor of something rotten. When we reached the Glacier we found that grasshoppers had been uncovered by melting ice and had washed down and over the face of the Glacier where they were in piles 2 to 4 feet deep and smelling to high heavens."

SOURCE OF THE GRASSHOPPERS

How do the grasshoppers become preserved in the ice, and why are they here when most glaciers have no such inclusions in quantity? Dr. Parker has explained to me the circumstances which he feels may be responsible for these conspicuous deposits in Grasshopper Glacier. The ice field of the glacier is in a saddle between high peaks, and there is considerable air movement, the air being funneled between the peaks and over the glacier. Insects of many kinds settle upon the glacier and the surrounding snow fields, some doubtless being carried by air currents until they become chilled above the glacier and settle. Dr. Parker has added:

> Another way in which large numbers of grasshoppers could have accumulated on the glacier would be as a result of a sudden change of weather conditions while a swarm of grasshoppers was passing over the Glacier even though it was too high to be affected by the cold air immediately above it. We know that swarms of grasshoppers remain in flight only while the air is warm. Sudden changes to lower temperatures, or cloudiness, often cause them to close their wings and plummet to the ground in great numbers. Storms are frequent in the high mountains, and on Grasshopper Glacier in July I have seen warm bright sunny weather followed within an hour by snow and near freezing temperatures. Had a swarm of grasshoppers been flying over the Glacier at that time it would have descended upon it and have been embedded in the snow and ice. I believe the successive large accumulations came about in this manner.

Even if not brought down by a storm, grasshoppers falling on the snow or ice become inactive after a few hours and eventually die. Satisfactory preservation depends upon low temperatures and especially upon the grasshoppers' becoming embedded in the snow or ice before decomposition reaches an advanced state. It is likely that certain grasshoppers reaching the glacier decompose and disintegrate before freezing takes place, while others may be covered immediately by snow and frozen so that a perfect "deep-freeze" effect occurs.

AGE OF THE GRASSHOPPER DEPOSITS

The question immediately arises as to the age of the lowest layers of preserved grasshoppers. Unfortunately no reliable estimate is available, though there are plans for making a study by the carbon-14 test, the most modern method available. This method is based on the fact that carbon-14 decays at a known rate, and when the amount of carbon-14 in a particular object is known, its age can be calculated (see Kulp et al., 1952).[3]

Roberts (1952) has briefly but concisely explained the test and has discussed archeological materials that have been studied by this method.

In August 1951, Dr. Irving Friedman, of the United States Geological Survey, visited Grasshopper Glacier and collected grasshopper fragments from the vertical ice face for the purpose of carrying out a carbon-14 test at the Institute for Nuclear Studies, University of Chicago. The sample proved, however, to be inadequate, being less than the approximate 15 grams of dry weight required, and so, on August 28-30, 1952, Dr. Friedman again visited the glacier, with three associates, and obtained more grasshopper material.*

Can it be that the ice at the bottom of Grasshopper Glacier dates back to the Pleistocene period or soon thereafter, or is it likely to be of much more recent origin? Though the eagerly awaited results of a carbon-14 test seem the most likely to give a definite answer, the historical geology of the area and some clarification of factors re-

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*See further comment on p. 326.

[3] As an example of an age estimate arrived at by the carbon-14 method, Kulp et al. (1951) report their results from various samples, including a fossil cedar log dredged from a harbor in Bermuda. The log is considered representative of a former cedar forest which now is covered by 20 to 50 feet of water and mud. From the test conducted at Columbia University, the age was calculated at 11,500 (±700) years. The importance of this particular age determination is that the tree containing the log presumably grew in the same position, indicating that the ocean was then at a much lower level; this in turn correlated with the period when much of the earth's water was still in the form of a glacial covering. On the basis of this and other confirmatory studies, the last main stage of the Pleistocene Epoch or Great Ice Age is thought to have been about 11,000 years ago. Kulp and his associates also ran a test on a large wood sample that had been found beneath gravel of the Mendenhall Glacier, Alaska. The sample was apparently from trees that had been passed over by the glacier, so that the layers of glacial deposits associated with the wood at that location are likely to be of a comparable age. This sample yielded an estimate of 1,790 years, with a possible variation of 250 years.

lated to the age of American glaciers supply informative background.

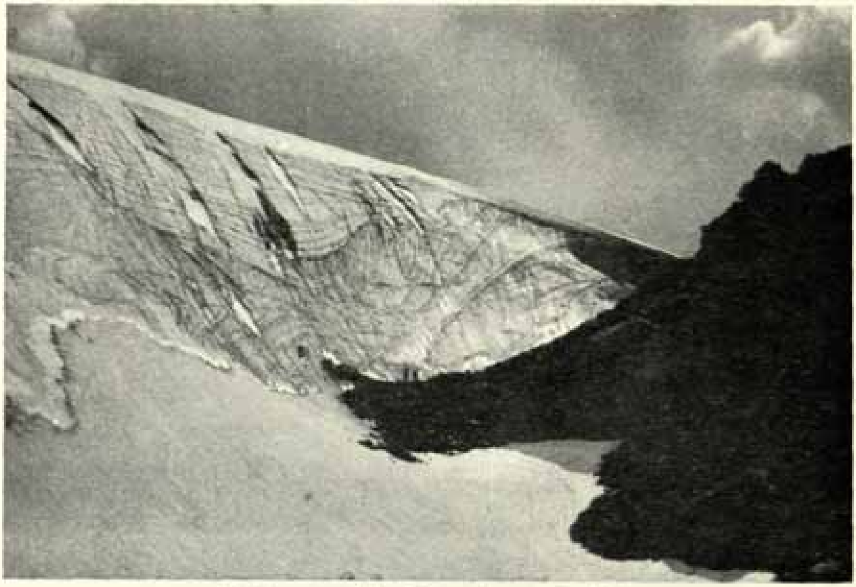
Bevan and Dorf (1932) give a brief digest of the topography and geological history of the Beartooth Range, explaining that in late Tertiary and early Quaternary time, following an uplift of the mountains, an ice cap developed on the plateaulike summit of the range. The ice was extensive and when at its maximum development comprised 15 different glacier systems in the northern and eastern parts of the Beartooth Range. Much of the area has since become a great irregular subsummit peneplain, some 3,000 to 4,000 feet above the surrounding plain, and sloping generally to the southwest. Upon this mountain mass the high peaks are arranged along a divide which runs from northwest to southeast. About the peaks many large cirques occur as silent testimony of early erosive glaciation, and in some of the scooped-out amphitheaters small glaciers now occur, one of them being Grasshopper Glacier.

The presence of existing glaciers in the Beartooth Range was not reported during the first explorations there. In reviewing North American glaciers, Russell (1885) quotes one of the exploring geologists, W. H. Holmes, regarding small glaciers in the Tetons of Wyoming, stating that in the Beartooth Range he was "unable to discover anything approaching a glacier in appearance, even in the center of the great mass about the sources of Clark's Fork and the Rosebud." If entirely absent then, of course the preserved grasshoppers of Grasshopper Glacier represent very recent deposits. The first scientist to examine Grasshopper Glacier, so far as I know, was James P. Kimball, of the United States Geological Survey, who made a geological reconnaissance of the area in 1898. In his opinion (Kimball, 1899, p. 213), Holmes did not visit the high country where glaciers are located. I have mentioned the Holmes statement to several scientists who have since visited Grasshopper Glacier, and they too feel that it is unlikely that he actually penetrated the Beartooth Range sufficiently to locate the glacier, in view of its relative inaccessibility.

How ancient are American glaciers, and do they all date back to the main "ice age"? In a series of studies by several investigators, the results of which have been assembled by the late Dr. Francois Matthes, then chairman of a committee on glaciers of the American Geophysical Union, much helpful background on the question is supplied (Matthes, 1941, 1942a, 1942b). In brief, it appears that a warm period, called a "climatic optimum," followed the Pleistocene and that the great majority of glaciers now occurring in the United States did not then exist. Studies of the salt content of Owens Lake, which is fed primarily by water from snow fields and glaciers in the Mount Whitney section of the Californian Sierras, and other investigations, suggest that these "modern" glaciers may not date back more than 3,600 to 4,000 years.

BASE OF GRASSHOPPER GLACIER, LOOKING SOUTHEASTERLY, SHOWING ICE CLIFF IN RIGHT FOREGROUND

In the immediate background of the glacier is Mount Wilse, named for A. B. Wilse, a photographer from Seattle, Wash., who accompanied Dr. James P. Kimball on the 1898 expedition. Photograph, of uncertain date, obtained from J. W. Rode, courtesy of Dr. J. R. Parker. This same picture was published by Rolfe (1936, p. 254), courtesy of the Northern Pacific Railway.

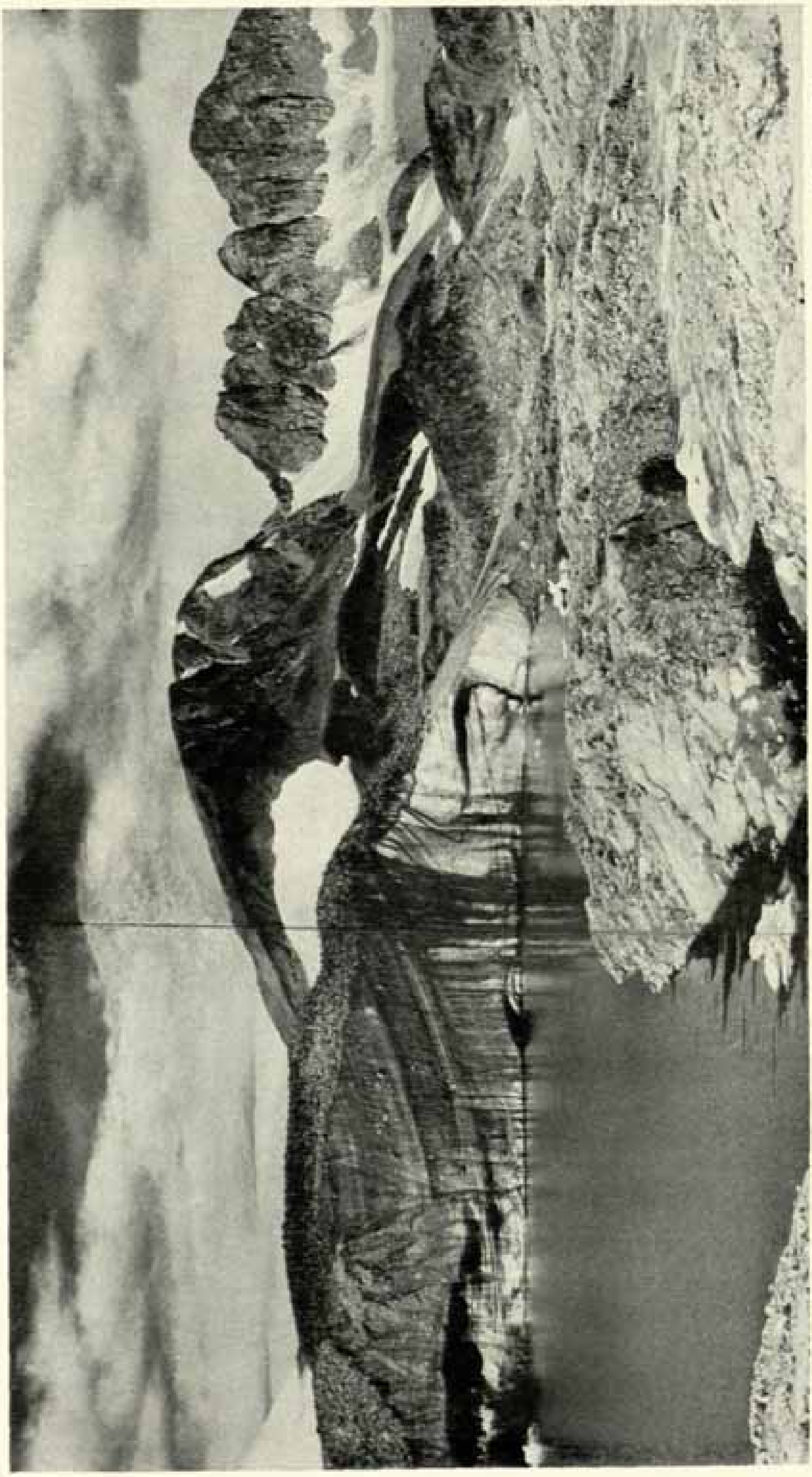


1. FRONT OF ICE CLIFF, JULY 13, 1922

View from moraine below showing unconformities and crumpling of ice strata. Arch at right apparently due to overriding of rock ridge.

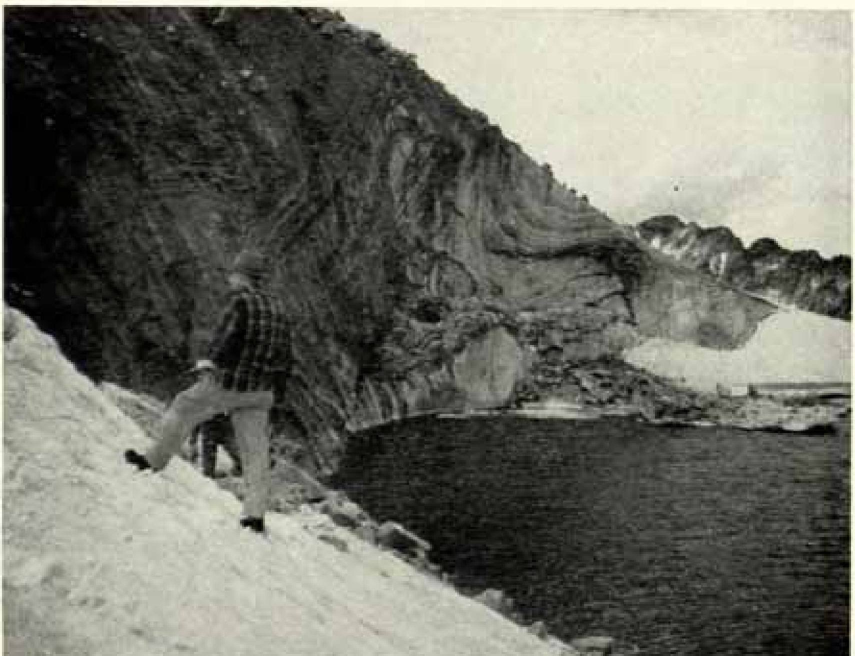
2. GRASSHOPPER GLACIER, JULY 14, 1922, LOOKING EAST ACROSS TOP OF ICE CLIFF AT THE FRONT OF THE GLACIER

Photographs by Dr. W. C. Alden, courtesy of National Park Service.



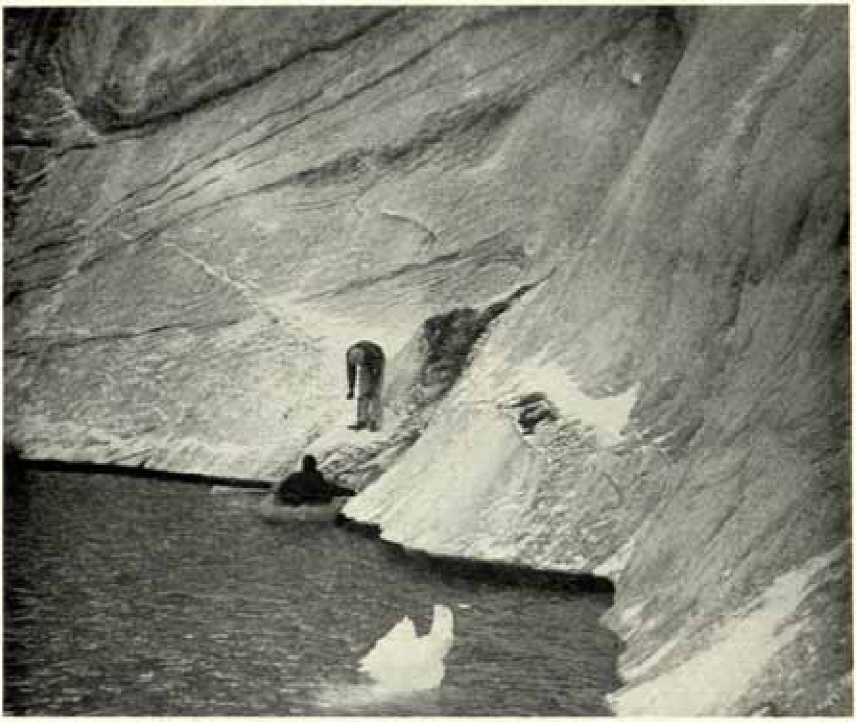
COMPOSITE PANORAMIC VIEW OF ICE CLIFF, LAKE, AND SURROUNDING AREA, LOOKING SOUTHWEST, AUGUST 28-30, 1952

Main area of recent glacier to the left of the picture. Photograph by Dr. Irving Friedman, U. S. Geological Survey.



TWO VIEWS OF ICE CLIFF AND LAKE IN AUGUST 1951, SHOWING SHELF OF ICE UNDER CURVED ICE CORNICE TO THE RIGHT

In 1952 the shelf was gone and the curving layers beneath the cornice were approached only by using a boat. Photographs by Dr. Irving Friedman, U. S. Geological Survey.

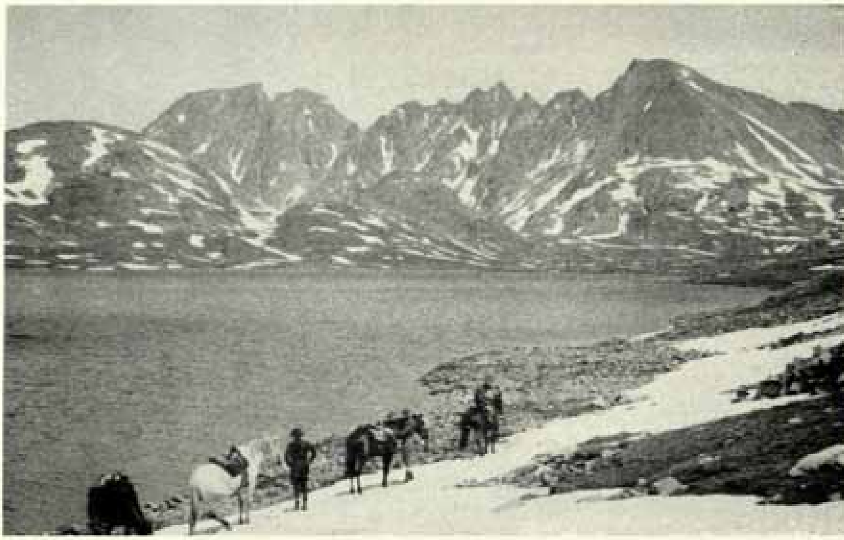


1. NEAR WESTERN END OF ICE CLIFF UNDER CURVING ICE CORNICE

Boring a hole in the ice at front of ice cliff, August 28–30, 1952, preparatory to blasting to obtain chunks of ice containing grasshoppers. Photograph by Dr. Irving Friedman, courtesy of U. S. Geological Survey.

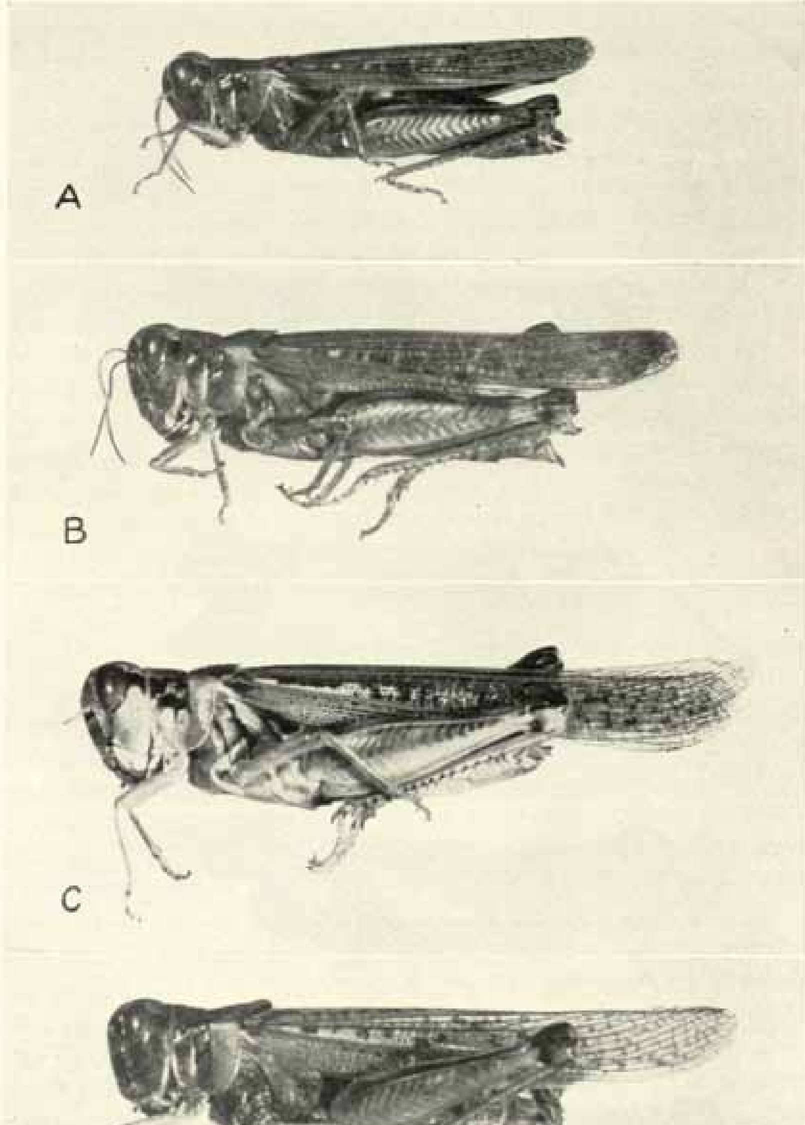
2. THE MORE RECENT GLACIER, AUGUST 2, 1949

Looking northeasterly. Margin of the morainic covering of "old glacier" in foreground at left; lake to the left hidden by dome of the "old glacier." Photograph by Barry Park, courtesy of U. S. Forest Service.



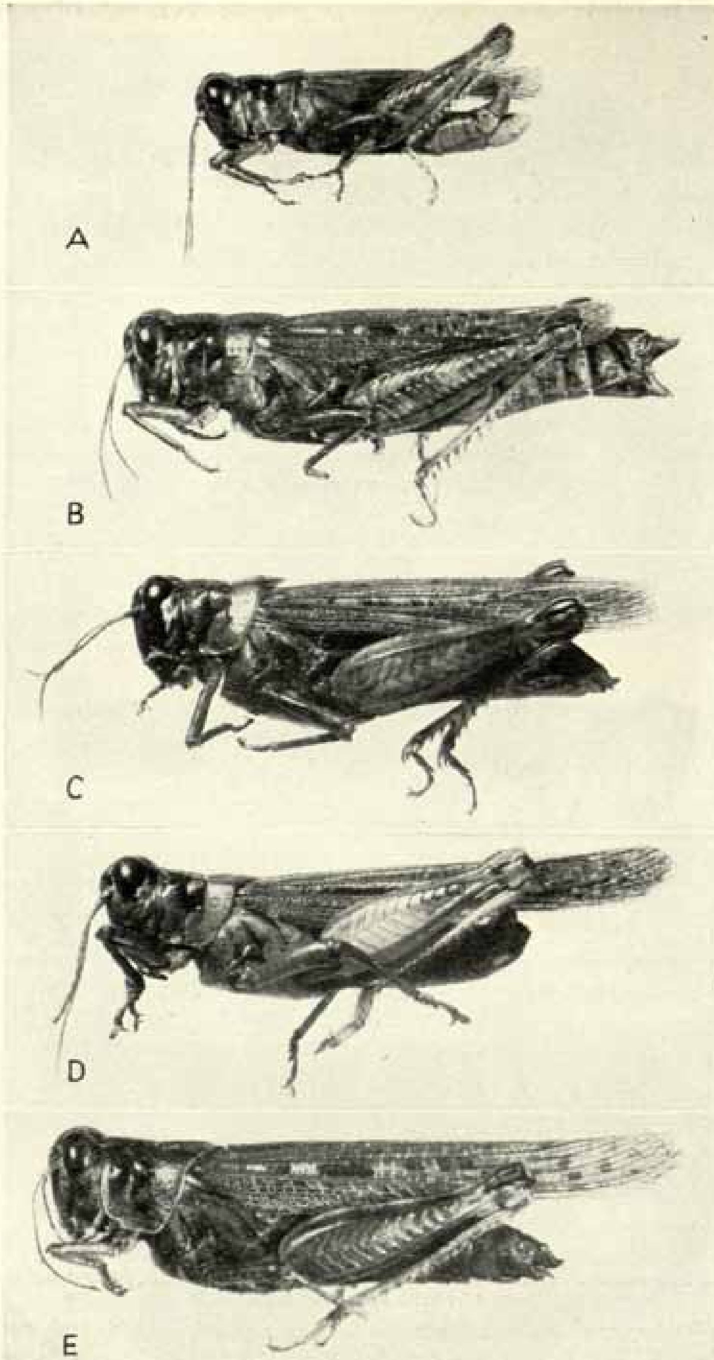
1. GOOSE LAKE, ON THE WAY TO GRASSHOPPER GLACIER, JULY 13, 1922
Photograph by Dr. W. C. Alden, courtesy of National Park Service.

2. SPECIMENS OF PRESERVED GRASSHOPPERS FROM THE GRASSHOPPER GLACIER
Photograph from Union Pacific System, courtesy of National Park Service.



MELANOPLUS MEXICANUS MEXICANUS (SAUSSURE), FEMALES, SHOWING DIFFERENCES IN SIZE AND WING LENGTH

A, typical eastern specimen from Stony Man Mountain, Shenandoah National Park, Va., 1933; B, moderately long-winged specimen from Independence, Kans., 1902; C, extremely long-winged specimen of a type rarely found, collected from a lush irrigated alfalfa field, Chandler, Ariz., 1945; D, an authentic historic specimen of Rocky Mountain grasshopper (from C. V. Riley collection), collected in Monona County, Iowa, August 1873. Enlarged slightly more than twice. Photographs by Floyd B. Kestner, Smithsonian Institution.



SPECIMENS OF MELANOPLUS RUGGLESI GURNEY, SHOWING DIFFERENCES IN SIZE AND WING LENGTH

A, male of solitary phase from Rock Springs, Wyo., 1922; B, female of solitary phase from Wild Rose Canyon, Panamint Range, Inyo County, Calif., 1922; C, female in intermediate phase from near Whitehorse, Oreg., 1949; D, male of gregarious (migratory) phase from Craine Creek, Humboldt County, Nev., 1948; E, female of gregarious phase from Gerlach, Washoe County, Nev., 1947. Enlarged 2½ times. Photographs by Floyd B. Kestner.

During this Recent period, in which we now live and to which the term "little ice age" has been applied, there have in turn been climatic fluctuations. In the Middle Ages comparatively mild conditions existed, but around A. D. 1600, as shown by buried villages in Iceland and evidence in Scandinavia and elsewhere, there began a moderate but definite expansion of glaciers. In recent decades there has been a tendency for many, but not all, glaciers to recede again. "The present recession of glaciers, which began in the 1850's and which since 1920 has proceeded at an accelerated rate, is merely the latest episode in the 'little ice age.' It may mark the end, or it may not" (Matthes, 1942b). Since Dr. Matthes' death it has become increasingly evident that the recession of many glaciers is decreasing and some are advancing again (Baird et al., 1951). About 7 years ago a minor climatic change of increased precipitation and lower temperature began to occur in Glacier National Park. Frequently, some years are required for minor changes in climate to have noticeable results at the foot of a glacier, so slowly are effects transmitted for the length of a glacier.

As examples of glacial decline, the Easton Glacier on Mount Baker, Wash., receded 4,900 feet between 1908 and 1936, and some small glaciers on the Cascade Range in Oregon have entirely disappeared in the past 25 years. The recession of the Nisqually Glacier on Mount Rainier has been conspicuous and has been carefully recorded, amounting to 4,708 feet from 1857 to 1951, an average of about 5,000 feet per year. There is a practical importance to the measurements made on the Nisqually Glacier because water originating there contributes to the municipal water supply of Tacoma, Wash. If the glacier eventually disappears or becomes much smaller than at present, supplementary sources may be required.

Changes in the size and appearance of Grasshopper Glacier have been observed by Dr. J. R. Parker, who has given me an account of five separate trips there. He first visited it with Dr. R. A. Cooley in July 1918, and they found the glacier much as shown in plate 1. He judged the exposed face toward the west end to be 50 to 75 feet from the ground to the top layer of ice and snow. He cut individual grasshoppers from the top layer at depths of 1 to 12 inches. Grasshoppers also were found in lower layers where exposed at the foot of the glacier, and dried grasshopper remains were found under many small flat rocks which occurred on the higher slopes adjoining the snow and ice field of the glacier. Dr. Parker reasoned that this last condition indicated that the glacier at sometime had covered a considerably larger area and had contained grasshoppers there before it had receded. He made other trips in 1922, and in either 1925 or 1926, and found the general appearance to be the same on each occasion. During a 1931 visit he estimated that the face was 25 feet lower. When there

in 1949, Dr. Parker found that instead of the sharp, high glacial face, as in 1918–31, the face had receded by melting and that there was a gentle upward slope to the snow-covered ice farther back against the mountain. The condition that occurred in 1951 is shown in photographs made by Dr. Irving Friedman (pl. 4).

At present the main area of the glacier appears newer than a dome-shaped mass of ice which is the best source of preserved specimens. This dome, well shown in the photographs, and sometimes known as the "old glacier," is what remains of the imposing ice cliff photographed by Dr. W. C. Alden in 1922 (pl. 2). F. C. Curtiss, of the Custer National Forest Headquarters in Billings, Mont., attributes the large amount of new ice covering the "old glacier" to the wet cycle which has occurred there since the dry years of the 1930's. With the recession of the "old glacier" the pool resulting from the melting ice has become enlarged, and the face of the ice cliff is very dark with included morainic debris and with that which falls down from the covering of the dome above.

Two principal types of glaciers, from the point of view of age, occur in the United States. The first category, much in the minority, consists of those which can with "reasonable certainty be said to have persisted from the Pleistocene ice age." They originate at higher altitudes or for other reasons appear much more permanent. The remainder, averaging smaller and located at lower altitudes for the most part, and including most of the glaciers of the United States, are thought to have existed only during the "little ice age" period. Thus, the age of Grasshopper Glacier is very uncertain, depending on the category to which it belongs. Although most of the North American glaciers of the "ancient" type occur in the Far West and Alaska it was believed by Matthes that several of that sort occur in Glacier National Park, Mont., and in the Wind River Range of Wyoming. More recent studies of the factors leading to the development of glaciers have suggested that all the Glacier National Park and Wind River Range glaciers instead belong to the "recent" category, thus originating within 4,000 years. The Beartooth Range glaciers have not been studied in detail from the standpoint of age, but they are comparable to most of the Wind River Range glaciers, with respect to altitude and their location in old glacial cirques on the east side of the divide where snow from westerly winds blows onto and augments the ice. The eventual placement of Grasshopper Glacier, regarding the category to which it belongs, may have a direct bearing on the age of the oldest insects there included.

THE SPECIES OF GRASSHOPPERS PRESERVED

Nearly 40 years ago preserved grasshoppers had been collected for scientific purposes from the ice of Grasshopper Glacier, but their oc-

currence was known prior to Kimball's survey in 1898. Prospectors in the 1880's probably discovered them. Notes filed at the United States National Museum by the late A. N. Caudell, a specialist in the identification of grasshoppers and related insects, include the remark that on September 26, 1914, and November 17, 1919, he prepared memoranda on Grasshopper Glacier for Dr. L. O. Howard, then Chief of the United State Bureau of Entomology, but the memoranda have not been located. An anonymous unpublished report from the Historical Records of the Custer National Forest states that Forest Service officers collected specimens in 1914 that were identified as *Melanoplus spretus*, which we now know as *M. mexicanus mexicanus*. Undoubtedly these specimens were examined by Caudell and led to the 1914 memorandum mentioned. Alden (1922) tells of gathering specimens which likewise were identified as *spretus* by Caudell. Thirteen specimens from the glacier are in the National Museum. They are somewhat fragmentary, but two are males, which possess the special features that are distinctive of species in the genus *Melanoplus*. They are clearly *Melanoplus mexicanus mexicanus*, commonly known as the lesser migratory grasshopper or Rocky Mountain grasshopper. The significance of these *two* common names and the long history of this species will be told here only sufficiently to explain why the discovery of this particular grasshopper in the ice is of outstanding interest.

During the past century, especially in the 1870's and 1880's, farmers of the Great Plains and of the western prairies beyond the Mississippi River often were plagued by great hordes of grasshoppers which appeared in migratory swarms and devastated crops. In its typical condition the dominant species had pink or bright-red hind tibiae, the wings were noticeably long, and migrations of many miles frequently occurred. This grasshopper had various common names, of which Rocky Mountain grasshopper has persisted, though it was often known as a locust. The scientific name applied to it by American entomologists during the early 1870's when federally supported investigations were in their infancy was *Caloptenus spretus* Walsh, later changed to *Melanoplus spretus* (Walsh). About the same time, especially farther east, it was noticed that certain grasshopers could scarcely be distinguished from *spretus*, though they averaged smaller and shorter-winged, did not migrate conspicuously, and the hind tibiae were occasionally pale bluish green. These smaller specimens are of the lesser migratory grasshopper, given various scientific names by the older entomologists working largely independently of one another and not realizing that the subject of their study inhabits most of temperate North America and that it looks somewhat different in various areas and under different conditions of food and climate. Its identity as *Melanoplus mexicanus mexicanus* was not finally established until

recent years (Hebard, 1917, p. 271). A more intriguing puzzle, one with thoroughly practical aspects, concerns the almost complete disappearance of *M. spretus* after the last big flights of the 1800's. Occasional specimens commonly considered to be abnormally long-winged representatives of the lesser migratory grasshopper are found from year to year, and during certain years moderately important flights of that species take place, but in spite of its importance as a pest there is no recurrence of the tremendous, devastating flights of the last century. It is now believed, with reasonable certainty, that only one species of grasshopper is involved in this particular problem; to it the earliest name (*mexicanus*) applies. The species is capable of undergoing changes in its behavior and appearance as a result of the ecological conditions of its environment. Thus, *spretus* is a synonymous name, and the common name Rocky Mountain grasshopper applies primarily to the optimum migratory form of the species.

THE PHASES OF MIGRATORY GRASSHOPPERS

The realization that a few species of grasshoppers, apparently including the majority of the major migratory grasshoppers of the world,[3] have this ability to modify their color, wing length, and tendency to migrate in swarms is one of the basic entomological discoveries of our generation. It is extremely important because destructive migratory species formerly would seemingly disappear after a period of abundance, and frequently in their place only small numbers of scattered and relatively unimportant grasshoppers could be found. Later, the migratory pest form would reappear in an unexplained manner. Credit for first suggesting that this transformation occurs, and for reporting the first observations that demonstrated it in the field, belongs to Dr. B. P. Uvarov, now director of the Anti-Locust Research Center in London. This idea, which became known as the Phase Theory, was proposed in 1921, and by various entomologists, especially those working in Africa, it has been advanced from a theory to the realm of fact. It has led to a much more realistic approach to the whole problem of migratory grasshoppers,[4] and places the

[3] In the United States and Canada there are some 600 species of grasshoppers, not including katydids, crickets, and other relatives. Of the 600, several dozen have destructive habits in relation to cultivated crops or range land. Of this number, only four are well known for their migratory flights. About a dozen highly important migratory grasshoppers infest foreign countries, among several thousand grasshopper species that have been described and named.

[4] The term "locust" as usually used means a grasshopper that is outstandingly migratory in its behavior. Foreign entomologists usually use "locust" in that sense and apply "grasshopper" only to the species that lack conspicuous gregarious and migratory habits. There is no clear line of distinction between the two, however, since both types of species belong to the same group and certain species are sometimes solitary and at other times migratory. Furthermore, some writers on the classification of grasshoppers refer in a general way to whole subfamilies of grasshoppers as "locusts," irrespective of

search for population build-ups and incipient outbreaks on a much more scientific basis than formerly. Aggregations of a species capable of undergoing phase transformation may be sampled and from the appearance of the individuals it can be determined whether they belong to the phase which typically is of minor importance (solitary phase), or whether in wing length and other characteristics there is a trend toward the typically long-winged and highly destructive migratory condition in which the individuals gather in compact swarms (gregarious phase). While the phase characteristics of samples are sometimes clear by simple inspection of specimens, in other cases it is necessary to measure parts of the body in order to obtain certain ratios which are valuable clues to phase change. The ratio most often used is that obtained by dividing the length of the front wing (called the elytron, or tegmen) by the length of the hind femur; hence the abbreviation, *E/F* ratio. With different migratory species the ratio that is most sensitive to phase changes, and thus most dependable as an indicator of phase condition, varies. For instance, it has recently been learned that a ratio utilizing the width of the grasshopper's head at the broadest expanse of the cheeks is very useful for identifying the phase of *Schistocerca gregaria*, the desert locust of North Africa and western Asia.

Now to return to the samples of *Melanoplus mexicanus mexicanus* from the solid ice of Grasshopper Glacier. They were first identified as *M. spretus* by Caudell who at the time did not have the benefit of modern studies by Faure (1933) and Brett (1947), which indicate the synonymy of *spretus*. The specimens I have seen are rather long-winged individuals suggestive of the gregarious phase, but they are too broken to permit complete measurements to be made. Furthermore, the samples include too few specimens for a reliable conclusion. When Dr. Parker visited the glacier in 1931 he noticed in particular the red hind tibiae of specimens uncovered by the melting ice. This agreed with the gregarious phase, though it did not rule out the solitary phase. When sufficiently large and perfect samples are obtained from the ice a statistical study of the *E/F* ratio may of itself be very suggestive of the correct biological nature of the specimens in the older preserved layers. If their age is also determined by the carbon-14 test or other means, we will then have information on the phase character of this highly important grasshopper for a known period in its past history, the doors to which are now entirely closed to us.

their tendencies to migrate. The possibilities for confusion are still further increased by the habit, among the general public in the United States, of calling cicadas "locusts." These insects, of which the periodical cicada or "17-year locust" is best known, belong to a quite unrelated group. For the sake of clarity, North American entomologists now tend to avoid the use of "locust" except when referring to foreign species of grasshoppers for which the term has clearly been established.

LIVING GRASSHOPPERS ON THE GLACIER

Until 1949 nothing unusual was known about living grasshoppers on Grasshopper Glacier. Forest rangers report finding grasshoppers and other winged insects alive on the snow field each summer (F. C. Curtiss, letter of Sept. 3, 1952). On August 14, 1922, Dr. Parker found many flying insects on the snow of the glacier, including a live specimen of *Pardalophora haldemannii* (Scudder), a widespread grasshopper common in both Montana and Wyoming. It was typical of species occurring at lower elevations of the surrounding area. That grasshoppers should occasionally be found at high altitudes on snow is not remarkable. Caudell (1902) recorded them, taken in 1901 from snow at the summit of Pikes Peak, Colo. Darrah (1951, p. 101) described a striking instance of grasshoppers on snow fields in valleys near the headwaters of the St. Vrain River, at the foot of Longs Peak, Colo., witnessed by a geological-survey party headed by Maj. J. W. Powell. On that occasion, August 23, 1868, they saw grasshoppers numbed by the cold so numerous on snow fields that they "literally could have been gathered in wagonloads." Two bears were feeding on the grasshoppers.[5]

As to the occurrence of insects on the surface of glaciers, Russell (1897, pp. 13–14), after mentioning how pebbles, part of the morainic debris on the ice, become warmed and melt holes into which they sink, states, "Leaves are frequently blown far out on glaciers and, becoming warmed by the sun, sink into the ice in the same manner as the pebbles already referred to, and even insects, especially butterflies, are conspicuous in such localities."

On August 1, 1949, Dr. Parker, accompanied by David G. Hall and Frank T. Cowan, hiked up to the glacier hoping to gather samples of the preserved grasshoppers. Unfortunately, little historic material was taken, but attention was attracted to something else—live grasshoppers on the snow. Since time was short, it being important to leave before darkness fell, only about 30 specimens were collected. Dr. Parker has estimated, however, that there was about one grasshopper to every 20 square yards of snow in the area visited, and that several hundred specimens could have been taken. Because of the inhospitable character of the surrounding terrain, and the way the

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[5] A newspaper account originating in Greeley, Colo., in 1934 stated that large deposits of grasshoppers had been discovered imbedded in snow and ice on Longs Peak in Rocky Mountain National Park, Colo. According to a pioneer resident, the source of the grasshoppers is explained by swarms which in 1876 flew from the plains and perished in the snow and ice of Hallet's Glacier, north of Longs Peak. Bears fed on the dead insects, preserved by natural refrigeration, for several years. The summer of 1934 was noticeably hot and dry in that area, and it was assumed that the grasshoppers uncovered by melting were the same ones reported to have flown to the Longs Peak region 58 years before. No further information bearing on the accuracy of this conclusion is available.

grasshoppers were distributed on the snow, it was obvious that they had come by air.

The dominant species present was *Melanoplus rugglesi.* Collected with *rugglesi* were two specimens (male, female) of *M. mexicanus mexicanus* (solitary phase) and one male of *Trimerotropis pallidipennis* (Burmeister). The latter is a widespread but not very important grasshopper. All were alive. Though then without a scientific name, *rugglesi* had attracted attention in Nevada since 1939 (see Gallaway, 1949), and during the previous month both Hall and Cowan had observed its flights in Nevada and Oregon. Both men were immediately struck by the similarity of the specimens on the snow to the material studied in the infested area.

Specimens of *rugglesi* subsequently sent to me were identified independently and before the remarkable circumstances of their capture on the snow in Montana, far from the normal habitat, were explained. I was especially interested in the species because during the previous May and June I too had studied this grasshopper in Nevada and Oregon. Briefly, the background concerning it is that before 1939 there are no definite records of important infestations, but in that year it appeared as a conspicuous migratory species feeding on sagebrush, rabbitbrush, and other range plants in Big Smoky Valley of central Nevada. Bands of immature individuals, or nymphs, advanced in fairly compact aggregations; then, as wings developed fully, swarms of adults at first took short flights. Later, when the grasshoppers were more thoroughly mature, their flights became longer and were dramatic affairs when witnessed by entomologists or local ranchers. An average of about 40 miles would be covered over a period of a week or more before a swarm would deposit the main egg supply for its progeny. These eggs would hatch the following year and the bulk of the population would again move forward, usually in a northerly or northwesterly direction. By the late 1940's the migrations had reached southeastern Oregon and northeastern California and in Nevada occurred only in the northwestern corner of the State. So far as then known to entomologists, the species had disappeared from central Nevada. At first there was some uncertainty concerning the identity of this grasshopper, but it was seen to be *Melanoplus occidentalis* (Thomas) or a close relative.

My 1949 field observations, and later studies of assembled reference collections, convinced me that the grasshopper had not been named, and I proposed a name in memory of one of my former teachers at the University of Minnesota, Prof. A. G. Ruggles, himself an enthusiastic student of grasshoppers and at least twice a companion of Dr. Parker on trips to Grasshopper Glacier. Little did he suppose that amid the rugged beauty of those great peaks of the Beartooth

Range a grasshopper new to science would one day be collected far from its native surroundings and be given his name!

But vastly more significant, from the standpoint of a field biologist, were my collections in Big Smoky Valley, and other localities where migrations had occurred a few years earlier, for they showed that *rugglesi* still existed there, though in scattered numbers, and the wings were shorter than in migrating swarms! A few specimens that obviously were completely solitary in phase characteristics were found in collections of grasshoppers taken at several localities in years before the important infestations began. Accordingly, phase transformation evidently occurs in *rugglesi*, though additional observations are required to supply the complete details of the changes that take place and the ecological conditions producing them.

The specimens of *rugglesi* found alive on Grasshopper Glacier were clearly distinct from the related *M. occidentalis* which inhabits the surrounding area of Montana and Wyoming and practically all the Rocky Mountain and northern Great Plains regions. The long wings, well-indicated by the *E/F* ratio, were typical of the optimum gregarious phase such as represented in migratory flights.

DISTRIBUTION OF MELANOPLUS RUGGLESI AND PROBABLE SOURCE OF GLACIER SPECIMENS

In 1949 the gregarious phase of *rugglesi* was known only in northwestern Nevada, northeastern California, and southeastern Oregon (mainly in the vicinity of Denio), in any case a distance of at least 500 miles from Grasshopper Glacier. A single specimen in the solitary phase was collected near Arco, Idaho, by Rehn and Hebard in 1928, and another of the same phase was taken at Rock Springs, Wyo., by Rehn in 1922. Field work may eventually disclose colonies of the gregarious type in southern Idaho and thereby suggest the possibility of their unreported presence there or at other localities in 1949. Owing to the widespread movements of *rugglesi* when migrating, however, and the phase changes that occur, collections made after 1949 will be unreliable indicators of what occurred in 1949. Meanwhile, it is helpful to examine circumstantial evidence suggesting that a 1949 movement to the glacier from Oregon or Nevada may have taken place.

Immediately after August 1, 1949, field men assigned to grasshopper survey work by the United States Bureau of Entomology and Plant Quarantine who were located in range areas both west and east of Grasshopper Glacier were alerted to watch for *rugglesi* in conjunction with their regular duties. No trace of *rugglesi* was found, though *occidentalis* was collected and submitted for checking.

In July 1949 extensive flights of *rugglesi* occurred in the infested area of Oregon and Nevada, and they remained in progress up to

August 1. Flights occurred both near ground level and at considerable altitudes. The grasshoppers usually fly into the wind, unless it is too strong to make headway against it. Winds which approach 10 miles per hour are probably strong enough in most instances to stop the grasshoppers or effect a change of direction. Since it is well known that air currents play an important part in the spread of insects, I consulted Weather Bureau records covering the period immediately prior to August 1, 1949, for the area concerned. Through the kind cooperation of several Weather Bureau officials, it can be stated that apparently the meteorological conditions on and just before August 1 favored a movement to the glacier from the southwest. On July 29–30 there was a 10-mile wind over southern Idaho blowing toward the east and northeast; this was strongest at high levels and may have carried the grasshoppers eastward. On July 31 there were strong eastward-blowing winds at 12,000 feet and above, weaker below. Over eastern Oregon on July 30 there was a 10- to 20-mile wind toward the northeast at 10,000 feet above sea level. (The base level of much of southeastern Oregon is 5,000 to 6,000 feet above sea level.) Reports from Boise, Idaho, and Ogden, Utah, indicate strong upward convection currents over southern Idaho July 30–31.

Archer B. Carpenter, supervising forecaster of the Salt Lake City, Utah, office of the Weather Bureau wrote (letter of September 8, 1949): "Several days prior to August 1, 1949, the winds at 10,000 feet (above sea level) were sufficient to carry the grasshoppers from southeastern Oregon into southern Montana if they were able to reach that altitude. Winds below 10,000 feet were of a similar pattern but lower velocities, and at higher altitudes a similar pattern but usually higher velocities."

One of the Grasshopper Glacier collectors, Mr. Hall, has reported to me his conversation with an air-line pilot who at about the same time saw a swarm of grasshoppers while he was flying in the vicinity of eastern Oregon. The circumstances suggested that the species might be *rugglesi*.

OTHER LONG-DISTANCE MOVEMENTS OF GRASSHOPPERS BY AIR

In considering the possibilities of a several-hundred-mile flight of *rugglesi* to Grasshopper Glacier, probably aided by air currents, it is helpful to review records of long flights by other species. These records show that flights of several hundred miles actually occur when circumstances are favorable. An example for which weather conditions were known and apparently times and points of departure and arrival also, is that discussed by Waloff (1946) for the desert locust of Africa, *Schistocerca gregaria*. Many individuals of this grasshopper were found in Portugal October 12, 1945, and the circumstantial evidence, which Waloff explains in detail, and which I have sum-

marized briefly here, made her feel fairly certain that the grasshoppers originated in western Morocco, where they probably left the morning of October 11, arriving over Portugal late that night or the next day. The distance involved was 600 to 800 miles, varying with different localities in Portugal where they were found. Very complete information on grasshopper movements in Africa was available, and the nearest reported swarm of a comparable age, the degree of sexual maturity after the final molt in that species being shown by color, was in western Morocco. On the morning of October 11 there was a sharp rise in temperature, which presumably would induce flight activity, accompanied by convection currents and a wind blowing out to sea. A few miles offshore a strong wind from the south, averaging about 30 miles per hour at 1,500 to 2,000 feet, was also recorded by meteorologists. The facts in this case are unusually complete, due in large part to the existence in Africa of a well-developed organization for compiling data related to migratory grasshoppers.

The occurrence of *gregaria* in Portugal is not new, Uvarov (1928, p. 253) referring to its occasionally being found there and concluding that "it seems certain that in all cases the appearance of the locusts has been due to strong swarms from Africa."

There are numerous recorded cases of long flights by *Schistocerca gregaria.* Scudder (1878) and Howard (1918) give separate instances of its being taken on board ships in the Atlantic Ocean about 1,200 miles from the African mainland. Uvarov (1923, pp. 34–35) reports specimens of *gregaria* from the islands of Cape Verde, Grand Canary, and Ascension, and he says those occurrences can be explained only as the result of flights from Africa. Swarms of *gregaria* usually travel about 20 to 30 miles per day, and settle down at night (Waloff, 1946), so these unusually long movements are of interest in illustrating the potentialities of migratory grasshoppers when aided by especially favorable weather conditions.

FACTORS INFLUENCING THE MOVEMENT OF GRASSHOPPERS BY AIR

Some basic principles bearing on long flights of grasshoppers have been treated in recent publications based on field work with the desert locust in Africa and the Middle East. J. S. Kennedy (1951) has analyzed the various factors involved in the behavior of swarms, and has presented a theory explaining long-range migrations. The chief factors are the condition of the grasshoppers, gregariousness, wind, sun, and landscape. The influence of wind was stressed, since swarms of *gregaria* usually fly into the wind by choice. If the latter is too strong, however, as is often true when it blows about 9 miles per hour or more, the grasshoppers are apt to turn aside. Then they most often settle or turn about and fly with the wind. Rainey and Waloff (1951) have given special attention to the effect of convection cur-

rents on flying grasshoppers, and their observations leave no doubt that uprising currents are highly significant in many long flights at high altitudes. Flying grasshoppers which come under the influence of convection currents in some instances are liable to be swept upward even to tens of thousands of feet and at velocities greater than their falling speed with wings closed. Such currents are probably responsible for various occurrences of grasshoppers on mountains at altitudes far above their normal habitat.

In recent years there has been a growing appreciation of the extent to which insects are carried by air currents. Many of the species transported either fly weakly or not at all. This fact was well shown by Glick (1939), who described collections made during a period of several years in the Southern States by using ingenious traps mounted on airplanes. I recently reviewed this and later evidence which favors the occasional long-distance introduction of insects by natural air movements (Gurney, 1949b).

Further observations on the reactions of *Melanoplus rugglesi* to external factors may be expected to show how closely this species agrees with *Schistocerca gregaria* in its fundamental behavior. Likewise, further collections from the layers of frozen grasshoppers in the glacier may eventually disclose specimens of *rugglesi*. These would be of much historical importance, because they would show that flights occurred long ago, though we now lack flight records earlier than 1939. It is logical to suppose that, at irregular intervals for centuries past, phase transformation of *rugglesi* has taken place, followed by long flights. In fact, early reports of the United States Entomological Commission (Riley et al., 1878, p. 106, App., p. 139; 1880, p. 7) record large numbers and conspicuous swarms of grasshoppers in the vicinity of Golconda and Winnemucca, Nev., in 1877 and 1878. This is the place where, about 1947, a migration of *rugglesi* occurred, one in the series of recent annual migrations reaching from Big Smoky Valley, Nev., to Guano Lake, Oreg., over a period of about 12 years. Circumstances suggest that the same grasshopper may have been involved in 1877–78, rather than the Rocky Mountain grasshopper as then supposed. No preserved specimens are known, however, and consequently the identities cannot be established. Grasshopper Glacier may yet contribute much of interest to the early as well as the current history of this Great Basin grasshopper.

OTHER LOCATIONS OF FROZEN GRASSHOPPERS

Although this account has been concerned mainly with Grasshopper Glacier, there is no doubt that grasshoppers which have been transported partly by air currents have frozen into glacial ice in many places. Bevan and Dorf (1932) mention a second "grasshopper glacier" of the Beartooth Range, located at the head of the West Fork

of Rock Creek. Its origin and conditions are probably comparable to those of the main Grasshopper Glacier which we have discussed. According to Kimball (1899), there are grasshoppers embedded in ice on the slopes of Mount Dewey, located about 6 miles southeast of Grasshopper Glacier. He said that they are perfectly preserved, as the ice is stationary, instead of being badly broken as often occurs in a glacier that is subject to movement.

In the central part of the Crazy Mountains of central Montana there is a "grasshopper glacier" at the head of Cottonwood Creek. During the warmer summers the grasshoppers are exposed in large quantities. This glacier is labeled on a United States Forest Service map of the Gallatin National Forest, published in 1947 and on a scale of five miles per inch. A short distance southeast of this glacier is another containing grasshoppers, which is not shown on the above map. The latter drains into Pear Lake, which in turn goes into the North Fork of Big Timber Creek. Both of the Crazy Mountains "grasshopper glaciers" are mentioned by Dyson (1952).

Hayden (1873, p. 2) related the observations of two men in a survey party who reached the summit of the Grand Teton in western Wyoming. There were many flying grasshoppers (species not indicated), especially in August and September, which became chilled and fell on the snow and ice in vast numbers. There they melted myriads of tiny holes in the ice, enabling the men to cling to the almost vertical icy side of the peak. (Judged from present knowledge of *Melanoplus rugglesi*, September would definitely be too late in the season for that species to be on the wing.) Michelmore (1934) mentioned a dead swarm of *S. gregaria* in the saddle of Mount Kilimanjaro in Africa. Shipton (1934), an experienced mountain climber, reported hundreds of grasshoppers, presumed to be *gregaria*, which he found embedded in the bare-ice surface of a glacier at over 16,000 feet above sea level on Mount Kenya in 1929.

This, then, is the story of Grasshopper Glacier, though many questions remain to be answered. It is certainly an unusual collecting place for insects, and persistence and good luck probably will eventually reward collectors with several species of preserved grasshoppers as well as other insects. Because both *Melanoplus rugglesi* and *M. mexicanus mexicanus* are important pest grasshoppers with unusual behavior and intriguing past histories, any new evidence from the glacier about them will be of interest to entomologists. Though the glacier with its preserved grasshoppers is a curiosity of nature, it is much more than that because of the basic facts of glacial age and insect movement by air currents that will be more fully understood as further information is gathered.

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NOTE ON THE CARBON–14 TESTS

On April 15, 1953, after the manuscript of the foregoing article was completed, a report was received from Dr. W. F. Libby, Institute of Nuclear Studies, University of Chicago, concerning an examination by the carbon–14 method of grasshoppers collected in 1952 by Dr. Irving Friedman in the deeper layers of the "old" glacier. Dr. Libby's conclusions are that the age may be most appropriately given as 45 ± 300 years and that the limits of error would be 45 ± 600 years. This indicates that these grasshoppers are quite modern, and it seems definite that they are younger than 600 years. Unfortunately, the samples examined have been rather small, and the standard errors involved by this method are sufficient to make an age estimate of such relatively recent material quite broad. The results appear to rule out the possibility that the grasshopper deposits are extremely ancient, and they add weight to the view that the Beartooth glaciers are of relatively recent origin.—*A. B. G.*

Recent Advances in the Study and Techniques of Anatomy[1]

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ANATOMY has the distinction of being one of the oldest sciences known to man. We shall not attempt here to trace its history from its beginning but will try to describe a few recent advances in the various divisions of this broad study. Anatomy in its present position, among the biological sciences, includes gross anatomy, embryology, neurology, and cytology. These can be broken down still further into smaller subdivisions. Early in biological history these four divisions were distinctly isolated phases of anatomy. Today all barriers among divisions of a scientific subject, and actually among fields of science in general, are ceasing to exist, a result that is creating a fusion of interests and a sharing of information.

GROSS ANATOMY

Gross anatomy had its early beginning among the Babylonians and Egyptians and carried over into the early civilization of the Mediterranean area. The Greeks under Asklepios and Aristotle failed to give us a complete picture of man's anatomy. Through the Greek Galen, anatomy advanced considerably, but it was not until 1533 that the first complete book of anatomy was written and that was by the Belgian Vesalius, with his "Epitome" and "De Humani Corpus Fabrica."

Descriptive gross anatomy has not advanced far since the time of Vesalius. In certain aspects, it is a sad commentary that modern textbooks of anatomy have followed the Vesalian pattern. There are a few brave souls who are presenting gross anatomy from a dynamic and functional view, but by and large the teaching and study

[1] Reprinted, with some revisions, by permission from Transactions of the Kansas Academy of Science, vol. 54, No. 2, 1951.

of this subject have remained in a static state. The problems of human growth should break down, to a considerable extent, this situation.

The physical anthropologists are now studying gross morphology of normal individuals and are comparing this with that found in slightly abnormal individuals. This sort of information is giving us a dynamic approach to our problem. The physical anthropologists in recent years, under the leadership of Weigenrich, Broom, Dart, and von Koningeswald, have been actively engaged in the study of ancient man. There seems to be no particular agreement among them as to man's exact origin. More practical problems in physical anthropology have been approached by Hooton at Harvard. Such vital studies as size and shape of gas masks, the dimensions of cockpits in airplanes, and dimensions of all types of garments in the clothing industry are practical examples in which the physical anthropologist has played a vital role. Probably the most exciting type of study among this group of researchers is the work of Sheldon in establishing what he calls the three morphogenic types. They are the endomorph, the mesomorph, and the ectomorph. From his studies these three groups of individuals have general types of behavior and mental outlook upon life. According to his classification, the man possessing endomorphy is a rather rotund, jolly individual who has a rather large gut and enjoys eating; in fact, he greatly enjoys life. The mesomorph, on the other hand, is a muscular heavy-bodied individual. The mesomorphs are the men who do the work of the world—sell life insurance and in general see that the wheels of society move along. The ectomorph, on the other hand, is a rather lean, brainy individual, less given to physical activity and has tendencies toward intellectual activity. These are broad general terms, and when a single individual is being studied charts are so prepared that the subject shows the greater emphasis in one type, but with characteristics in one or both of the others. Psychiatrists have made use of this classification. These groupings aid them in a general way to point toward their diagnoses.

Certain philosophers, especially the school led by Charles Morris of Chicago, using Sheldon's classification, have shown that persons with these different tendencies seem to have, in general, attitudes toward life with a certain physiological and psychological bent. For example: Morris, who has given us 13 ways for patterns of living, has presented statistical data showing that these three classifications of Sheldon follow within certain paths and ways of life. It is interesting to see how a physical anthropologist classifies individuals into three categories, then how this classification is taken and used by a philosopher who has turned scientist (Morris) to study ways by which man lives. These two systems—one by a philosopher-scientist and one by a physical anthropologist—dovetail very satisfactorily.

EMBRYOLOGY

A knowledge of embryology is fundamental to the understanding of the adult organism. The foundation for the science of embryology was laid by Aristotle through his original observations and theoretical acumen. It was he who said that if one wishes to understand the present structure, one must study its past evolutionary history. Karl Ernst von Baer (1792–1876) is, in the modern sense, considered the father of descriptive embryology. This early phase of embryology was predominantly descriptive of the changes in form and structure during development. However, since embryology is not a static science but one that is alive and dynamic, it is not looked upon as a science dealing with structure alone, but with form and function. Embryology then, has paved the way to an understanding of how the adult organism reached maturity.

In addition to morphology, embryology has made valuable contributions to our understanding of developmental behavior. In this realm George E. Coghill (former head of the University of Kansas Department of Anatomy) laid the basic groundwork. His study of the development of the nervous system in the larval form of *Ambystoma tigrinum*, a primitive land vertebrate belonging to the salamander group, showed that behavior was not the welding together of individual reflex arcs as they appeared in the embryo, but that the organism behaved as a whole and that discrete individual reflexes emerged out of this total behavior pattern. This work began in 1913 and continued until Coghill's death in 1941. His contributions were significant in other fields than the straight morphological study of the developing embryo.

Psychologists and philosophers were eager and keen to grasp the meaning of Coghill's contribution to the study of behavior. He showed that in the development of any organism the anatomical and neurological structures came into being far in advance of their functional capacity. Since Coghill's study of the development of *Ambystoma*, similar research has been undertaken in higher organisms including man. It is generally held by those working in the field that Coghill's conception of behavior holds true in all forms. Davenport Hooker, of the University of Pittsburgh, working for the past 20 years on embryonic and fetal development in man, has shown that the Coghillian principles of development hold here also. The over-all picture of these findings indicate clearly that all organisms develop in an integrating field, and during the course of this orderly development discrete movements emerge which are always under the dominance of the total organism.

The picture of man's development from the single fertilized ovum to the fully formed adult is gradually coming into focus. Important

research on this phase of the problem has been conducted at the Department of Embryology of the Carnegie Institution of Washington, D. C., led by the late George Streeter and followed by specialized workers not only at the Institution but throughout leading universities of this country. By careful observation under rigidly controlled techniques in cooperation with gynecologists and the obstetricians, scientists studying the development of the human organism have mapped man's structural development with a surprising degree of accuracy. The advances here in embryology have been tediously slow; they depend naturally upon securing embryos at an exact known date after fertilization. These developmental changes have been expressed in three-dimensional models, representing young human embryos ranging from a few hours to 21 days after fertilization.

EXPERIMENTAL EMBRYOLOGY

Despite the advancement in our knowledge of structural development, it became apparent during the latter half of the nineteenth century that the descriptive and comparative approach was quite inadequate for a better understanding of the developmental process. Though descriptive embryology could show in detail how such structures as the brain and the ear develop, it failed to throw any light on the causes that led to their formation and later differentiation. Hence, the causal-analytical approach was applied to embryological development, and experimental embryology came into being.

Wilhelm Roux (1850–1924), a German anatomist, became the foremost advocate of this new approach. Hans Spemann (Germany) and Ross G. Harrison (United States of America) soon took over the leadership in experimental embryology. Spemann in 1935 won the Nobel prize for his discovery of the organizer.

The basic problem of the experimental embryologist is one that concerns the concepts of *determination*. This new generation of biologists continuously seeks the answer to such questions as: Which factors determine the origin and further development of a given part of the egg or embryo? What effect does external environment have upon development? Actually, in such questions one is asking: Why and how do cells differ in their ultimate fate? The mechanism of organ determination has been carefully analyzed by the experimental embryologist, but it is doubtful if the whole answer will be found here. The classical example is the determination of the lens by the eye vesicle. It was found, principally by the Spemann school, that the optic vesicle, an outgrowth of the brain, comes into contact with the overlying head epidermis and stimulates the latter to form a lens vesicle. When the optic vesicle is removed, no lens is formed. The induction of a lens

is not an isolated case, for it has been found that the entire nervous system of vertebrates is called forth by an inductive act. The recent work of J. Holtfreter (Rochester, Minn., a student of Spemann) and J. Needham (Cambridge, England) indicates that the inductive process is mediated by a chemical substance. There is considerable disagreement as to its exact composition in which speculation concerning its nature ranges from certain proteins, fatty acids, and nucleic acids to Needham's steroids.

The discovery of the organizer by Spemann and Hilde Mangold (1924) was of extreme importance to the experimental embryologist. It was found that when the upper lip of the blastopore, during the process of involution, was cut out and transplanted to the flank of another gastrula it proceeded with its invaginating movements. When this transplanted material reached the inside of the gastrula it underwent differentiation into a complete or partial embryo. This inductive force in itself is not unusual, but the most remarkable feature was that all the structures so originated were combined to form a whole, well-integrated, secondary embryo on the host. This organizer action is essentially and fundamentally a combination of self-differentiation and of complex induction.

These studies on the nature of the organizer and the inductors led quite naturally to the origination of a new type of experimental embryology, one which Needham calls "chemical embryology," but because of the broadness of its scope it could more appropriately be called "physiological embryology." At first the investigations were purely chemical and of an analytical nature, e. g., the chemical analysis of whole eggs. Recently attention has been centered on the enzyme systems as they become active during the process of development. It is here that the concepts of the chemist, the cytologist, the geneticist, and the embryologist merge. Physiological embryology is the basic or unifying branch of the whole field of embryology.

CYTOLOGY

Cytology deals with the structure of cells. To the biologist the cell is what an atom is to the chemist and physicist, i. e., it is a fundamental morphological and physiological unit in the structure of living organisms. The development of this biological discipline has for the most part coincided with the development of the compound microscope. The earlier nineteenth-century cytologists were, however, concerned almost entirely with descriptive or morphological cytology. The role that cytology was destined to play in cell physiology did not begin to unfold until the establishment by the Morgan School at Columbia University of the chromosome theory of inheritance. This

approach resulted in the later utilization of specific knowledge regarding a chemical and physical phenomenon for the identification and localization of the cellular components.

In spite of our increased knowledge of the cell, the primary problems have changed only in degree, i. e., from morphological to physiological. We are still interested in the structure of protoplasm and in its submicroscopic or molecular structure and not as to whether it appears reticular, fibrillar, or granular in nature. The cytologist has literally joined hands with the chemists, the physiologists, and the physicists in an attempt to unravel the intricate workings of the cell in all the complex phases of its life—development, maintenance, and reproduction. We are not, however, concerned with these phases per se but instead with the mechanism of cell function during these phases.

Cell function can be understood only through a knowledge of the intracellular components, that is, the chemical components which make up the cell. At the chemical level, enzymes dominate the scene. Enzymes constitute more than half of the solid matter in most cells. The number of different enzymes and their individual action and requirements may be astronomical in number. There is a rapidly growing conviction that cells differ only to the extent that their enzyme components differ. Waddington (1948) characterizes development as essentially a sequence of chemical changes that have secondary physical effects expressed in the morphology of the embryo. Beadle, in his work on Neurospora, postulates a one-gene, one-enzyme relationship. One wonders if the gene-enzyme relationship is that direct or that simple. It has been suggested, and there is strong support for the hypothesis, that the nuclear gene expressed itself by means of a cytoplasmic unit, the so-called plasma gene. No matter how the gene makes itself felt, the final action is an enzymatic one. Potter (1950) says, "that when a particular group of enzymes is organized in one way, a liver cell results; with a slightly different collection of enzymes appropriately organized, a kidney cell results; and with another assortment of enzymes, a cancer cell results." If function of either the normal cell in all its phases or the abnormal cancer cell is to be understood, the enzyme pattern which characterizes it must be determined.

Cytology has played and is continuing to play an important role in determining these enzyme patterns. This development results in a new cytology, one which overlaps into the now-related fields of genetics, morphogenesis, biochemistry, cellular physiology, and enzymology. It is, of course, a cytology based on entirely new techniques, i. e., new to the biologist. Many of these techniques were actually borrowed as developed by the chemist and the physicist, while others have been modified to fit the needs of the biologist. These new procedures have made it possible to identify, localize, and in some

cases to measure quantitatively chemical substances within the cell itself without radically changing it. It is this phase of cytology with which we shall now deal.

CYTOLOGICAL AND MICROSCOPICAL TECHNIQUES

Enzymes, proteins, nucleic acids.—Northrup (1949) in his discussion on "Enzymes and the Synthesis of Proteins," emphasizes the close relationship which exists between enzymes, proteins, and viruses. Nucleic acids obviously fit into the same picture whether one considers them from the standpoint of a conjugated protein, i. e., the nucleoproteins, or as enzymes. It has been suggested that the nucleic acids may, acting as coenzymes, funnel energy into metabolic actions.

Chemically, cellular components vary, depending upon the function of the cell and the physiological condition of the main tissue mass of which the cells are a part. Despite this chemical variability, the nucleic acids are always present as one of the fundamental components. It is now well established that two types of nucleic acids exist, ribonucleic acid and desoxyribonucleic acid. The two are to be found in both plant and animal cells. Ribonucleic acid is concentrated for the most part in the cytoplasm and the nucleolus, desoxyribonucleic acid in the chromosomes. The organization and perfection of histochemical and cytochemical methods for the detection and measurement of nucleic acids at a microscopic level, have stimulated an intensely renewed interest in the nucleoproteins and their prosthetic groups, the nucleic acids.

Recent investigations have shown that nucleic acids are involved in many vital cell functions. Desoxyribonucleic acid (DNA) condenses on the chromosomes during division, at which time it becomes apparent that a new gene chain has been or is being synthesized. There is, furthermore, an apparent high concentration of ribonucleic acid (RNA) in those tissues active in protein synthesis (secretory glands, embryos, tumors, etc.). Such self-duplicating bodies as viruses and plasmagenes, both of which may be closely related to genes, have proved to be nucleoprotein in nature. In Muller's (1950) opinion the genetic material itself, that is the gene, is a nucleoprotein, but he assumes that the difference between genes, like the specificity between enzymes, lies chiefly in the protein and not in the nucleic acid.

The most impressive technique devised for the identification, localization, and possible measurement of the two nucleic acids is that by Casperson (1936), the ultraviolet absorption method. Casperson (1950) describes in detail the apparatus and procedures in his new book, "Cell Growth and Cell Function." Between 2500 and 3000 A. the absorption of the cell is usually dominated by that of the nucleotides and proteins. This broad band can be further broken down to

narrower limits: (1) at 2600 A. absorption of the pyrimidine or purine ring of the two nucleic acids occurs; (2) at 2800 A. there is found the maxima in absorption of the aromatic amino acids.

Ultraviolet methods, when properly controlled, give a measure of the total nucleic acids, but the two main types (RNA and DNA) can be distinguished only by removing one or the other through treatment with a specific nuclease. There has been considerable controversy about the ultraviolet absorption of living cells; e. g., it has been found that the amount of absorption increases with the length of exposure. Commoner and Lipkin (1949) raised the question as to the degree of orientation of the nucleic-acid molecule. If the molecules are oriented, is the orientation sufficient to invalidate the quantitative data so obtained? A second probable source of error lies in the danger of light scattering, which Casperson (1947) has discussed in detail. In view of the above factors one should accept with caution any theories based on their quantitative value. This conclusion does not mean that ultraviolet spectroscopy is without value, since qualitatively the information is invaluable.

Chemically the nucleic acids can be identified and localized by: (1) the Feulgen reaction, (2) basic staining, and (3) Brachet's ribonuclease technique.

Feulgen and Rossenbeck (1924) adapted the Schiffs-base reaction to cytology for the visual identification of desoxyribose nucleic acid. Under proper controls this procedure is qualitatively specific, though there is little to support its quantitative value. The extensive literature on the subject has been reviewed by Stowell (1945) and Lumb (1950). The latter author in the same paper critically analyzed all the more commonly used nucleic-acid techniques.

Of equal importance are the methods for the detection and localization within the cell of various types of enzymes. Most techniques of this sort involve incubation of the cellular material in a suitable substrate solution, with the production at the site of enzymatic activity of a colored substance or of a substance which can be converted into a colored compound. There are tests of this nature for the localization of cytochrome oxidase, peroxidase, amino oxidase, lipases, proteases, glucoronidase, phosphorylase, alkaline and acid phosphatase, and others. None of these techniques, with the exception of alkaline phosphatase has been subjected to a critical analysis. Danielli (1946) established the validity of the alkaline-phosphatase technique when properly controlled. A detailed account of the possible significance of the alkaline-phosphatase enzyme to nucleic acid and protein metabolism and the process of calcification is to be found in J. R. G. Bradfield's recent review article, "The Localization of Enzymes in Cells" (1950). For procedures, consult Glick's (1949) book, "Techniques of Histo- and Cyto-chemistry."

Centrifugation.—The possibility that various enzymes may be bound to or absorbed on mitochondria motivated the development of the technique of the separation of cellular components by centrifugation. The earliest important separation was achieved by Bensley and Hoerr (1934). In their paper they describe the process of isolating large granules which proved to be mitochondria. Subsequent investigators (Claude, Dounce, Hogeboom, Lazarow, Mirsky, Moog, Palade, Pollister, and others) perfected the differential centrifugation technique and isolated in addition to mitochondria the much smaller microsomes, glycogen particles, whole nuclei, and chromosomes. Tests for enzyme activity confirmed the original postulation that mitochondria are the most important site of intracellular enzymes. If one recognizes the obvious limitation of this technique which destroys the intracellular relationships the results obtained can be extremely valuable in the identification of enzyme systems.

Microchemical analysis of biological materials.—Lowry and Bessey (1946), through the use of a specially designed curvette and the preparation of materials at low temperatures (−20° C.), adapted the Beckman spectrophotometer for the measurement of the chemical components of extremely minute sections of cellular material. They were able to obtain quantitative measurements on volumes as low as 25 cmm. (0.025 ml.). With their adaptations, for example, they have measured ascorbic acid in 0.01 ml. of serum, vitamin A and carotene in 0.035 to 0.06 ml. of serum, and ascorbic acid in the blood cells and platelets of 0.1 ml. of blood. With this technique it is conceivably possible to make quantitative analyses of whole nuclei cleaved from frozen tissues.

Microdissection.—One of the outstanding techniques of recent years has been that of microdissection. There are four or five different types of microdissecting instruments, but the one used by Chambers probably leads the field. In this approach to the living cell, small needles or knives are made by drawing out glass tubes or glass rods into very fine points and edges. These tubes are then placed in holders which can be maneuvered most gently and accurately within ranges of 1 or 2 microns or fractions thereof; nuclei of cells can be removed; chromosomes can be pulled out; myofibrilla and neurofibrilla can be teased and pulled out of their respective fibers by this ingenious method. By this application scientists are agreed now that these structures can no longer be considered artifacts, but actual organoids of the living cell.

Another advantage of the microdissecting techniques is that small quantities of material can be injected into a living cell, thus enabling the student to study experimentally the functions of various protoplasmic constituents.

The quartz-rod transilluminator.—One of the most fascinating techniques that has been devised in the last few years is that of the quartz-rod-transilluminator method of Dr. Melvin H. Knisely, head of the Department of Anatomy, University of South Carolina. This technique permits light to be brought to living tissues in which heat is not transmitted. Only the heat of irradiation is present, and this can be eliminated or drawn off by the continuous flow of normal physiological salt solution over the tissue being observed. Three outstanding discoveries in recent years have been made by the use of this technique. In 1935, Knisely discovered that the spleen had a closed circulation and had the power of regulating the amount of formed elements of the blood held within one of the individual units of the spleen, namely, the sinusoid. This observation was a rather striking discovery. Knisely could actually see the sphincter activity of an individual sinusoid after it began to constrict and hold back the blood cells while at the same time allowing the plasma to escape through the latticelike wall of the individual sinusoid. In studying the liver Knisely also showed that there was a sphincterlike activity at the point just before the sinusoid enters the central vein. In both the spleen and liver he showed that there was a rhythmiclike activity of filling and emptying the individual sinusoid. He also established the rate of red cell destruction by the liver in its selective phagocytic function. Here he showed that as a red cell became old or injured in some way, a lining cell of the liver sinusoid instantaneously engulfed the red cell. This effect was not only observed and reported by Knisely, but his color photography is superb in showing the above activity. Knisely's discovery of sludged blood was a unique revelation to the medical profession. Using the quartz-rod-transilluminator method, he showed that under pathological and disturbed conditions in all animals studied, red cells of the blood stream were agglutinated within the vessels themselves. Even in minor injuries, especially in surgical shock, sludging became excessive. In more than 600 human patients observed by the quartz-rod-transilluminator method in the sclera of the eye, Knisely has observed a sludging of blood. This sludging is observed in varying degrees of intensity from the result of a minor cold in which there is very little sludging to extreme cases of malaria where excessive amounts of sludging occurs. Knisely has concluded from his studies that all human ills produce this phenomenon.

The next big step that will follow undoubtedly will be a discovery of some method of "unsludging" the blood. Intensive studies in several laboratories are now under way to understand more clearly the factors involved in producing the sludge in the first place. The study of sludging is being observed on experimental animals with

cancer of various origins and other diseases. Human patients, in a few centers of America, are also being studied intensively.

PHASE MICROSCOPY

Phase microscopy is used to observe materials that are too transparent for ordinary bright-field study. Specimens usually include such objects as living organisms, unstained tissue, slightly pigmented or faded preparations, emulsions, and plastics.

The American Optical Co. offers the following brief explanation of the theory of phase microscopy:

In the phase microscope a diffraction plate or coating is added within the objective and an annular diaphragm below the condenser of the bright-field microscope, thereby converting slight and invisible alterations of light passing through the specimen into images which may be seen and photographed. The annulus in the condenser controls the illumination on the diffraction plate or coating, where the light from the specimen and its surround is selectively modified so that it will recombine into an image of adequate visibility. The range of phase objectives makes possible several degrees of contrast, with or without reversing of bright and dark details, to provide best visibility, to emphasize detail, and to insure that no detail is missed in the microscopic examination of such materials. All objectives have incorporated into them the latest developments in this relatively new field.

THE ELECTRON MICROSCOPE

The electron microscope has so far only limited application in biology. This limitation is brought about by the fact that the material studied has to be in very highly desiccated condition and the thinness of the material is of an extremely small order. One cannot observe material that is 2 or 3 microns in thickness. It has to be 0.2 or 0.3 μ in thickness in order that the electron microscope can bring out in detail structures that could not otherwise be seen. Its greatest use eventually, and probably even now, is that it can deal with large protein molecules within certain fibrillae of protoplasmic strands. However, it may be that new inventions or new techniques in electron microscopy will render this instrument more useful to biology. The instrument does not use ordinary light source, but depends upon X-rays to bring out the objects observed. Instead of glass or quartz lenses, the lenses of the electron microscope are large electromagnets which may constrict or diffuse the X-rays as an ordinary microscope does light.

TISSUE CULTURE

Tissue culture has given us considerable advantage in studying living systems. Under this technique, cells or tissues may be removed from the living body and kept alive in a medium adequately supplied

by necessary nutrient requirements. Thus one is enabled to experiment indefinitely upon various tissues and cells. An outstanding example of a contribution by this technique was that made by Dr. Ross Harrison, of Yale. He was able to show, for example, that all the cells of a developing nervous system were independent of one another and did not unite in a common syncytium. This tissue technique has many ramifications under varying experimental approaches.

ISOTOPES

The most recent types of technique in microscopic anatomy are those concerning tracer isotopes and autoradiographic procedures. The fondest hopes and dreams of scientists have been to determine accurately the presence of any particular substance at a given time within certain tissues of plants and animals. Not only have they been used to determine accurately the presence of such substance, but also as a method showing how the plant or animal organism metabolizes these materials. By radioactive isotopes, one can, either by the geiger-counter method or autoradiographic techniques, determine the presence and amount of any substance that is either naturally autoradioactive or artificially made so. One of the most common uses of radioactive isotopes in this particular field has been to determine the uptake of iodine by the thyroid gland. By giving radioactive iodine to an individual, the amount of iodine absorbed in the gland can be determined. Under experimental and normal conditions, one can determine to a certain extent the manner by which the thyroid gland utilizes iodine. These new techniques are used not only in tracer work but also in therapy. For example, the administration of radioactive iodine to a patient suffering from cancer of the thyroid gland will alleviate, and, in certain instances, cure the cancer. One of the most striking examples of this technique is the study in which the body metabolizes radium. It has been known for many years that radium, strontium, and barium have a great affinity for bone. Investigators would like to establish positively whether radium behaves as calcium does.

In our own laboratories, for example, Dr. Frank Hoecker and the senior author of this paper have shown that radium is not distributed evenly or uniformly throughout the bone either in the rat or in man. We have devised techniques where we can, by autoradiographic methods, determine accurately in space, not only the presence of radium but the amount found in bone after its administration into the body. Our technique is one in which we determine photographically by our autoradiographs the presence of radium in any particular spot by superimposing the photomicrogram of the bone and the

autoradiogram of the photomicrogram of the alpha particle tracks. We feel that this technique is probably the most accurate available.

NEUROLOGY

Neurology is too broad a subject, covering both the basic science and clinical fields, to be treated here. In the study of neurology the mathematician, the engineer, the pathologist, and the physiologist have opened a new field, namely, cybernetics, which is the study of communication in the animal and the machine.

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Livestock Parasitology in the United States[1]

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[With 1 plate]

Although the Act of the Congress of the United States establishing the Department of Agriculture became effective in 1862, 21 years elapsed before animal-disease investigations on a sustained basis were undertaken by the Department. In 1883 a Veterinary Division was established in the Department of Agriculture. In the next year the Congress established the Bureau of Animal Industry in the place of the Veterinary Division, and Daniel E. Salmon, a capable young veterinarian who had made investigations for the Department of Agriculture and later headed its Veterinary Division, became the Chief of the new Bureau. The Bureau of Animal Industry, besides being given other responsibilities, was charged with the duty "to provide means for the suppression and extirpation of contagious pleuropneumonia and other contagious diseases among domestic animals."

Even before the Bureau came into existence, the livestock and meat industries of the United States had already developed to such an extent that they had sizable surpluses for export. Beef and pork, as well as live animals, had been exported for a number of years to various European countries. Unfortunately, several countries had placed restrictions against these importations on account of disease which might be conveyed to their native stock, or because of human health hazard in consuming meat from diseased animals. Aside from the export restrictions, American stockmen faced serious difficulties from the diseases to which their stock at home was subject. Among these diseases were some of parasitic origin, the nature of which either was not understood, or for which effective control measures had not yet been developed or put into general use.

[1] Address of the President, American Society of Parasitologists, November 16, 1951, Chicago, Ill. Reprinted by permission from the Journal of Parasitology, vol. 38, No. 2, April 1952.

The disease which was then known as murrain, or splenic fever, or Texas fever, caused great consternation among livestock producers, especially in the northern States, who saw their animals stricken and die when they followed the trails of apparently healthy cattle that had been driven northward from Texas and elsewhere in the South. So great was the fear among northern cattle owners of the danger to their herds from southern cattle that rigorous action was taken, sometimes accompanied by threats of violence, to prevent cattle from Texas from being driven over the trails which led to the northern markets. Another parasitic disease, known as sheep scabies, was ravishing flocks on the western ranges. On account of the highly contagious nature of this skin disease, the importation of sheep from the United States to other countries was barred, and in this country the disease was spreading as a result of the uncontrolled movement of livestock. Cattle scabies, too, lurked in the background as a disease requiring serious attention, if the increasing herds were to be maintained on a high level of efficiency. The internal parasites of the country's livestock were practically unknown at the time the Bureau of Animal Industry was established. However, one parasite of swine, *Trichinella spiralis*, was well known in this country, and abroad it was regarded as exceedingly dangerous on account of its potential harmful effects on human beings. By 1881 several countries in Europe had already placed an embargo on pork from this country, and the Department of State instituted, therefore, an inquiry to ascertain the causes that might render this meat dangerous to human health.

These, then, were the principal known problems in parasitology in relation to an expanding livestock production that confronted the Bureau of Animal Industry in 1884, when Salmon and his few assistants began "to provide the means for the suppression and extirpation" of disease of farm animals. The manner in which the Bureau fulfilled its responsibilities, the investigational work that had to be carried out before suppression and extirpation could be undertaken, the means adopted to carry out the programs, and the success achieved, constitute an important and fascinating chapter in the history of livestock hygiene and disease prevention. Only those parts of the chapter which relate to parasites and parasitic diseases can be reviewed in the course of this address, and only by a few outstanding examples.

TICK FEVER

Although it is uncertain when the disease now known as tick fever, or bovine piroplasmosis, was first introduced into the American colonies, it is probable that it came in with importations of cattle from the Spanish West Indies and Mexico, perhaps sometime in the seventeenth century. By the end of the eighteenth century the disease was

apparently well entrenched in the United States, because by 1795 the State legislature of North Carolina prohibited by law the driving of any cattle from the low coastal areas to the highland parts of that State between the first day of April and the first day of November. In 1814 Virginia barred cattle from certain parts of South Carolina, and in 1836 North Carolina barred cattle from South Carolina and Georgia, between the dates aforementioned. Despite these and similar restrictions, tick fever continued to spread with the growth of the livestock industry and the development of transportation facilities and markets. Gradually it spread over the entire South, and often invaded different sections of the North. In 1867 the Kansas Legislature appealed to Congress to authorize the Department of Agriculture to investigate Texas fever. By 1877 the disease had caused much harm throughout the country and continued to spread, despite the energetic methods that were being adopted to stem its tide. When the overland movement of cattle proved difficult or illegal, animals were moved by boat and landed in northern markets, with the result that their contact with northern cattle decimated prize herds that were being established after the Civil War.

An investigation was made in 1868, partly at the instigation of stockmen and partly under Federal auspices, by Prof. John Gamgee, a British expert on animal diseases, assisted by two medical officers of the United States Army and others. Among the conclusions reached were that cattle "become affected in consequence of the nature of the soil and vegetation on which they are fed, and the water which they drink." With regard to the popular idea then prevalent that ticks had something to do with the disease, Gamgee stated "that there is not the slightest foundation for the view that ticks disseminate the disease." In another place Gamgee stated, "The tick theory has acquired renown during the past summer but little thought should have satisfied anyone of the absurdity of the idea." Salmon, who in 1879 investigated tick fever under a commission from the Department of Agriculture, reported in 1880 as follows: "The tick theory scarcely explains a single one of the many peculiar phenomena of the disease," a conclusion which was generally shared at the time by those best informed on animal diseaes.

Following the organization of the Bureau of Animal Industry in 1884, and the opening at the same time of an experiment station on the outskirts of Washington, D. C., as part of that Bureau, an opportunity was afforded to the handful of young researchers whom Salmon had collected, to investigate the most pressing livestock maladies that were exacting a severe toll from the resources of farmers and stockmen. In 1888 studies on tick fever were already in progress. In that year Theobald Smith, the leading investigator of Salmon's small coterie of

scientists, observed the destruction of the red blood corpuscles of cattle sick with tick fever. In the following year three important discoveries were made in the Bureau of Animal Industry with reference to ticks and tick fever: (1) Smith observed a parasite in the red blood cells of the affected animals (pl. 1, fig. 1) and, on the basis of this discovery, explained the breakdown of the erythrocytes and the various lesions he observed while conducting postmortem examinations of cattle that had succumbed to the disease. (2) While Smith was carrying out these studies, Kilbourne, who was in charge of the modest experiment station aforementioned, started an experiment which ultimately led to the elucidation of the mode of transmission of Texas fever. What Kilbourne did in 1889 is contained in the following statement, written by Smith as part of his contribution to the Sixth and Seventh Annual Reports of the Chief of the Bureau of Animal Industry for the years 1889 and 1890:

> During the summer of 1889 Dr. F. L. Kilbourne in arranging the various enclosures at the experiment station for the exposure of native cattle to the infection of Texas fever, conceived the happy idea of testing the popular theory of the relation of ticks to the disease. This he did by placing southern (North Carolina) cattle with native cattle in the same enclosures and picking the ticks from the southern cattle as soon as they had grown large enough to be detected on the skin. This prevented any ticks from maturing and infecting the pasture with the eggs, and hence prevented any ticks from infesting native cattle subsequently. At the same time in another enclosure the ticks were left on the southern cattle. The natives in the latter field died of Texas fever: those in the former did not show any signs of the disease.

(3) Curtice worked out the life cycle of the fever tick for which he created a new genus, naming it *Boophilus*, and determined for the first time, in connection with tick life-history studies, that this parasite spent its entire developmental cycle, beginning with the seed tick, on the same host, instead of dropping off the host after each molt. This important discovery made it possible to apply certain measures to control these ticks, and paved the way for tick eradication, which finally resulted in the extermination of bovine piroplasmosis from the United States.

Additional investigations, carried out jointly by Smith and Kilbourne between 1890 and 1892, established conclusively that neither the soil from pastures on which ticky cattle had grazed, nor direct physical contact of healthy with affected animals, was involved in the transfer of the disease from parasitized to susceptible cattle. Moreover, by placing on susceptible cattle the seed ticks that had hatched from the eggs deposited by gravid female ticks, the symptoms and lesions of tick fever, as well as the causative microparasites, were observed in the animals which became experimentally infected. Finally, it was shown by blood inoculations that the microparasites,

named *Piroplasma bigemima*, were the causative agents of the disease, and that the tick, *Boophilus annulatus*, merely served to transmit them.

The determination of the nature of the causative agent of tick fever and its mode of transmission, as well as the demonstration of the main facts in the life cycle of the arthropod carrier, is certainly among the outstanding achievements in microbiology. These discoveries, significant as they were from a scientific standpoint, did not by themselves ease the burden on livestock producers in the South, whose cattle could not be shipped to northern markets, except for slaughter, between the middle of February and the middle of November, in conformity with measures that had been adopted in the meantime to confine tick fever to the areas where it was enzootic. All the Southern States, from Virginia to Florida, and extending westward to include Texas and Oklahoma, were in the enzootic area. These States, along with California, were sooner or later placed under Federal quarantine. Therefore, to meet the practical needs of cattle producers, and to afford relief to a large section of the country which was seriously hampered in the development of a well-rounded agricultural economy, it became necessary to devise means for freeing cattle in the South and elsewhere of fever ticks. Investigations were begun in 1892 in which many veterinarians outside the Bureau of Animal Industry participated. These investigations were continued for several years beyond the initiation, in 1906, of a systematic campaign, under joint Federal and State auspices, with the objective of eradicating cattle fever ticks from the United States.

During a period of about 15 years various materials were tested as smears, sprays, and dips for the destruction of cattle ticks, in an effort to find a chemical that would destroy these arthropods without injuring their hosts. Substance after substance, as well as various combinations of substances, were tested and discarded, because the ticks proved to resist them much better than the cattle. As a desperate measure, cattle were even driven into the ocean's surf, in the hope that the pounding of the waves would dislodge the ticks. By 1903 crude petroleum was generally accepted as superior to any other tickicide discovered up to that time. Other control measures were tried, including active and passive immunization of cattle against piroplasmosis; starving the ticks by removing the cattle from the pastures contaminated with tick eggs and larvae, and keeping the pastures vacant for several months; and rotation of cattle on pastures, based on the demonstrated facts in the life history of the arthropod vector. These and other measures were tried as adjuncts to, or substitutes for, dipping of cattle in medicated baths.

In 1906 experiments were initiated with arsenical dips, which had already been used in Australia and Cuba for tick eradication. Arsenic

proved to be superior to any other tickicide that had been used up to that time in this country. By dipping tick-infested cattle in arsenical solutions every 2 weeks, which was the procedure finally adopted, most of the ticks on the cattle were poisoned by the chemical. Ransom determined that the engorged ticks which survived dipping laid fewer eggs on the ground than those from untreated cattle. Of the larvae that hatched from the eggs laid by the dipped female ticks, many died before they could get onto cattle. The seed ticks which succeeded in crawling onto cattle and living there were destroyed by the next dipping in arsenic. In short, the cattle were used as the collectors of the seed ticks present on the pasture, and the arsenical solution was used to destroy them on the cattle. With successive dippings the numbers of ticks found on cattle maintained on tick-infested pastures gradually diminished and disappeared altogether after several months of repeated dippings, at intervals of 2 weeks, throughout the spring, summer, and early fall months.

I have dwelt at considerable length on tick fever because it was the first parasitic disease of livestock on which an all-out attack was made in this country, with a successful outcome, and also because the story of tick fever in the United States is unparalleled in the annals of disease control, human or animal, anywhere in the world. With no definite knowledge whatsoever available in the beginning as to the cause, or mode of transmission, of the disease, all the facts pertaining to its nature and mode of spread—which certainly was a surprising one at the time it was made—and habits and mode of life of its arthropod vector, were brought to light as a result of research carried out in one place. Moreover, the means whereby the vector could be destroyed, without unduly injuring the host, also were discovered. This paved the way for cutting the lifeline by means of which the piroplasms were carried from the blood of one bovine to another. Finally, on the basis of the facts ascertained through long-sustained experimentation, a death sentence was pronounced on the two arthropod carriers of the disease, *Boophilus annulatus* and *Boophilus microplus*, and on the sporozoan parasites which they conveyed to their bovine hosts. That this sentence was carried out after more than four decades of strenuous effort, and in the face of strong opposition, is certainly a tribute to the research workers who forged the weapons of tick destruction, and to the many who used them.

Cattle fever ticks and the disease they transmit have been eradicated from the United States, except from a long, narrow strip of territory adjacent to the Rio Grande River. This strip, which is about 500 miles long, extends from Devils River near Del Rio, Tex., to the Gulf of Mexico, and to an average depth of 4 to 5 miles. As

far as can be foreseen now, the cattle in this buffer zone will remain under quarantine until fever ticks are eradicated from Mexico. Despite the systematic dipping of cattle in the buffer zone, the drifting of animals from both sides of the river maintains the tick infestation, accompanied by occasional cases of piroplasmosis.

SHEEP SCABIES

At no time did scab or scabies of food-producing animals present a challenge that was even remotely comparable to that presented by the once mysterious malady called Texas fever. In 1884 the cause of sheep scab was well known, as was also the life history of the mite, *Psoroptes equi* var. *ovis*. The research that brought these facts to light was done in the first half of the nineteenth century, when it was shown by experiments that scabies in sheep did not develop in the absence of mites, and could be produced experimentally by transplanting the specific scab mites from affected to healthy sheep. It had been established also that the losses from this disease were severe, and resulted in the shedding of the wool, marked emaciation, anemia, and exhaustion which finally ended in death of a large percentage of untreated animals.

Before the turn of the century sheep in large areas of this country were affected with scabies, and many stockmen were forced to forsake sheep raising on account of the ravages of this disease. In fact, so severe were the monetary losses sustained by owners of scabby flocks, that Salmon and Stiles in 1898 regarded this disease as second only to hog cholera, from the standpoint of the loss of invested capital in livestock raising. The large bands of sheep on the Great Plains and in the Rocky Mountain region, as well as sheep in the feeding centers farther east, were most severely affected. Moreover, diseased sheep from those areas were sent to the large markets of the country, thereby spreading scabies almost everywhere. As a consequence of the uncontrolled marketing of scabby sheep, the stockyards became contaminated and many animals that were purchased there were likely to develop the disease.

Various plans were tried to arrest the further spread of scabies and to devise means of eradicating it. In 1895 a decree was issued, pursuant to authority granted by the Congress, prohibiting scabby sheep from entering stockyards or any other places where animals are handled for interstate trade, or to enter into interstate trade, but no apparent progress was made in checking the disease. Subsequent orders required cleaning and disinfecting boats, railroad cars, and other vehicles which had been used for the transportation of scabby sheep; prohibited railroads and other transportation companies, and captains of steamboats, from receiving for transportation, or from

transporting from one State to another, sheep affected with scabies; and required, moreover, that all sheep shipped from stockyards to other States for feeding purposes be dipped in some preparation that would kill the mites. These devices alone did not show sufficient promise, however, in accomplishing the desired results. Even stationing of inspectors at shipping points in western States and at public stockyards to supervise dipping was insufficient to make a significant dent in the extent of the disease, or to sharply curtail its dissemination. It was not until a Federal quarantine was placed on all the territory west of the eastern borders of North Dakota, South Dakota, Kansas, Oklahoma, and Texas—an area covering 1,700,000 square miles—that a promising plan for extirpating sheep scabies from the United States actually got under way.

Under the new plan, inspections of sheep for evidence of scabies were made systematically on the farm and range. Treatment by dipping, under governmental supervision, in medicated solutions of established efficacy was also required for all flocks that were affected with, or had been exposed to, scabies. This plan, initiated in 1905 and still in effect today to a limited extent, resulted in the eradication of scabies from sheep in areas of this country where it was once widespread, and in reducing it elsewhere.

In 1898, Salmon and Stiles, in a publication on sheep scabies, reviewed critically the dips then in use, reported their own experiments with dips, and settled on two, namely, nicotine and lime-sulfur. These two dips have been used successfully ever since 1905 in millions of dippings. During the past few years the Zoological Division of the Bureau of Animal Industry developed a dip that, in many ways, is superior to, and much simpler to use than, the two that received official sanction. The active ingredient of the new dip is one of the chlorinated hydrocarbon insecticides, hexachlorocyclohexane, generally referred to as benzene hexachloride, or BHC for short. This chemical has been standardized for scabies eradication, on the basis of its gamma isomer content, to provide a margin of safety that should meet most of the likely contingencies that are apt to arise. The new treatment is rapidly gaining the approval of sheep producers and livestock sanitary officials. Through its use, the relatively small residue of what was once the most debilitating disease of ovine stock can be eradicated, I believe, in much less time than with the old treatments.

TRICHINAE IN SWINE

When Joseph Leidy reported in 1846 to the Academy of Natural Sciences of Philadelphia the occurrence of trichinae in the superficial part of the extensor muscle of a hog, he inadvertently took the first

step that resulted in placing a stigma on pork produced in this country—a stigma which has persisted for many decades. By 1881 restrictive measures against the importation of pork from the United States were promulgated by various governments of continental Europe—Italy, Austria, Germany, and France following one another in rapid succession. In the year before this prohibition went into effect, 70 million pounds of pork from the United States had been exported to France, and 43 million pounds to Germany. For the next 10 years pork from the United States was shut out by governmental decree from nearly every market on the Continent of Europe. To regain this export trade, there was inaugurated in 1892 a system of microscopic inspection of all pork intended for export. This inspection, which was terminated in 1906, was carried out only to meet the requirements of the import countries, some of which required a similar inspection under their own meat hygiene practices. Under current Federal meat inspection there is no provision for microscopic inspection of pork intended for any purpose whatsoever. The abandonment of microscopic inspection of pork for export resulted from reports, especially from Germany, that trichinae were found from time to time in pork that had been imported from the United States and certified as free of these parasites. This was not surprising, considering the fact that it was well known in countries that had had experience with this scheme of prophylaxis that the detection of trichinae by microscopic inspection is, at best, a hit-or-miss method. The parasites were not discovered, as a rule, in lightly infested carcasses and were overlooked at times even in those that harbored sizable infections.

Studies made in this country before 1891 showed that only about 2 percent of the hogs were infected with trichinae. The routine microscopic inspections of pork (pl. 1, fig. 2), that were made over a period of years thereafter showed that in over 8,000,000 hogs from which muscle tissue was examined microscopically, live trichinae were found in only about 1.5 percent. Studies made a decade or so ago by the Bureau of Animal Industry by the far more accurate digestion technique (pl. 1, fig. 3), also showed an over-all infection rate of about 1.5 percent. When critically analyzed, however, the newer figures actually showed that in the intervening years there occurred a sharp reduction in the prevalence of trichinae in swine, especially in those raised on the farm. In one series of examinations, involving both microscopic inspection and digestion, it was found that in only 21 percent of the diaphragms in which trichinae were discovered by the digestion technique could these parasites be demonstrated by microscopic inspection. During the past 2 years, trichinae in very small numbers were found in our laboratory by the digestion technique in about 1 percent of about 1,200

diaphragms from Corn Belt Hogs,[2] but only negative results were obtained when samples from the same diaphragms were examined microscopically with painstaking care. Therefore, the 1.5 percent trichinous hogs discovered by microscopic inspection several decades ago undoubtedly represented only part of the infected carcasses that were then present in this country.

Unlike the findings in farm-raised hogs, in which the extent and degree of infection with trichinae are apparently on the downgrade, those in garbage-fed hogs which, fortunately, constitute only a very small percentage of the total hog slaughter in this country, continue to show a high incidence and a comparatively high degree of infection. Recent studies in our laboratories showed that over 10 percent of garbage-fed hogs from the eastern seaboard still harbored trichinae, and that the degree of infection was so high that about half of the infected samples were detected by careful microscopic inspection alone.

Under Federal meat inspection, parasites and the lesions they produce in edible portions of carcasses must be removed by trimming before the carcasses or affected parts are passed for human food. If the infection or associated lesions are so extensive, however, that trimming would be impossible or impractical, the carcass or part is condemned. Since trichinous pork does not differ in appearance from noninfected pork, it follows that trichinous hogs may be passed for human food, under Federal and other meat inspection, almost every day. Fortunately, however, raw pork, as such, is seldom eaten in this country intentionally, and then only by persons having a capricious appetite, or who have become addicted to this habit because of national origin or association with homes where this unhygienic dietary custom prevails. Cooked trichinous pork presents no danger whatsoever, a fact of which Leidy was well aware when he explained to the Philadelphia Academy of Natural Sciences in 1866 the circumstances under which he first discovered trichinae in pork 20 years earlier. Actually, he found these parasites in a slice of cooked pork he was eating, and stated that he had already satisfied himself that such meat was safe, because parasites generally were destroyed by thorough cooking.

The Bureau of Animal Industry has repeatedly informed the public that raw or inadequately cooked or cured pork is dangerous. In the absence of any known system of inspection whereby trichinous pork could be tagged and eliminated from the channels of trade, the problem has been met in the only other way that is possible and practical. Through its meat inspection service, the Bureau of Animal Industry rigidly enforces a requirement that no ready-to-eat article of

[2] Since this paper was written, the infection rate by microscopic examination of over 3,000 diaphragms was found to be 0.63 percent.

food shall contain any muscle tissue of pork, unless that meat has been refrigerated, or heated, or otherwise treated, in a manner that will insure the destruction of trichinae. The background for these requirements lies in extensive investigational work carried out by Ransom and his associates and by others in the Bureau of Animal Industry. In 1913 Ransom determined, following exhaustive tests, that certain low temperatures, compatible with the practical requirements of the meat industry, destroyed the vitality of trichinae. Later investigations established the fact that the heating of pork to a temperature of not less than 58° C., as well as certain curing procedures also destroyed these nematode larvae. These findings, translated into action by Federal meat inspection, have given to the American people for several decades a protection from pork-containing products that otherwise would have been the most fertile sources of trichinosis.

EARLY INVESTIGATIONS OF INTERNAL PARASITES

Aside from trichinae and a few other helminths of livestock, little was known at the time the Bureau of Animal Industry was established about the kinds of parasitic worms that occurred in our domestic animals, and even less was known about verminous diseases. Curtice, Stiles, Ward, and a few others contributed much that helped to lay a foundation upon which those who followed built a sizable structure of knowledge of the helminths and the diseases they cause in food-producing animals. In this address only the early work on the helminth parasites of livestock will be mentioned.

Even while sheep scabies was receiving preferred attention, it was recognized that the internal parasites of ovines could not be ignored. Stomach worms already had a reputation as being injurious parasites of sheep, and it was assumed, moreover, that there might be others that had the capacity of doing serious harm. It is not surprising, therefore, that Curtice, who began his studies in the Bureau of Animal Industry in 1886, should have embarked on a study of the parasites of sheep. That study resulted in the publication of a treatise on the subject, which contained much that was new and significant. Perhaps the outstanding contribution made by Curtice, while engaged in this study, was the discovery of the cause of nodular disease which, because of the resemblance of its lesions to those produced by the tubercle bacillus, had been considered as intestinal tuberculosis and studied, therefore, from a bacteriological standpoint. Curtice determined, however, that the nodules were caused by nematode larvae, which he recognized to be the developmental stages of mature worms localized in the large intestine, and named by him *Oesophagostomum columbianum*.

Stiles, who followed Curtice as the parasitologist of the Bureau of Animal Industry, brought to bear on his investigations a wide knowledge of zoology and parasitology, together with a strong bent toward preparing comprehensive studies and reviews of the morphology, classification, and taxonomy of parasites of all sorts, including arthropods. Independently and in collaboration with Hassall, he contributed extensively to our knowledge of the cestodes of ruminants and of related tapeworms of rabbits and hares, parasites of importance in the inspection of meats, nematode parasites of ruminants, and related problems in parasitology. Stiles also was one of the earliest workers to investigate verminous diseases of ruminants, which he found to be associated principally with stomach worms and, to a lesser extent, with other helminths.

Ransom, who succeeded Stiles in 1903, resumed the studies of ruminant parasites begun by Curtice 15 years earlier, limiting his investigations to the nematodes, but extending them to include the roundworms of all the domestic ruminants. With the painstaking precision which characterized his scientific work, Ransom showed that the nematode fauna of ruminants in this country was richer than his predecessors had recognized or suspected. He established, moreover, sound and concise morphological criteria for the identification of the genera and species involved. In his classic study of the life history of the stomach worm, *Haemonchus contortus*, and of other nematodes of ruminants, he determined that there was a pattern of larval development and behavior, which has since been found to fit, in a general way, the strongylid nematodes of herbivorous animals as a whole. Ransom's investigations of ruminant parasites were brought together in a monograph on the nematodes parasitic in the alimentary tract of cattle, sheep, and other ruminants. Though this study was published in 1911, it is still a useful and prized possession of livestock parasitologists the world over, and in demand even today.

INVESTIGATIONS OF ANTHELMINTICS

Some years ago a pharmacologist in one of our leading medical schools called attention to the fact that most of the anthelmintics then known were derived from plants. He even speculated that this might indicate a fundamental antagonism between animals and plants, the one group being capable of producing substances that are more or less injurious to the other. That most of the older anthelmintics were of plant origin is evident from the mere enumeration of such substances as turpentine, areca nut, thymol, kamala, chenopodium, male fern, and santonin, among others.

In 1918 Hall and Foster published the results of an experiment involving most of the then known veterinary anthelmintics, and con-

cluded that many, which by tradition had been regarded as highly efficacious, were actually without merit. They discarded, one after another, most of the older vermifuges they investigated, and gave a nod of approval to only a few, namely, copper sulfate, oil of chenopodium, oleoresin of male fern, turpentine, and nicotine. Shortly after the publication of these results, Hall introduced into the armamentarium of anthelmintics two synthetic substances, both chlorinated hydrocarbons, namely, carbon tetrachloride and tetrachlorethylene. Though these compounds were found to have some application in the treatment of livestock for the removal of helminths, their chief value lay in their efficacy for the removal of hookworms from man and carnivores. Several related synthetic compounds, notably normal butyl chloride, normal butylidene chloride, and hexachloroethane, also were found to be of value in medicating parasitized livestock.

Aside from carbon tetrachloride and hexachloroethane, which are still used in treating domestic ruminants for the removal of liver flukes, the chlorinated hydrocarbon anthelmintics, as well as most of the other anthelmintics used earlier, have been replaced to a great extent by more effective drugs. This is due principally to a discovery made in the Bureau of Animal Industry in 1939, concerning the anthelmintic efficacy of thiodiphenylamine, or phenothiazine. This substance was synthesized in 1885, but lay dormant for many decades before anyone thought of using it for therapeutic purposes. First brought into experimental use as an insecticide and later as a urinary antiseptic, it was found to be of great value in treating horses, cattle, sheep, goats, swine, and poultry for the removal of certain nematodes. Though launched as an anthelmintic only two years before we became involved in World War II, 3 million pounds of phenothiazine were manufactured in the United States for anthelmintic use in 1944, to protect our livestock, especially sheep, from the depredations of roundworm parasites. Today, when our livestock must again be carefully safeguarded as a defense measure, the annual production of phenothiazine in this country is about 5 million pounds, and would greatly exceed that figure if present-day shortages did not limit the volume of production. A number of foreign countries, especially those with large sheep populations, have been making strong appeals to this Government for allotments of phenothiazine or the parent substance, diphenylamine, adequate to protect their sheep and other livestock from parasites in times of emergency.

Because anthelmintics are more or less specific in their action, investigators working in this field are faced with the responsibility of discovering more effective drugs than are now available for the treatment of specific verminous diseases. Recently, sodium fluoride came into use as a treatment for the removal of ascarids from swine

and has almost displaced all other treatments previously used for this purpose. Lead arsenate is rapidly displacing older treatments for the removal of tapeworms from ruminants. The recent discoveries of anthelmintic drugs also have opened up opportunities to parasitologists for careers with commercial firms that manufacture or formulate anthelmintic and other parasiticidal chemicals.

DISCUSSION

It is evident from the discussion of even a few of the problems with which the livestock parasitologist in the United States has been dealing that the research findings and action programs based on them have been directed mainly to the conservation and increase of food and fiber, needed by a population that has been steadily increasing. However, it is evident also that the production of livestock cannot be increased indefinitely, because our available grasslands and our capacity to grow livestock feed are limited to a large extent by our geographic boundaries. Since extending our geographical frontiers is certainly not part of our national policy or ambition, our increased food production in the future will require, among other things, pushing steadily to the new frontiers that are opened up by scientific discovery.

How soon we shall reach a saturation point in our ability to support the increasing numbers of livestock that will be needed in keeping with the growth of our population, and how extensive this increase will have to be, cannot now be predicted. It should be borne in mind, however, that great progress is already being made in developing genetically superior strains of food-producing animals and in discovering superior methods of preventing virus, bacterial, parasitic, nutritional, and other diseases of animals, as well as suppressing their insect pests.

Whether we shall be able to support indefinitely an increasing population is a question that has already aroused considerable discussion. The neo-Malthusians, who take the pessimistic view, foresee dire consequences in increasing populations, especially in countries that are already overcrowded. They regard the introduction of new and improved public health measures into the so-called backward countries as merely hastening there the approach of mass starvation. Also, they charge that the introduction of life-prolonging measures merely aggravates the food problem in those parts of the world that already have teeming populations, now living on a low nutritional plane, if not actually facing famine. In fact, they ask bluntly what is accomplished by saving millions of people from malaria and other diseases in the world's most congested areas, if this will merely result in giving them added time to suffer from malnutrition and finally die of starvation.

These are, indeed, difficult questions to answer today, in a world that is already beset by more perplexities than it can find time to resolve. The livestock parasitologist adds little or nothing to the world's perplexities, however, but like other agricultural scientists, offers much that can help to resolve them. The livestock parasitologist is a conservationist, being essentially concerned with maintaining and increasing the supply of human food which, in the final analysis, is the greatest of our natural resources.

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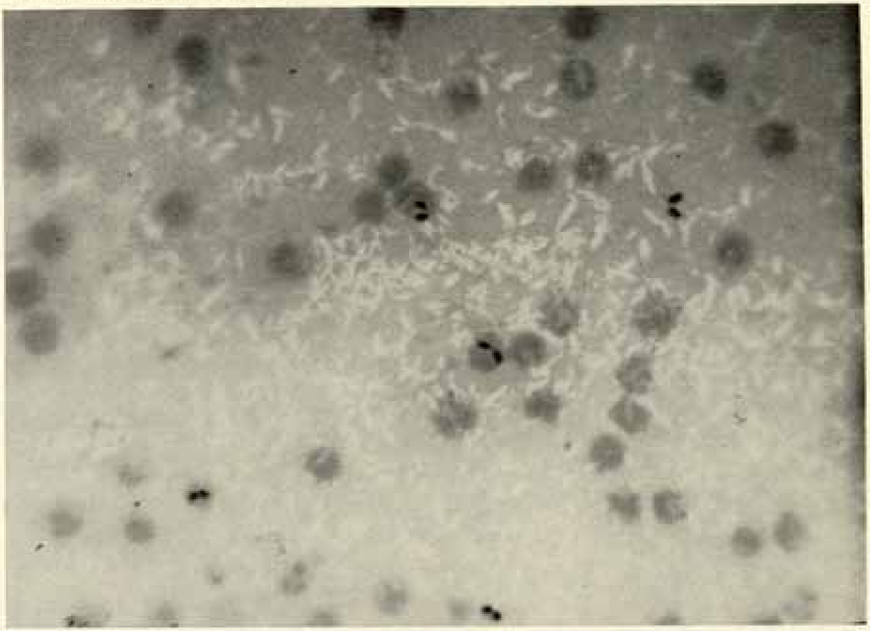
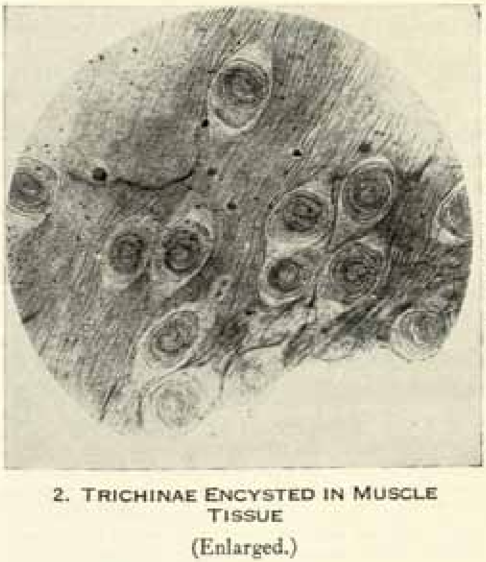


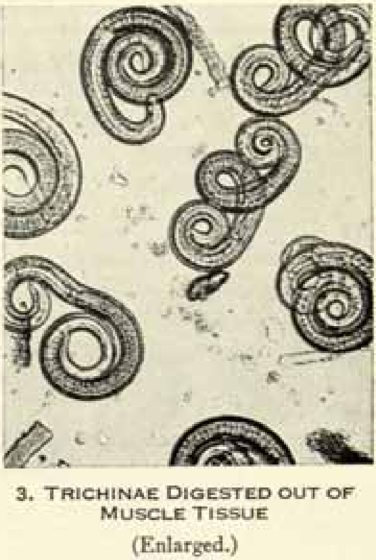
1. CATTLE-BLOOD SMEAR SHOWING TWO PEAR-SHAPED, DARK-STAINING ORGANISMS IN SOME OF THE RED BLOOD CELLS

These organisms are the causative agents of tick fever or piroplasmosis. (Greatly enlarged.)



2. TRICHINAE ENCYSTED IN MUSCLE TISSUE

(Enlarged.)



3. TRICHINAE DIGESTED OUT OF MUSCLE TISSUE

(Enlarged.)

Botanizing with the Okinawans

By EGBERT H. WALKER
Department of Botany, U. S. National Museum

[With 10 plates]

OKINAWA Island first became a real place in the minds of the people of the United States in April 1945, when our Armed Forces made there the last significant island invasion of World War II. With that invasion the United States Government assumed responsibility for another native population. It was my good fortune to spend over three months in the summer of 1951 botanizing in the Ryukyu Islands [1] southwest of Japan, of which chain Okinawa is the largest and most important island. My mission was to aid the United States Civil Administration in solving some of its economic problems through botanical investigation.

The war left these islands in an impoverished condition. They had been governed by Japanese officials, though the people of the Ryukyus are not strictly Japanese. With the departure or subsequent removal of the former officials, the Ryukyuans were left with inexperienced leaders. A third of Okinawa Island, the most important part, was devastated by the violent battles of the war. Sugar refineries were gaunt spectres, shipping facilities were wiped out, and even the markets for the possible exports from these islands were gone. Postwar rehabilitation of Ryukyuans, especially of Okinawans, from the Pacific Islands, South America, and elsewhere increased the population of the islands from about 839,000 in 1940 to over 940,000 in 1952, too many for the land to support as it was then being farmed; and the requirements of an occupying force, still engaged in extensive military operations, even today seriously hamper recovery.

It is the task of the United States Civil Administration of the Ryukyus, a part of the United States Army, to make these islands

[1] The confusing multiplicity of names of these islands is due to the variant transliterations of the original Japanese and Chinese names by peoples of many western as well as eastern countries. Among the principal variants are: Lew Chew, Lewchew, Lieuchieux, Liu Chiu, Liu Ch'iu, Liuchiu, Liukiu, Liu-Kiu, Loo Choo, Loo-Choo, Loochoo, Luchu, Riu-kiu, Riu-Kiu, Riu Kiu, Riukiu, Ryukyu, and Ryukyus. The last two are accredited by the Board on Geographic Names, U. S. Department of the Interior.

more self-sufficient. Those in charge have undertaken a new and difficult job, but they are attacking the problems in a realistic manner and at their roots. In order to bring about this urgent recovery, the administrators recognize that they must have exact scientific information on which to base their decisions and programs. Such information is all too scanty. As far as botany is concerned, although the area has been an integral part of the Japanese Empire since 1871, Japanese scientists in 1941 still considered it the dark region of Japanese botany. Naturally westerners knew little of the area, although English, Dutch, French, German, and American naturalists had occasionally collected plants there since about 1800. The last western botanist permitted to visit the region was E. H. Wilson, of the Arnold Arboretum of Harvard University, who was there in 1917 (*15*).[2] Of course, the Japanese botanists have studied the area to some extent but have not as yet produced the comprehensive treatment of the flora that is needed. There is, however, one work that partly supplies this need and is important to this story of botanizing in the Ryukyus in 1951. It is a Flora of Okinawa written by three local botanists and now mimeographed in Naha, Okinawa, by the United States Civil Administration (*8*).

PREPARATION OF A FLORA OF OKINAWA

Many of the men of the United States occupation forces in the Ryukyus after the war ceased in 1945 were natural-history minded. They were, however, frustrated in their attempts to satisfy their curiosity about the plants of their environment by the lack of any adequate books to guide them. They needed a Flora of Okinawa, and, as with other determined people, they soon found a solution. In Sakuya Sonohara, ardent Okinawan botanist and teacher of agriculture and forestry, they found a man capable and willing to write such a Flora (pl. 1, upper, right). Acting on the suggestion of these botanically interested American servicemen of the occupation forces, Lieutenant Commander Hanna, director of the Education Department, American Naval Military Government in Okinawa, and Atsuo Yamashiro, director of the Education Department, Okinawan Civilian Administration, asked Mr. Sonohara to prepare this work. But Sonohara, nearing 60 years of age, soon became ill of malaria, and his younger friend, fellow teacher, and botanical associate, Shinjun Tawada (pl. 1, lower), discovered his plight and his worthy task and, fearing the death of his teacher before its completion, joined eagerly in the work. Here, it seemed, was the opportunity they had long sought to write a Flora of Okinawa. But the obstacles were great.

[2] See references at end of text.

Every published scientific flora or enumeration of the plants of an area should be based on a collection of plant specimens. These document and support the publication and are referred to when questions arise concerning the validity of the published record. These Okinawan authors had been studying the plants of Okinawa and the other Ryukyu islands for many years and had collected numerous specimens. Although they had never had an opportunity for academic botanical training, they knew their plants well. They had corresponded with Japanese botanists and guided them when they came to Okinawa to collect, even as they guided me in 1951, and had learned much from them. For over 25 years Sonohara had been building up a herbarium on which he hoped to base his projected Flora of Okinawa. But, like many other Okinawan treasures, it was a war casualty, burned during the invasion in 1945. He had sent specimens to Japan for study by specialists and for deposit in Japanese herbaria, but these were unavailable for reference in this task of writing a flora in 1945–46. Thus, except for their memories and a few far-from-adequate Japanese botanical books which they had been able to save, they had nothing to work with, a situation that would have stopped less determined and ardent botanists. They even lacked paper on which to write, but Tawada's friend, the Shuri city postmaster, fortunately had a usable supply and girl assistants to rule it by hand as needed. Thus they persevered, and in spite of these handicaps, finally, after several months, prepared in English, a language foreign to them, a systematic enumeration of over 2,500 species of Okinawan plants. It gave their scientific, Japanese, and Okinawan names in Romanji, with notes on their distribution, habitats, and uses. Space was left for someone else to insert the English names of those few, mostly introductions, that had such designations. To them this work was the fulfillment of a dream, and naturally they hoped it would be published. Then, behold, Sonohara's malaria left him; and the manuscript was turned over to the Americans, who received it with eagerness and gratitude.

In spite of its lack of documentation and its recognized shortcomings, this manuscript supplied a need. With it the servicemen could find names for their collections, at least tentative ones that could be verified later by more critical study elsewhere. Previously there was nothing; now there was at least a guide. It was, however, only one manuscript for the use of many scattered naturalists, and its duplication was clearly needed. Accordingly, Dr. Arthur Galston, then agricultural officer with the occupying forces and now associate professor of biology in the California Institute of Technology, brought the manuscript with him when he returned to the States and sought its publication.

Because of my desire to promote botanical collecting, especially by our servicemen in all parts of the world, so as to enlarge the col-

lections in the United States National Herbarium under the Smithsonian Institution, I assumed the task of preparing the manuscript for duplication. Its lack of documentation by specimens studied by the authors was recognized, but, if duplicated, it could be a useful aid in building a new reference herbarium. This Flora lacked references to scientific publications, but these I could supply. Documentation by specimens, however, was impossible, since the National Herbarium and other American herbaria contain a mere sprinkling of specimens from the Ryukyus and since access to Japanese herbaria was impossible. The Flora of Okinawa was, therefore, far from scientifically acceptable. During this work I was in correspondence with the two original authors and with the third author, Tetsuwo Amano (pl. 1, upper, left), another ardent Okinawan botanist, who, on his repatriation after the war from duties as a forester with the Japanese in Manchuria, supplied many additions to Sonohara's and Tawada's list.

SCIENTIFIC INVESTIGATION IN THE RYUKYU ISLANDS

At this point the United States Civil Administration of the Ryukyus, called USCAR for short, the successor to the naval government earlier in charge, found in the Pacific Science Board of the National Research Council—National Academy of Sciences in Washington an answer to its need for scientific information on which to base its programs for bringing about greater economic independence and self-sufficiency in these islands. It made a contract with the National Academy of Sciences which enabled the Pacific Science Board to conduct two joint programs with the Civil Administration for "Scientific Investigation of the Ryukyu Islands," characteristically designated the SIRI program. One part of this program called for a botanical survey of the Ryukyu Islands.

Learning of my special interest in the botany of the Ryukyus, the Pacific Science Board asked me to undertake this mission. The United States National Museum, Smithsonian Institution, generously released me for four months from other duties. This seemed to me an almost God-given opportunity to collect documented scientific plant specimens that would constitute a foundation for the Flora of Okinawa by Sonohara, Tawada, and Amano. Furthermore, the work would begin to supply the Army's need for basic botanical information on the area. It was stipulated in the objectives of the trip that I would give aid to agricultural, forestry, and other economic projects then under way. As these objectives developed, there was added that of helping to establish a herbarium at the recently created University of the Ryukyus (pl. 2, upper). The core of this herbarium would be a selected set of the specimens from those collected under the SIRI program after they were properly identified.

I wish here to express my appreciation to the Pacific Science Board and the Smithsonian Institution for providing all the supplies and equipment needed for this work and for the thorough preparations for the trip. I am likewise deeply indebted to the United States Army for its generous support and able guidance, especially to Brig. Gen. James M. Lewis, in charge of the United States Civil Administration in the Ryukyus, and to Richard M. Varney, of the Forestry Section, Food and Natural Resources Department, USCAR in Naha, Okinawa. Many other civilians, both American and Okinawan, rendered valuable assistance, without which the objectives of the mission could not have been attained, and to them I am deeply grateful.

BOTANIZING IN OKINAWA

After 23 years of herbarium work, largely on the eastern Asiatic collection in the Smithsonian Institution, it was indeed a great satisfaction to receive this assignment to collect specimens in the field and to see the live plants previously known only by their dried representatives. Traveling on Army orders, I left Washington by air on May 31, 1951. En route, I visited Japanese botanists and institutions in order to enlist their cooperation in identifying the specimens to be collected. About 6 hours after taking off from Tokyo on June 12, the Army transport plane, on which I was the only civilian passenger, opened its door at the Naha airport, and I stepped forth into the soft, humid, midnight breeze of Okinawa.

Before going further with this story it will be well to gain an understanding of the geography, climate, and other pertinent features of the Ryukyu Islands. The map (fig. 1) shows them as a 775-mile-long necklace draped between the island of Kyushu, the southern and most subtropical of the main area of Japan, and the northeastern tip of Formosa or Taiwan, with Okinawa Shima, or Okinawa Island, in about the center. This archipelago is obviously a drowned mountain chain with the higher parts still protruding above the sea. In latitude Okinawa lies as far north as Miami, Fla. West and north lie China and Korea within easy bomber and jet-fighter distance across the shallow East China Sea. On the east and south the floor of the Pacific Ocean drops off steeply from the narrow Ryukyu shelf to one of its deepest trenches.

Geologically the Ryukyu Archipelago is composed of three rather distinct arcs. The central arc consists of Paleozoic and igneous rocks and contains the larger islands, including, from north to south, Yaku Shima, Amami-Oshima, Tokuno Shima, the northern part of Okinawa Shima, Ishigaki Shima, and Iriomote Shima. The outer or eastern arc consists of Tertiary and young rocks and includes Tanega Shima, Kikai Shima, the southern and eastern part of Okinawa Shima,

Miyako Shima, and Hateruma Shima. The western or inner arc consists of the islands of volcanic origin, including those of the Tokara Gunto or Archipelago, Tori Shima, Aguni Shima, and Kume Shima. On some of the northern islands of this arc there are still active volcanic vents.

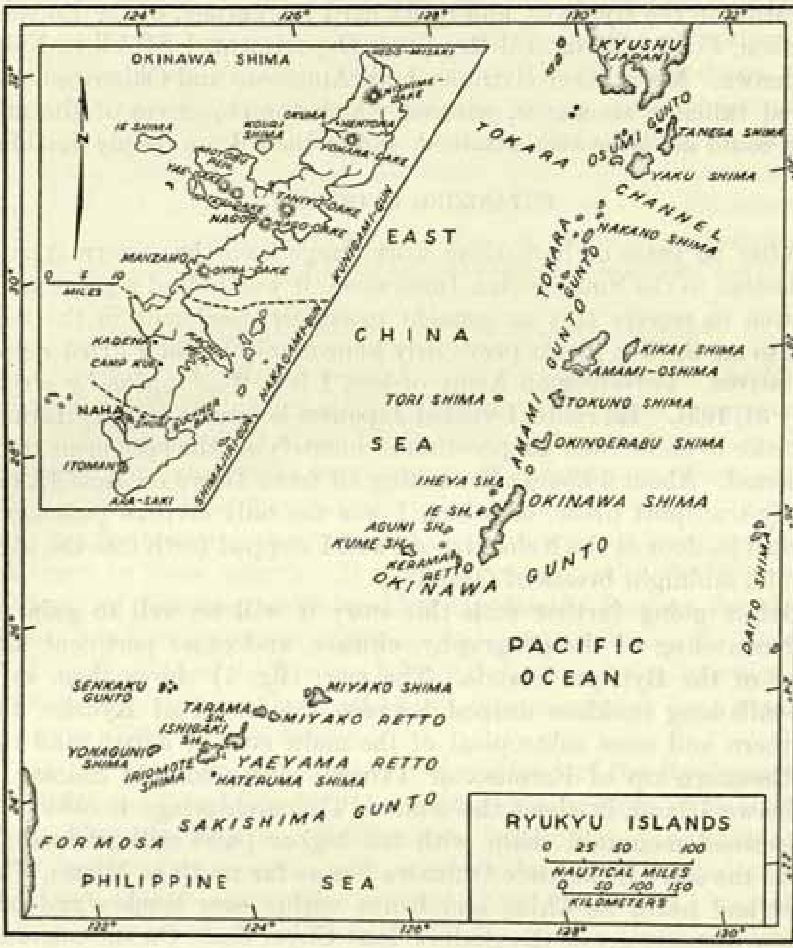


FIGURE 1.—The Ryukyu Islands group.

The principal geographic features of the chain are shown on the map. Politically the Osumi Gunto or Archipelago north of the deepest transverse channel, the Tokara Channel, and the Tokara Gunto south of this channel are parts of Japan. The remaining guntos, or island groups, are now governed by the central independent Ryukyu-seifu or government established in Naha, the capital, on Okinawa Island. This operates under the guidance of the United States Civil Administration with headquarters also in Naha. This

recently established Ryukyu-seifu replaces the governments of the four units into which the Ryukyus were divided after the war and operates directly through the local town or island governments. There are still United States branch administrative offices established on Amami-Oshima, Miyako, and Ishigaki Islands.

Okinawa Island is 65 miles long and 2 to 8 miles wide, with protruding peninsulas and intrusive bays here and there. Its postwar population is about 580,000. Its three "counties," Kunigami-gun, Nakagami-gun, and Shimajiri-gun, are units commonly referred to, being the domains of the independent kings of historic earlier times. From the narrow neck southward one traverses the rolling hills and plains, with evidences of the war's destructiveness on every hand (pl. 2, lower, and pl. 3, upper). The rocks and soils here are of geologically recent origin, gravels, clays, and limestone, the last often exposed in strikingly rugged ravine sides and jagged knobs protruding sharply above the level land, these pitted and penetrated by caves. This limestone is the coral so often referred to in describing the war terrain, though true coral exists mainly in the reefs which abundantly line the island's shores. Because of its less rugged terrain this southern portion is largely under cultivation, or at least human control, and is dotted with villages, towns, and cities, the largest, Naha, the capital, with 44,790 population, and Shuri with 20,014 (December 1950). As one goes north from the narrow neck of the island he leaves the depressing war zone, and his spirits rise with the increasing height and ruggedness of the hills and the abundance of vegetation (pl. 8, lower). Here steep, forested mountains occupy most of the land, rising in peaks to over 1,600 feet, accessible only by trails from the coastal road on the west and the lesser one on the east. Agriculture is confined to the river mouths, coastal strips, and lower foothills (pl. 4). Nago, with 14,842 postwar population, is a relatively trim place with hardly a war trace. Geologically the mountains are of more ancient limestone and sandstone, with a few igneous intrusions.

The climate of the Ryukyu chain is oceanic, although dominated in part by the monsoon winds blowing toward the great Asiatic continent in summer and from it in winter. The summer temperatures [3] are raised above the level one would normally expect at this latitude through the influence of the Japanese or "kuroshio" (=black) current flowing up from the hot South China Sea. The thermometer, however, seldom reaches into the 90's, and 96° F. is the highest temperature on record. The discomfort of this climate is due to the combination of monotonous and relatively high temperatures, high humidity, and bright sun. The average annual temperature for Naha

[3] The following figures are taken from the Civil Affairs Handbook (*1*).

on Okinawa is 72° F., but the mean daily maximum for the hottest month, July, is 89°, the average for the summer being 81°. The coldest ever recorded is 41°, and the winter average is about 62°. In summer the average humidity runs from 76 to 80 percent, and in winter the mean minimum is about 73 percent. At Naha the mean annual rainfall is nearly 83 inches, with the average lowest in December of about 4.3 inches and the average highest in June of about 10 inches. More than half the days of each month are classed as rainy. The most significant factor alleviating this gloomy picture of high heat, humidity, and rainfall is the sea breeze and drying sun. One can slosh in mud while blinded by dust. A major factor in the climate is the periodic typhoons, which in summer and early in fall all too frequently roar up from southern regions and sweep along this chain. On some islands only one crop of rice a year is planted because a second one is too likely to be ruined by a typhoon. The raging winds not only affect the life of the people but are, undoubtedly, one of the major factors in the natural selection of the flora.

So on June 13 I was established as a civilian botanist under the guidance of the United States Army, which furnished housing, transportation, supplies (other than what I brought), regulations and MP's to guide my conduct and to guard my health, medical attention, and, indirectly, assistants, all of these items being classed by the Army as "logistic support." The Forestry Section of the Food and Natural Resources Department of the United States Civil Administration, with headquarters in Naha, supervised and provided liaison for my operations. Housing was found in a quonset-hut area in Naha, provided for certain Army officers and civilians mostly concerned with operation of the busy port, and food was available in its officers' mess.

The separation of western and native life in an occupied area was glaringly evident, and intermingling with the Okinawan peoples and their life was by no means easy, the language difficulty being paramount. It was some days before I was able to meet the Okinawan botanists, the authors of the Flora, whom I found to be most agreeable companions and associates both on botanizing trips and in indoor associated labors. In the course of my work I met many other Okinawans, but these three were my special associates. Mr. Tawada had just been specially employed by the Okinawan Saion Forest Research Nursery and assigned to work with me. Amano, employed by the Okinawan equivalent of the Department of Agriculture, joined us when he could be spared and spent many after-hours with us. Mr. Sonohara sometimes broke away from teaching in the Nago Agricultural High School halfway up the island to join our forays. As eager botanists these three cannot be surpassed, and to their wholehearted cooperation, extensive knowledge of the flora, and tireless

labors is due the success of this trip. We were all working together for a common end, the advancement of botany in the Ryukyu Islands. Headquarters for our operations and adequate space for our drying apparatus were generously provided by the Okinawan Government's agricultural experiment station in Naha, the Yogi Agricultural Institute.

Dr. Floyd Werner, of the University of Vermont, the first entomologist with the SIRI program, was also located here with his Okinawan associates (pl. 8, upper). We coordinated our operations and traveled together as a collecting unit, using the same jeep. It may well be imagined that there was seldom any extra space and that frequently considerable finagling was necessary to see that the MP's would not find more than the legal five persons in our vehicle. Fortunately they would not have counted the gear. In spite of Werner's and my almost complete lack of knowledge of Japanese and the Okinawans' lack of English, except for Mr. Tawada who knew enough, plans were made and operations carried out remarkably smoothly. When in doubt as to what was going on, a common enough circumstance, we left ourselves in the hands of our Okinawans—and all went well.

At first we were limited to short trips in daily requisitioned jeeps, and so we became acquainted with the highly altered vegetation of war-devastated southern Okinawa. But such plants are integral parts of any flora; indeed, they are often of more economic significance than the more remote native plant associations, which to the botanists are admittedly much more interesting. When, on July 4, the Army at some sacrifice finally assigned a jeep to us for unlimited expeditions, we established headquarters in Nago for a week of botanizing in the forested mountains and remote parts of the island. Specimens were sent daily by local buses to attendants at Yogi who kept the plant driers going day and night. The traditional method of drying specimens by absorbing their moisture content by means of blotters or felt driers is quite impossible where high humidity prevails as in Okinawa. Instead, bundles consisting of specimens alternating with corrugated cardboard or corrugated aluminum sheets were strapped together and suspended vertically over Japanese-made kerosene lanterns. Heat from the lanterns rose through the corrugations, furnishing enough gentle hot air to dry the specimens in one to several days.

Through July and early August field trips of a week or less alternated with returns to base to recuperate and to care for the specimens collected.[4] We made trips to the tops of several of the higher mountains, sometimes climbing up the narrow, slippery trails used by wood cutters in carrying out on their shoulders selected logs of the more

[4] For details of places botanized, see my paper listed at end of text, reference *12*.

valuable species. Sometimes we pushed our way along abandoned and overgrown trails, always keeping a wary lookout for new plants and the lurking "habu," the poisonous snake for which this island is too often maligned. Outside of a dead one, crushed by Amano's heavy heel before I came puffing up, and a less poisonous "hemihabu" seen on one of the southern islands, I saw none of these reptiles. I rather suspect, however, that more than one lay quietly where they were. The Okinawans at least were always alert to this danger.

One of the best collections was made in the jungle called Taminatougan (pl. 6, upper). This area, running up the side of a mountain to a limestone precipice, was a protected religious shrine and was left untouched by the wood cutters and thus showed the native flora better than most areas. We collected freely, but I doubt if our scientific collecting was regarded as any transgression of its sanctity. Never to be forgotten was the trip to another shrine area, Manzamo or Banzamo, which means "a million people sit down," referring to the open, park-like nature of this seaside cliff summit and its open grove of Luchu Island pines. Here there is a stone monument to an Okinawan poetess, Onna Nabe, bearing her poem commemorating the visit in ancient times of the Shuri King to this revered spot:

Nami nu Kwin tumari	(Die away the sea;
Kaji nu Kwin timari	Be quiet the wind;
Shuyui Tin-janashi	I would welcome and bow
Myunshi wugama	To the Shuri King.)

But of more significance to a botanist was Manzamo as the original and only known home, technically called the type locality, of a new species of *Portulaca*. On the summit of an almost barren, spray-dashed limestone cliff, Tawada in 1949 had discovered a plant he thought represented a new species and had sent specimens to me, along with a drawing. It was technically described by me as *Portulaca okinawensis*, accompanied by Tawada's illustration, in April 1951 in a Washington scientific journal (*14*), the first botannical paper jointly authored by an Okinawan and an American. On this visit we supplemented the original collection with more specimens and photographed in color the diminutive plant and its sweeping outlook over the East China Sea.

On this same cliff were also collected herbarium specimens and viable seeds of *Aster asa-grayi*. This native Ryukyu aster was originally named *Calimeris ciliata* by the famous American botanist Asa Gray, from collections made in "Osumi"[5] in the notrhern Ryukyus by a botanist with the United States North Pacific Exploring Expedi-

[5] The precise locality is not clear. We may assume Gray's designation of Osumi refers to some island in the Osumi Gunto.

tion, which immediately followed the Perry Expedition that opened Japan to western trade. When the beloved Japanese botanist Prof. Tomitaro Makino found it needed a new name, he graciously honored its first describer.

It would be superfluous here to mention more of the places visited and the interesting plants collected. The midsummer months, however, are not the ideal ones for plant collecting, for many species are through flowering and have not yet developed mature fruits, and the fall flowering plants are still gathering strength for blossoming forth. Full flowering and fruiting specimens are those most desirable for representing the species. However, by August 12 we had assembled nearly 800 collections, or over 2,500 specimens for shipment to Washington. Further operations here would yield a progressively decreasing return of new material. On August 13, after a 10-day delay in finding transportation, Mr. Tawada and I embarked on the **FS–204**, an Army supply boat which made a monthly visit to the scattered United States stations, and the next day went ashore on remote Iriomote Island, far down the chain.

BOTANIZING IN THE SOUTHERN RYUKYUS

Iriomote Shima is about 14 miles wide and 17 miles long. Almost the entire surface of the island consists of heavily forested mountains running up to 1,350 feet. The lower courses of several streams are drowned estuaries lined with mangroves (pl. 10, upper). There are a few small villages, but no roads and no wheeled vehicles, barring rusting bulldozers and coal-mine trucks no longer usable for lack of parts to repair them. The mine, however, which then was being operated by American interests, boasts a railroad about 2 miles long, which brings coal to the loading dock. Ships call only occasionally, however, and the industry is by no means a thriving one. Lumbering has been carried on, but the last American attempts were given up not too long ago, and when Tawada and I sought the interior by means of the logging road, winding up from the farthest point on the Nakara River which we could reach in a small boat, we found it so badly washed out that even traversing it on foot was hazardous. The botanizing, however, was superb, as it was everywhere we went on this island (pl. 10, lower).

The nisei Japanese Mr. Katz, temporarily in charge of the American headquarters for the mine, gave me quarters and food and a room for preparing our specimens. From here we sallied forth each day on foot or by boat to more distant parts. Tawada was thoroughly familiar with the region, as he had been a teacher in Sonai village years ago and knew the best collecting places. Sonai

was the most prosperous village I saw in all the Ryukyus. The war had hardly touched this remote island, and the people, except those connected with the mine, seemed to be happy and thriving.

Perhaps the most memorable trip we made was the one up the Urauchi River. We crossed over the day before from our base in Shira-hama to Sonai, where the local forest office made us welcome for the night and the local hotel sent steaming Japanese food. Next day we crossed the flats, climbed a ridge, and dropped down to the river bank where a boat awaited us. Thence we were skulled up the river a few miles between heavily forested mountain slopes (pl. 5 lower, and pl. 10, center) to the lower falls, whence we proceeded on foot along the gorge to the upper falls, collecting as we went. Time out was taken for a swim in a pool, the only time I was comfortably cool in my whole Ryukyu visit.

After each of these trips into the field, hours were spent working up the notes, improving the specimens, painting them with alcohol and formalin, and wrapping them tightly in bundles. In this condition they would keep from decaying until our return to Naha in Okinawa, where they were subsequently dried.

Iriomote is friendly, it is wild, and it is remote. For restful isolation it is ideal. No boats, other than small strange fly-by-night craft with ancient throbbing diesel engines, called while we were there; hence nothing could be sent or received, most regrettably mail. Radio telephone communication, however, was maintained with the United States Army's Yaeyama Civil Administration Team's headquarters on Ishigaki Island, the next one east of Iriomote. By this means, Lt. Col. Hazen C. Schouman, in charge of that team, extended Tawada and me an invitation to come out to sea next day and join his official inspection trip in the 50-foot police boat to still more remote Yonaguni Island to the west, the last in the chain and almost within sight of Taiwan.

Yonaguni Shima is a plateau scarcely 7 miles long and 2½ miles wide, bounded on almost all sides by sheer limestone or sandstone sea cliffs (pl. 9, upper). There are two small, partly artificial harbors suitable for small craft. Two peaks rise up above the plateau to 740 and 600 feet, but they bear only poor secondary forests. The island is well populated and extensively cultivated or grazed. The Americans recently built for them their first motor roads totaling 9 miles, thus initiating the motor age in this end-of-the-earth spot. Still more recently the Americans had broken up with a heavy hand an extensive and lucrative smuggling trade with Communist China. Hence, there were no friendly looks for a stray American botanist, and only the children smiled at me, as they did everywhere I went in the Ryukyus. Here I felt quite unwelcome. Nevertheless, I was invited to join

the people's official welcome to the colonel and his party, where we were entertained far into the night by speeches, food, and drink, and an elaborate program of native and Japanese dances.

On Yonaguni, botanizing on the tag end of one day and the whole of the next yielded a relatively few new plants, but since I was the first American to collect here, so far as known, we tried to make as good a collection as we could in this limited time. Fortune attended this venture, and we returned to Iriomote without mishap or rough seas. We could have been stranded for days or even weeks, had a typhoon blown up and held the police boat in the diminutive port.

After a few more days of collecting on Iriomote, my kind host from the mine operations took us and a load of Okinawans to Ishigaki Island in an ancient LCM, a relic of that great fleet of shallow-draft landing ships which proved so important and serviceable in the war. Here Colonel Schouman and his staff graciously provided all we needed, especially a jeep, for six more days of collecting. Here were roads reaching almost everywhere, and again we sallied forth on rubber tires as on Okinawa.

Ishigaki Island is in rather striking contrast to the islands visited to the west. It is about 8 miles in diameter, with a long, slender peninsula extending from the eastern shore northward, and shorter and stubbier peninsulas on the northwest corner and upper western side. The lower half or more of the island is a highly cultivated rolling plain, largely of raised limestone with much evidence of having once included coral reefs. Heavy forested mountains, rising up to about 1,700 feet, stretch across the northern part, dropping down almost to the water's edge on the farther side. The mountains are largely of igneous Paleozoic rocks overlooking the plains of younger gravels, sandstones, shales, and limestones. The shores of Ishigaki are generally low and reef-lined. There is no harbor, but the coral reef on the south runs far out to sea, partially protecting the open, shallow roadstead off Ishigaki City, where all but the smallest ships must cast anchor. On threat of a typhoon, they take shelter in Funauki Bay, one of the deep, protected estuaries on the far side of Iriomote Island within sight to the west. Agriculture here is somewhat different. Farmers more often live in the city and ride out daily on horseback or springless carts to work their fields of sweetpotatoes, rice (both upland and wetland), sugarcane, and other crops. Fresh pineapples were seen and enjoyed. Many other crops are raised, and improved farming is encouraged by a thriving agricultural research station, an agricultural high school, and other organizations.

The city of Ishigaki, on the broad, flat southern coast, is neat and laid out on an unusually regular pattern of streets. These are almost

solidly lined with walls built of neatly arranged coral heads or boulders from the shore or offshore reefs, or of trimmed blocks of surprisingly easily cut limestone from inland quarries. It boasts good stores, government buildings, schools, and a famous and conspicuous weather station with a long record of uninterrupted service.

In the 6 days of collecting there, we touched at least the major spots, the east, west, and southern coasts, the northwest peninsula with the village of Kabira, carefully studied by the ethnologist Dr. Allan Smith while in special residence there, and points en route. We climbed the central mountain (pl. 9, lower), though our guide, a local forester, missed the overgrown trail to the highest peak and we viewed our goal from a no less botanically satisfactory, but slightly lower, outlying knob. Of special interest was the work of the forest office, which kindly provided space for our work and housing for Mr. Tawada. The director proudly showed us lumbering operations, forest control, promising forest nursery stock, and experimental plantations, especially unique stands of *Podocarpus marcophyllus*, and of other species in an abandoned stream bed.

All these islands are beautiful, but the beauty of Ishigaki stands out most vividly in my memory, recalled often with the aid of my color photos. From an eminence, Kara-dake (pl. 9, center), close to the eastern shore, scenes of incomparable beauty and color stretched out in all directions. The deep blue of the open sea, separated by a white surf line from the varied light greens, whites, and yellows of the coral lagoons and shore; the rich yellowish greens and browns of the wind-rippled grass cover on the rounded hills marked off by narrow stream valleys studded with rice paddies, sparkling in the lowering sun; the dark forested mountains to the northwest like a great backdrop (pl. 9, lower); and beyond and above the great billowing clouds reaching up to the blue of the sky—such memories cause others, well forgotten, to fade away. Equally vivid was our departing view of Ishigaki Island, from the little pulsing *Wakaba Maru*, as we skirted its northern coast heading homeward on September 7. The sea was glassy, absorbing and enriching the intense azure of the sky, and throwing it back from the smooth curve of the foam-flecked bow wave. Beyond this curve the sea took up the greens of the shore from the dark shadows in the mountain forest to the bright yellow-greens of the two rounded and suggestive knobs at Kabira. Above were again the billowing clouds, so ever-present in the Tropics. Indeed, plant collecting is not all sweat and toil and dull, dead, enigmatic, pressed specimens for musty museum cases.

The *Wakaba Maru* dropped anchor at Miyako Island, and again I was a grateful guest at the United States Army's establishment. So highly cultivated is Miyako and so devoid of almost any habitats for

native plants except roadsides and seashores that it has little attraction for a roving botanist. It should be one's first rather than his last island. But yet on our two little forays, additional species of Okinawan[6] plants were found which were not yet represented in our collections, and others received better representation. We stopped briefly at an agricultural school and passed the gaunt spectre that once was a modern sugar refinery, which, if spared, would have been an invaluable factor in postwar rehabilitation of the local economy. Nearby, a blindfolded horse went round and round, operating an ancient, primitive sugar press, and in crude vats unrefined sugar crystallized out of the frothing juice.

On September 10 we returned to Naha to dry our southern-gathered specimens and to pull together the loose ends before departure. After a farewell Japanese dinner in a neat little upstairs restaurant, we unceremoniously, as seems to be the custom there, said our farewells—one can't be effusive or highly selective of sensitive words when only the simplest are understood and those unaided by grammar and rhetoric. One can only hope that one's affection and respect are transmitted by other than linguistic means.

Long before daylight on September 19, my plane again rose into the air, swung roaring over sleeping Naha, and was soon lost in the clouds that never opened till we dropped into the rain below them, and looked again on breath-takingly beautiful Japan, neat, clean, relatively prosperous, and completely ordered, at least so it seemed in contrast to the struggling Ryukyus. After further visits with Japanese botanists, attendance as the only foreign guest at the seventeenth annual meeting of the Botanical Society of Japan, and some hours of research in the herbarium of the University of Tokyo, I was off for home via Wake Island, Hawaii, Travis Air Force Base in California, Oakland, San Francisco, and Chicago—and arrived in Washington late on September 30, 4 months to a day from my take-off.

RESULTS OF THE EXPEDITION

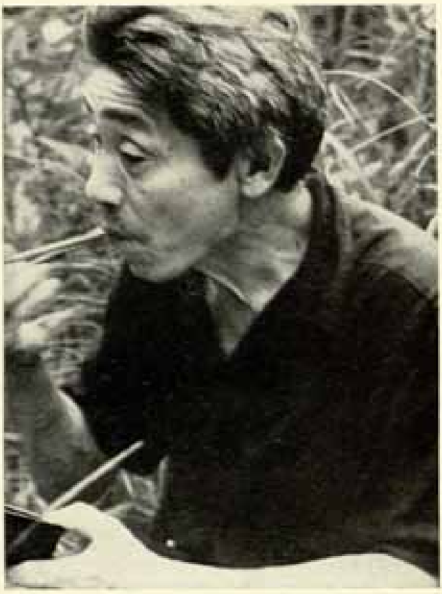
About 1,500 collections, totaling over 6,000 specimens, were flown back to the United States by Army cargo plane. When identified, the first set of these specimens will be deposited in the United States National Herbarium under the Smithsonian Institution, where it will remain along with other Ryukyu specimens to support in part the Flora of Okinawa. One set will go to Japan for study by specialists there, who will report their determinations. Another will go to the Bernice P. Bishop Museum in Honolulu, the main center for many Pacific studies and for deposit of scientific collections made on the

[6] For usage of the name "Okinawa," see annotation in the bibliography, reference 8.

many expeditions which the Pacific Science Board is sponsoring. Still another set will be laid aside for return eventually to the University of the Ryukyus on Shuri Hill, the site of the well-known ancient Shuri Castle, traditional home of former Okinawa kings. Here it will be available to foresters, agriculturists, teachers, and students of Ryukyu plants engaged in further botanical study. The still remaining specimens will be be sent to various other institutions in America or Europe on an exchange basis. Thus are herbarium collections built up.

There remains the task of critically identifying the specimens gathered on the 1951 SIRI program along with reexamination of other collections made by Okinawan botanists both before and after this expedition, various servicemen's collections now in the United States National Herbarium, and the collections by Charles Wright made on the United States Exploring Expedition (the Ringgold and Rodgers expedition), which immediately followed the Perry Expedition, and those gathered by E. H. Wilson in 1917 for the Arnold Arboretum of Harvard University (*15*). In addition, and as a result of making the acquaintance of Japanese botanists and institutions, duplicates of important collections which they have made in earlier years in the Ryukyus have been received. Perhaps the Japanese specialists will reexamine other collections in Japan while studying the SIRI specimens sent to them. Thus all will aid in documenting the Flora of Okinawa.

This critical examination of herbarium material may seem somewhat remote from the needs of administrators engaged in alleviating distressing economic conditions. However, when perfected, this Flora of Okinawa will give foresters knowledge of the native and introduced trees that occur there. It has already been invaluable in preparing a requested booklet, "Important Trees of the Ryukyu Islands" (*13*). Agriculturists will know what weeds there are which may become obnoxious among their crops or act as alternate hosts for crop-destroying insects. Administrators will be better able to draw up quarantine laws for the exclusion of harmful plants and animals, some of which have already arrived unimpeded and are threatening this over-burdened economy. Landscapers and soil conservationists will know what plants are available for their use in covering and enriching bared and sterile fields, or for shading buildings and roadsides. It may help grazing projects or airfield construction in finding native grasses for their varied needs or to know which ones are pests and should be eradicated before they become too well established. Those developing measures for control of insects carrying human diseases must know the proper names of the plants that harbor these pests. Indeed, many are the practical questions that can be answered through the aid of a regional flora.



OKINAWAN BOTANISTS

Upper: Time out for lunch while botanizing on Nago-Dake. Left, Mr. Amano; right, Mr. Sonohara.
Lower: Mr. Tawada, with plant press and bundle of specimens, and a habu stick to deal with the dreaded poisonous snake. Photograph by Floyd Werner.

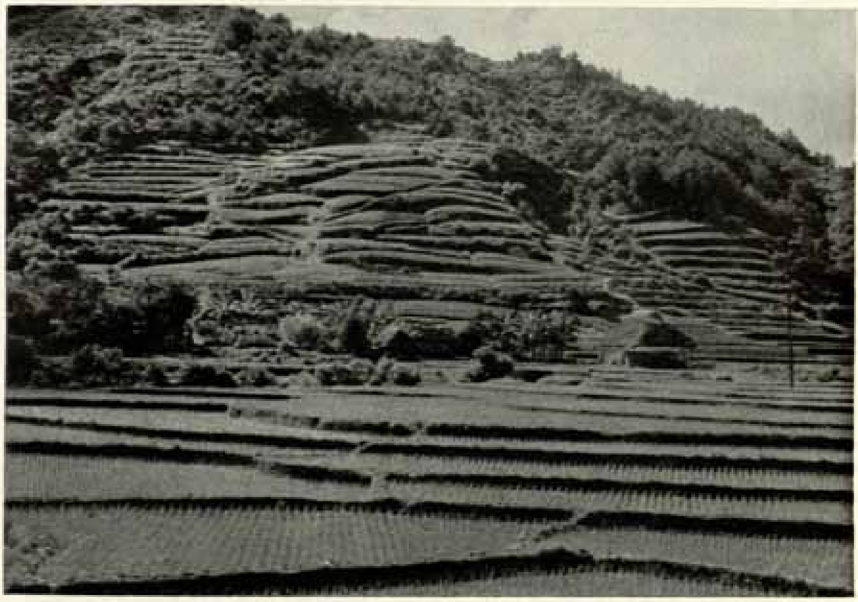
NEW CULTURE ON RUINS OF THE OLD

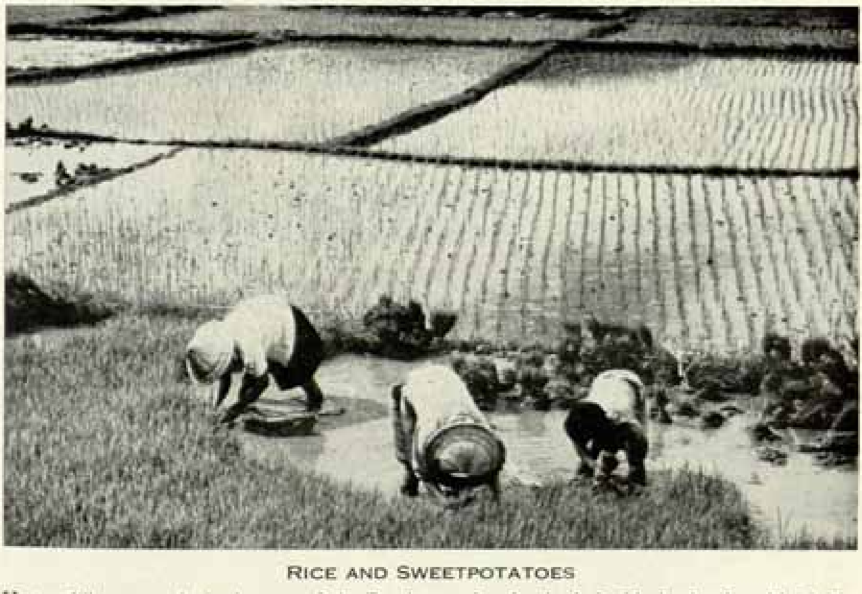
Upper: The administration building of the postwar-established University of the Ryukyus, built on the site of the throne room of ancient Shuri Castle, the war-destroyed famous reminder of the early independent Okinawan kings. Photograph by Harold Coolidge.
Lower: The approach to an ancient shrine on this hill in Naha overlooking the sea is all that survived the war.

FARMS AND SUGARCANE

Upper: Treeless southern Okinawa, the scene of terrific World War II battles, is now mostly farm land, broken up into diminutive fields.

Lower: Stalks of sugarcane, the third most important crop, being offered for sale by farm women on the annual festival day in memory of the honored family ancestors. Photographs by Orin A. Hills.





RICE AND SWEETPOTATOES

Upper: The two principal crops of the Ryukyus; rice, in the irrigable lowland paddy fields, and sweetpotatoes, on the terraced slopes extending up to woodland beyond.
Lower: Bundling rice seedlings, densely grown in meticulously prepared seed beds, preparatory to transplanting into flooded paddy fields shown beyond. Photograph by Delos Flint.

FORESTS AND FUEL

Left: Dense, broad-leaved, evergreen subtropical forests, like those of Iriomote shown here cover the higher, less accessible mountains of these islands.
Right: Timber and fuel are carried from these mountains on human backs or heads. Photograph by Delos Flint.

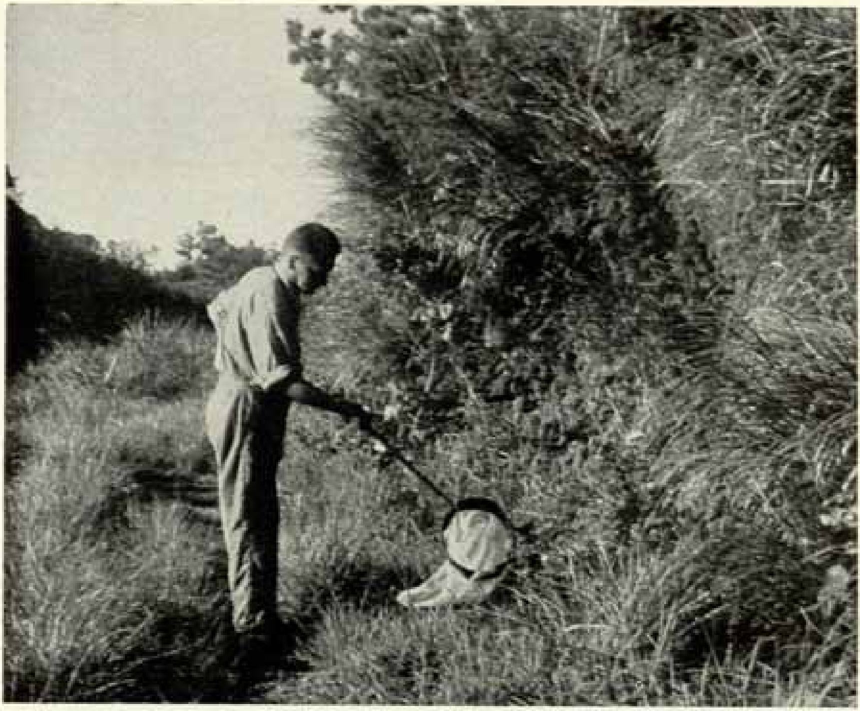
FOREST AND SWAMP PLANTS

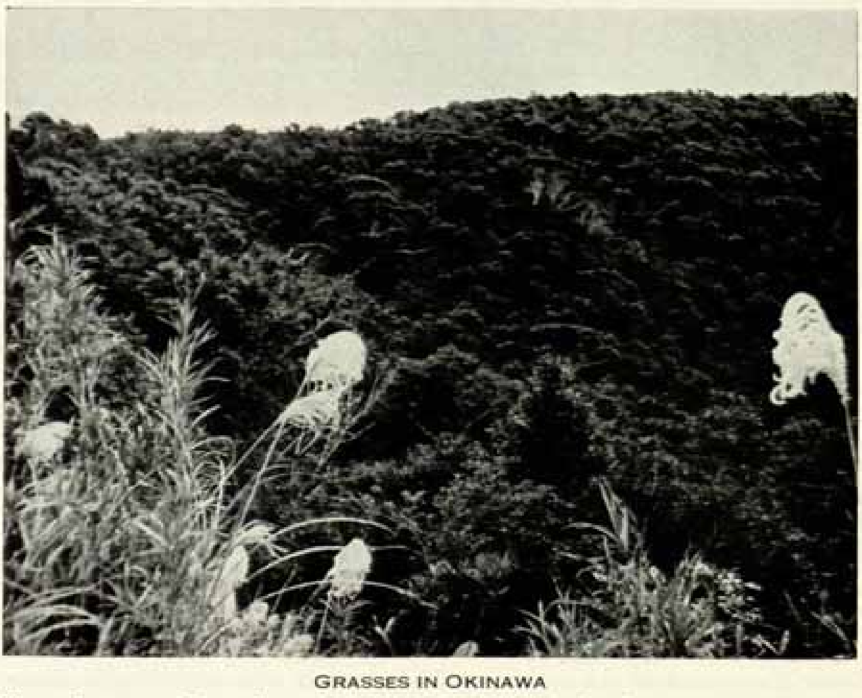
Upper: Okinawan botanists Sonohara and Tawada inspect an ancient strangling fig or banyan, whose basket roots enveloped and choked its host and whose aerial roots grew into supporting props.

Lower: The nipa palm was discovered in a mangrove swamp on Iriomote Island, its most northerly known occurrence.

PINES AND CYCADS

Upper: The Luchu Island pine, which becomes in age a characteristic flat-topped tree of the open lower lands. Photograph by Delos Flint.
Lower: The stiff-fronded dark green palmlike sago cycad, *Cycas revoluta*, common in the grasslands, often among scattered pines. Photograph by R. W. Simonson.

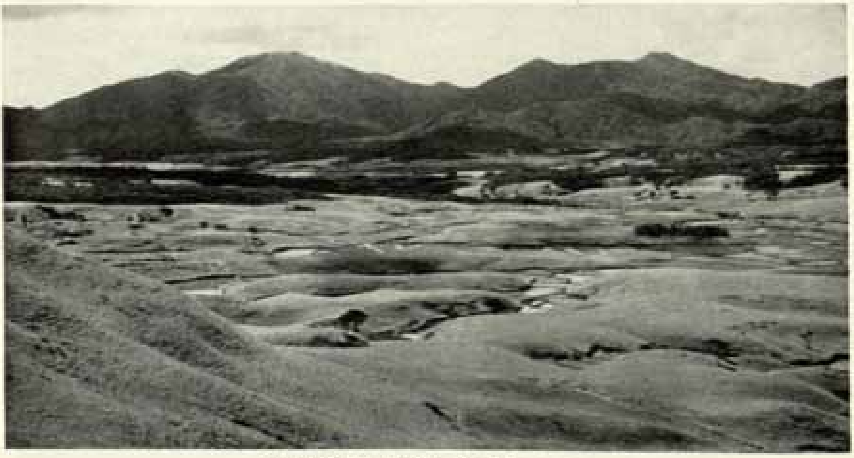




GRASSES IN OKINAWA

Upper: An entomologist collects among the coarse grasses so abundant in the war-disturbed areas.

Lower: In the fall the silvery plumes of the coarse grass, *Miscanthus floridulus*, dominate the landscape. Dense evergreen forest in background. Photograph by W. G. Urseny.



HEADLANDS AND GRASSLANDS

Upper: The bare-topped eastern headland of small Yonaguni Island, last in the chain, where horses, goats, and cattle graze.

Center: The grassy dome of Kara-dake on Ishigaki, vantage point from which the photograph in the lower figure was taken.

Lower: Yellow-green grassy pastures cut by shining paddy fields in the runlets stretch away toward the dark, heavily forested backdrop of mountains rising to Omoto-dake, 1,706 feet high.

TIDAL ESTUARY VEGETATION ON IRIOMOTE

Upper: Pandanus or screw pine lines the established near shore, while a mangrove grows out over the tidal mud from the shore beyond.

Center: A valued timber tree, *Heritiera littoralis*, now rare, grows just beyond the mangrove trees along the tidal Urauchi River bank.

Lower: Tawada takes a specimen from a mangrove shrub, *Avicennia marina*, whose breathing roots rise fingerlike through the sand from long, radiating, buried roots.

REVIEW OF THE VEGETATION

Floristically, Okinawa Island is divisible into the southern war-disturbed and the northern undisturbed parts. The southern end, especially below the narrowest neck of the island, has an unkempt, barren appearance due in the first place to the paucity of trees, the barrenness seemingly only augmented by the few scattered remains of the prewar trees. Those that the Japanese army did not use in building defenses, the Americans blew down to eliminate snipers. Encouraging headway, however, has been made in planting trees, and the Saion Forest Nursery gives much promise of a better woody vegetation in the near future. In the second place, the barrenness is augmented by the unkempt aspect of the abundant cover of tall, coarse bunch-grass, mostly *Miscanthus floridulus*. In the fall, however, this grass adds a silvery sheen to the landscape, for then it bears abundant large white plumes on stalks higher than one's head (pl. 8, lower). Other common coarse grasses are cogon grass, *Imperata cylindrica* var. *major*, and *Saccharum spontaneum*,[7] also with whitish inflorescences. The abundant thick-stemmed stiff-leaved, dark-green, palm-like cycads, *Cycas revoluta*, (pl. 7, lower), are characteristic features of the landscape, growing on the shores, hills, limestone knobs, and edges of cultivated fields. Where the battle eddied around a spot, there might remain characteristic open stands of the Luchu Island pine (pl. 7) with intermingling cyads and coarse grasses. Currently many of these pines are dying from the depredations of an insect pest. The rough limestone knobs and cliffs that jut out here and there are usually clothed in shrubs and scraggly trees. Among them especially are various species of banyan, the most common being *Ficus retusa*, which can be anything from an almost climbing vine or at least a clinging shrub on the bare face of a rock to a broad and venerable tree with huge spreading branches hoary with hanging aerial roots (pl. 6, upper). The appearance of barrenness is further augmented by the American installations built on great bulldozed and leveled areas, once hills and valleys covered with grass, trees, or cultivated fields. Okinawan villages are nearly always hidden in abundant verdure, partly for the comforting shade, partly for typhoon protection, and perhaps partly because the principle of laissez-faire lets nature make them so. It is too soon to predict with confidence what nature will do to the American installations, but if the wet weed field I saw green with new verdure three weeks after it was bulldozed into barrenness is any indication, perhaps even southern Okinawa will be green again throughout. Already one sees along the roads and among the houses many planted feathery casuarinas (*Casuarina equisetifolia*) and acacias (*Acacia confusa*) and other introduced ornamental trees.

[7] Improperly called kunai grass in American wartime publications.

On going north one's spirits rise as he meets the first aggregation of large, untouched, flat-topped Luchu Island pines. From then on the vegetation lends a more peaceful and pleasing aspect. Less weedy thickets line the highway, and the villages are better hidden among protecting trees. Most striking among the cultivated trees in almost every village is the "fukugi," *Garcinia spicata*, a dark-green, thick-leaved introduction from southern Asia, its shape reminding westerners of the lombardy poplar. It grows in close rows along the streets or property lines, and, because of its slow growth, one can guess from the size of its "fukugi" trees the age of a village.

The road north on either side of the island follows the shore closely, for inland the hills and mountains become ever more rugged. Hence, one sees many littoral trees and shrubs, mostly unfamiliar to those of continental temperate climates. Common among them are: *Hernandia sonora* (*Hernandia ovigera*) (Hernandiaceae); "wild bean," *Pongamia pinnata* (Leguminosae); sea hibiscus, *Hibiscus tiliaceus*, and Portia tree, *Thespesia populnea* (Malvaceae); Alexandrian laurel, *Calophyllum inophyllum* (Guttiferae); Indian almond, *Terminalia catappa* (Combretaceae); *Cerbera manghas* and *Lactaria iwasakiana* (Apocynaceae); velvet-leaf tree, *Messerschmidia argentea* (Boraginaceae); *Premna obtusifolia* (Verbenaceae); *Guettarda speciosa* (Rubiaceae); *Scaevola frutescens* (Goodeniaceae); and thatch screwpine, *Pandanus tectorius* var. *liukiuensis*. Perhaps the last is the most striking and characteristic tree or shrub of the shores (pl. 10, upper) and the higher wastes, and a very useful plant for thatch, hat-weaving materials, and other products. But its most important functions is to protect the areas behind it from the sea and wind.

Near Gesashi village on the east coast of Okinawa above the middle, we visited a typical mangrove swamp where a stream flowed into a bay. There on the exposed muddy tidal flat stood the characteristic mangrove tree, *Rhizophora mucronata*, on its conspicuous and somewhat ridiculous stilt or prop roots. Its associates were the red-flowered *Bruguiera conjugata* and the white-flowered *Kandelia candel*. Other typical mangrove associates were there, all properly zoned toward the higher and drier land. Mangrove swamps, however, were better developed and more significant in the southern islands (pl. 10, upper and lower).

All the land that can be cultivated is, of course, given over to crops. From the beach sands to far up on the mountains are cultivated fields (pl. 4). Where rice can be irrigated by gravity, that is the staple crop. But the largest crop is the sweetpotato, grown everywhere on level ground and on terraced hillsides, with grassy ridges between the sloping fields, carefully protected from erosion by well-tended vegetation, which often included the characteristic cycad.

Formerly, at least, sugarcane (pl. 3, lower) was the third principal crop, grown only in the south, but the former sugar mills and the market for the sugar produced are only now being restored. Although there are many other crops, one is impressed by the dependence on sweetpotatoes. This makes more serious the problem of combating the recently introduced and seriously threatening sweetpotato weevil and the sweet potato blight. When not cultivated, the cleared slopes are planted, or at least often grow up in pines or other second-growth forest trees. All are sources of fuel, and one is impressed by the important industry in the northern villages of hauling down from the hills poles and small trees, cutting and splitting them into fuel size, and stacking the wood on the roadsides, whence trucks may carry it to the larger towns. This activity makes serious inroads on the forests wherever they can be reached. Among the first invaders of these cleared lands are, of course, various shrubs and weedy trees, among them, perhaps, being *Trema orientalis* with banyans following after, usually beginning as epiphytes and finally strangling and replacing the host trees. Sometimes camphor trees (*Cinnamomum camphora*) or other useful species are planted. In the far north the narrow, steep ravines filled with the light-green spreading leaves of the fiber banana are a striking feature. The slopes between and the headlands are spotted with dark-green cycads.

Turning now to the higher slopes and more remote mountain peaks, one finds an almost unbroken tropical evergreen jungle composed of a great variety of trees, with understories of lesser trees, shrubs, and vines. Epiphytes are not specially numerous, as in many tropical jungles, but the ground is hidden under a well-developed herbaceous cover. The most valuable trees for man's uses are various oaks, *Quercus, Lithocarpus;* chestnut, *Castanopsis lutchuensis;* and several laurels (Lauraceae), such as *Machilus thunbergii, M. longifolia, Cinnamomum japonicum, C. loureirii,* and *Actinodaphne lancifolia.* Equally sought after for timber are members of the tea family (Theaceae), such as *Adinandra ryukyuensis, Camellia miyagii, Cleyera japonica, Shima liukiuensis, Ternstroemia gymnanthera,* and *Tutcheria virgata,* and members of the persimmon genus (*Diospyros*) in the ebony family (Ebenaceae). A characteristic, easily recognized tree is the native palm *Arenga engleri.* Indeed, these forests, which the Japanese botanists characterize as laurisilvae, are rich in species. Now and then we saw in the northern mountains remnants of plantations of the Japanese cedar, or sugi, *Cryptomeria japonica,* but this, probably the most valuable of all trees in Japan, is not indigenous in the Ryukyus except in the northern islands, where it forms natural forests at high elevations, notably on Yakushima. The central and southern Ryukyus apparently lack sufficiently high, cool elevations

for both sugi and the hinoki or false Japanese cedar, *Chamaecyparis obtusa*, also tried in plantations here.

Another important group of native forest trees, especially high on the mountains, is the podocarps, *Podocarpus macrophyllus* and *P. nagi*. Chiefly above where these grow one usually finds a pure stand of bamboo forming an extensive zone or a completely capping, almost impenetrable thicket. We were grateful that we could follow the timber-cutters' trails kept open through these thickets and jungles by constant use. Every little way we would find a layer of bark and chips, marking where a tree had been cut, trimmed, and roughly squared. From there it had been carried on the cutter's shoulder, supported by the handle of his ax across his other shoulder, on down the mountainside. His wife might carry down easily an apparently staggering load of branches for fuel (pl. 5, right). This process of selective cutting lets the forest grow continuously but results in its steady deterioration through removal of the more valuable trees.

Everywhere in these forests there are ferns, ranging from large tree ferns, *Cyathea fauriei* and species of *Alsophila*, to the tiny delicate, filmy ferns, *Hymenophyllum* and *Trichomanes*, growing in the murky forest on wet soil or clinging to shaded tree trunks. Our presses were loaded with these varied spore producers. There were mosses, too, but we had to neglect these lowly forms in order to concentrate on the higher plants.

Grasses, of course, were less significant in the forests than in the open but occurred everywhere, and we collected examples of many species. Next to the coarse grasses already mentioned, in respect to interest, however, rather than conspicuousness, come the several species of *Zoysia*, a low, thick-growing, somewhat wiry grass of waste fields, often found on high limestone headlands, where it cannot escape in times of storm being drenched with saline spray. It forms a good durable turf and is so desirable for planting on sterile soils at new housing areas that it is being removed from some natural areas, such as Banzamo, with detrimental effects. Members of this genus are frequently sought for golf courses in America and may play an important part in covering airfields between the runways, but it seems that better techniques for its cultivation need to be developed. Perhaps our sending back live samples to the U. S. Department of Agriculture may help this cause. Another ground cover is *Lepturus repens*, found in thick stands on the upper tidal shores or mud flats south of Naha and elsewhere. Along with *Sporobolus virginicus* it performs the valuable role in many parts of the world of helping reclaim land from the sea. Bamboos, contrary to expectation in this Far Eastern land, seem to play a relatively small role in its economy. In Okinawa these woody grasses were seen only here and there, except for the high mountain

zone already mentioned, appearing to supply solely the limited local needs, especially materials for thatching houses and weaving baskets. Only on the island of Yonaguni were they found growing commercially, an extensive plantation there covering a large area on the side of a ridge, whence they are exported. The paucity of domestic animals in Okinawa seemed out of harmony with the apparent potentiality for grazing. Perhaps this is a temporary postwar condition, related also to the shortage of fencing materials. But there seem to be plenty of forage grasses, only awaiting further agronomical study to initiate their beneficial use, though of course they are soil binders wherever they grow. It was noticeable after the war that the weedy grass *Echinochloa* invaded the uncultivated ricefields in great quantity and would have furnished food for domestic animals had any been left to eat it.

References have already been made to the vegetation of the southern islands in connection with the account of our collecting activities. The vegetation there is largely the same as on Okinawa, with but minor variations. The agriculture differs a little. For example, though both rice and sweetpotatoes are grown on Yonaguni Island, the purposes are different. The people are said to eat the rice and feed the sweetpotatoes to the pigs, whereas on Iriomote they are said to eat the sweetpotatoes and export the rice for needed cash. In Yonaguni we saw much grazing, especially above certain sea cliffs. The animals—cattle, horses, and goats—are confined by thorny hedges of *Pandanus*, American agave, and other plants with repelling spines.

On Iriomote we found many mangrove swamps along the margins of the estuaries (pl. 10, upper). These reach out into the water and by their impeding roots cause the silt to settle. On the landward side of these mangrove swamps may come *Pandanus* and other plants. These further stabilize and build up alluvial flats at the heads and margins of these estuaries. Then man clears the forest and grows rice and other crops. From our headquarters in Shira-hama each morning we watched the people paddle in narrow canoes or row in larger boats upstream to till their fields and return at night with their harvest. One mangrove swamp we visited was the sandy bottom of a stream flowing into the sea. There we found, besides the mangrove plants already mentioned, the characteristic shrub *Avicennia marina* (Verbenaceae) (pl. 10, lower) sending out long underground stems from which arise fingerlike aerial breathing roots, reminiscent of the cypress knees of our southern swamps. There were also a semiclimbing vine in low dense clumps, *Dalbergia candenatensis* (Leguminosae), the mangrove fern *Acrostichum aureum*, and the medium-sized, widespread, more or less poisonous tree *Excoecaria agallocha* (Euphorbiaceae). Our most exciting mangrove discovery, however, was the

nipa palm, *Nipa fruticosa*, deep in a many-channeled swamp at the head of Hinai Bay on the north side of the island (pl. 6, lower). This is its most northerly known occurrence. It has not been previously recorded from the Ryukyus, but, as later learned, Japanese botanists knew of its presence on another small island just south of Iriomote. It is not known in Formosa. Perhaps these Ryukyu occurrences arose from drift from the Philippines carried in the Japan Current, which does not touch Formosa.

On the trip up the Urauchi River we collected or noted many mangroves along the shore with other trees commonly associated with them, especially *Heritiera littoralis* (Sterculiaceae) (pl. 10, center), a striking, widespread, light-barked tree, so much sought for timber and so easily reached by boat that it is rather scarce today, and *Barringtonia racemosa* (Barringtoniaceae), whose fallen white corollas with abundant long stamens floated past us on the ebbing tide. Here we found a single plant of pandanus with extra large and vicious thorns, growing along a shore thick with normally spiny pandanus plants. Elsewhere on this island we found a pandanus plant with no thorns at all except at the bases of the terminal delicate white leaves, which were still unopened and unexposed to the light. Thus the variability in this widespread littoral plant gives problems for future taxonomists and perhaps material for a wide range of economic uses. As we progressed farther up this stream the mangroves dropped out and the drier-land woody vegetation overhung the banks, such as banyans with buttressed bases; the Chinaberry or pride-of-India, *Melia azedarach* (Meliaceae), probably brought in and planted at some settler's hut and now escaped and growing in more open places; *Macaranga tanarius* (Euphorbiaceae); *Dendropanax iriomotensis* (or *Textoria iriomotensis*) and *Shefflera octophylla* (or *Agalma lutchuense*, as it has been called by Japanese botanists) (Araliaceae); tree ferns; the Japanese snowbell, *Styrax japonica* (Styracaceae); the native palm *Arenga engleri*; and even a red-flowered rhododendron, *Rhododendron eriocarpum* (Ericaceae), still in bloom though it was mid-August.

As in Okinawa, the most significant plants of Iriomote are those that comprise the widespread dense evergreen forests, especially members of the oaks, the laurel, the tea, and the ebony families (pl. 5, left). These have been given considerable attention by foresters and lumbermen. The United States Army has prepared sets of wood samples from timbers cut in these forests during lumbering operations soon after the war's end.

Of Ishigaki Island little more need be said. A striking contrast to the coarse, unkempt bunch grass (*Miscanthus floridulus*) covering hills of southern Okinawa was the smooth grassy appearance of the

hills and valleys of the eastern side of this island (pl. 9, center and lower). The grass, though mixed, seemed predominantly cogon grass (*Imperata cylindrica* var. *major*), though it was not then (early September) in bloom. It was reported that Okinawa before the war bore the same aspect. Thus it seems that *Miscanthus* is a first invader of disturbed areas and that the churned-up battlefields gave it a start in Okinawa. We know the vegetation will change little by little. But will fields of *Imperata cylindrica* and other more gentle-appearing grasses replace this rank growth in the course of succession and Okinawa take on the beauty of Ishigaki? Only time will tell. It may, however, be said, with no element of doubt, that the Ryukyus are full of interesting plant problems and ever will be.

THE FUTURE

The 1951 SIRI botanical program was primarily concerned with determining the species of plants which occur in the Ryukyus. The task is not yet complete, but we are now in a better position to deal with the perhaps more glaringly urgent problems of economic botany in these islands. Likewise the ecological study of the various plant formations, especially of the economically productive forests and grazable grasslands, can now be undertaken with more promise of scientific accuracy and completeness, because we know better the plants of which these formations are composed. Programs for plant introduction (7) and for establishing plant quarantine laws should materially benefit from the Flora of Okinawa and from the steadily increasing reference collection of plant specimens that will support a future revision of this work. It is hoped that from the Flora of Okinawa by the three Okinawans there may come not only works by westerners, such as the "Important Trees of the Ryukyu Islands" now in press (*13*), but also many more publications by Okinawans (*8*, *9*) and Japanese, on other vital subjects, such as the grasses, the weeds, the shrubs, the ferns, and many others.

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Bromeliad Malaria

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[With 2 plates]

Malaria is an extremely complex disease, controlled by a series of variables. The first variable is the protozoan *Plasmodium*, which is the cause of malaria. This organism has a life cycle alternating between some species of vetebrate animal and a mosquito. It consists of several species, four of which occur in man. These four differ in their relation to climate as well as in the symptoms that they produce and in their response to treatment. Since they hardly ever produce immunity beyond one of their numerous regional strains, the strictly clinical problem is excessively complex in itself.

The anopheline mosquitoes, which carry human malaria, are a greater variable, with numerous species differing widely in their habits and relation to environment. The usual method of controlling malaria is by elimination of the mosquito carrier, but first the species involved must be identified, since they vary greatly in habitat, and it is impractical, if not impossible, to kill all the mosquitoes. For instance some mosquitoes enter houses freely and can be dealt with by DDT (dichlor diphenyl trichlorethane) in the adult stage, while others bite only out of doors and must be killed as larvae. The investigator must also consider three other factors in looking for a mosquito that is a carrier: anthropophily or its taste for man, its numbers, and its susceptibility to malaria (Rachou and Ferreira, 1947), the final proof being the discovery of the malaria organism in mosquitoes of the suspected species.

All mosquitoes are alike in spending their larval stage in the water, and in many instances they have been controlled by draining swampy areas and by oiling small bodies of water or adding fish to them. However, the mosquitoes of the subgenus *Kerteszia* breed in bodies of water too numerous and inaccessible for the usual control technique. They have adapted themselves to development in the tanks of different species of Bromeliaceae.

The term "bromeliad malaria" has been coined (Downs and Pittendrigh, 1946) to cover this situation, and it is hard to see how it can be improved, although the bromeliad is neither disease, carrier, nor host. It is the host of the carrier and thereby adds another set of variables to the study of malaria.

There are about 1,600 species of Bromeliaceae, all but one being natives of the New World. They are almost exclusively herbs, and the more primitive types are terrestrial and store water only in the tissues in the manner with which we are familiar. However, the more advanced types have adapted themselves to life above ground. They are not parasitic but are capable of living independently on bare rocks, trees, and even telegraph wires. This they have accomplished by two types of development. In one the narrow leaves have developed a dense scaly covering that soaks up water like a blotter and then transmits it to the tissues within. In the other the broad flat leaves overlap in a watertight spiral forming a tank (pl. 1). According to the species, the tank may hold a thimbleful to over a gallon of water.

Like the entomologist, the botanist has the problem of identifying species and determining their habits in order to discover their importance in the spread of malaria. The types of bromeliads without tanks do not enter the question of malaria, but there are several hundred species with tanks that must be taken into account. Of these the rarer in any given region may be ignored, as Pittendrigh has shown (1950c) that it is the frequency of a species rather than the size of its tank that determines its importance in the spread of malaria. Other factors are the shape of the tank and the habitat of the species. Tanks with narrow openings harbor few or no mosquito larvae, while those with broad tops hold many (Downs and Pittendrigh, 1946). Both mosquitoes and bromeliads have height ranges in the forest. In order to be effective in malaria spread a bromeliad must have the same height range as some mosquito that is a carrier. Again suspicions must be varified, this time by a careful census of the different species of mosquito larvae found in the bromeliad tanks. Finally, although the bromeliad is not a parasite, it does show a preference in trees, or rather it finds it easier to secure a perch on some species than on others, and thereby adds yet another variable to the over-all problem.

In fact the whole cycle of malaria is so complex and presents so many vulnerable spots, that the surprising thing is that it survives at all; and yet it is one of the most successful of all disease organisms. Another surprise is that bromeliad malaria with all its additional complexities was understood almost as early as the commoner type.

THE DISCOVERY OF BROMELIAD MALARIA

In 1897 Ronald Ross in India demonstrated that malaria is carried by mosquitoes. In 1898, Adolpho Lutz, who was to gain fame later as

a conqueror of yellow fever in Brazil, was sent to investigate cases of malaria that were developing among construction crews on the new São Paulo-to-Santos railroad line (Lutz, 1950). Now malaria has generally been associated with marshy regions, but this epidemic was in the construction camps cut out of the virgin forest on the precipitous seaward slopes of the Serra de Cubatão where the water ran off as fast as it fell.

Lutz had the suspicion that some blood-sucking insect was responsible, and one evening in camp he noticed a small mosquito (*Anopheles cruzii*) that lost no time in hovering around but attacked with great speed and voracity. Later he was pleased to find that anopheline mosquitoes are carriers of malaria and that he had been correct in suspecting this species.

The next question was where could a mosquito breed in such a completely drained area. In his travels Lutz had observed various groups of plants that held water in their leaves, and he was familiar with the work of Fritz Mueller, the Santa Catarina naturalist who had studied the different forms of life found in bromeliad tanks. After considerable fruitless search, Lutz found bromeliads containing larvae of the mosquito in question, and in 1903 he published his findings in a paper entitled "Waldmosquitos und Waldmalaria."

The first reaction to Lutz's story of bromeliad malaria was one of almost complete incredulity. Other scientists pointed out how difficult it would be for such a type of malaria to attack humans, and the complex set of conditions that would be necessary for an epidemic to start. For one thing, any mosquito, to carry malaria, must first bite an infected man, then survive against all its natural enemies for several days while the malaria cycle followed its course, and after that bite an uninfected man. It seemed highly improbable that a forest mosquito would have the opportunity for the repeated biting necessary to carry malaria (Knab, 1913). Nevertheless, over the years opinion swung more and more to Lutz's views as evidence in his favor accumulated. Then it was suddenly discovered that the supposedly impossible chain of circumstances had produced a persistent (endemic, in medical language) plague of bromeliad malaria in two widely separated regions, the Island of Trinidad in the British West Indies, and the state of Santa Catarina in southern Brazil.

BROMELIAD MALARIA IN TRINIDAD

The malaria problem in Trinidad made a strong contrast to the situation originally studied by Lutz, for being on relatively level ground the possibility of swamp-breeding mosquitoes could not be ruled out at the start (Downs and Pittendrigh, 1946). When, in 1942, the principal carrier was definitely identified as *Anopheles bellator*,

a bromeliad breeder, the factors of the infestation became evident. Later some interesting observations by Pittendrigh (Downs and Pittendrigh, 1946, 1949; Pittendrigh, 1950a) showed why *bellator* was mainly responsible. The climate in the forest varies regularly from the ground to the treetops and plant and animal life is zoned accordingly. A mosquito species like *Anopheles homunculus* that breeds near the ground finds few bromeliads so that its numbers are relatively small, and outside conditions are such a contrast to its constantly dark and moist habitat that it leaves the forest only under extremely humid conditions. *A. bellator*, on the other hand, is concentrated near the top of the forest where the great mass of bromeliads offers excellent breeding grounds. The dry sunny climate offers less contrast to nonforest areas and consequently *bellator* leaves the forest readily to attack man (fig. 1).

The center of the infestation was in the cacao plantations, the backbone of Trinidad agriculture, so that this time man had brought the forest and its mosquitoes to him rather than entering it, like the men in Lutz's studies. Cacao planting in Trinidad involved setting alternate rows of cacao and quick-growing immortelles (*Erythrina glauca* and *E. poeppigiana*), the latter to give the cacao plants necessary shade. Bromeliads from the nearby forests invaded the plantations like weeds and found particularly favorable perches on the immortelles, covering them in profusion. With the bromeliads came swarms of mosquitoes that until now had been too remote in the forests to act as carriers. However, in the plantations they came in contact with the workers living there and the disease shortly developed to crippling proportions.

Local health authorities and the scientists of the Rockefeller Foundation set out to control the disease and soon found that previous experience with malaria was of little help. The usual ditching and draining procedure was completely useless against a carrier that bred above ground. Cutting down the trees would have solved the health problem but would have been economically ruinous.

In Trinidad, *bellator* spends little time in houses (Downs and Pittendrigh, 1946), so it had to be eliminated in its natural habitat and the best way appeared to be by removing its bromeliad breeding places. Given the short flight range of the mosquito, it seemed possible to protect the cacao workers by clearing the bromeliads from the plantations by hand. Crews went to work pulling the bromeliads off the trees, but it was soon evident that progress was too slow to make appreciable headway against the disease. Meantime studies of the bromeliads had shown that even the commonest species differed greatly in their receptivity to mosquitoes. *Gravisia aquilega* and *Aechmea nudicaulis* were of almost identical frequency, yet the

former, with a broadly funnel-shaped tank, averaged 90 times as many mosquito larvae per plant as the latter with its slender-necked vase (Downs and Pittendrigh, 1946). However, before this knowledge could be used in a more selective form of removing bromeliads, the breaking of the brittle limbs of the immortelles caused several accidents, so that this line of attack had to be abandoned and another sought.

The second attack was along chemical lines and proved successful. Because of the peculiar structure of the epiphytic bromeliads it was possible to kill them without injuring the trees on which they grew.

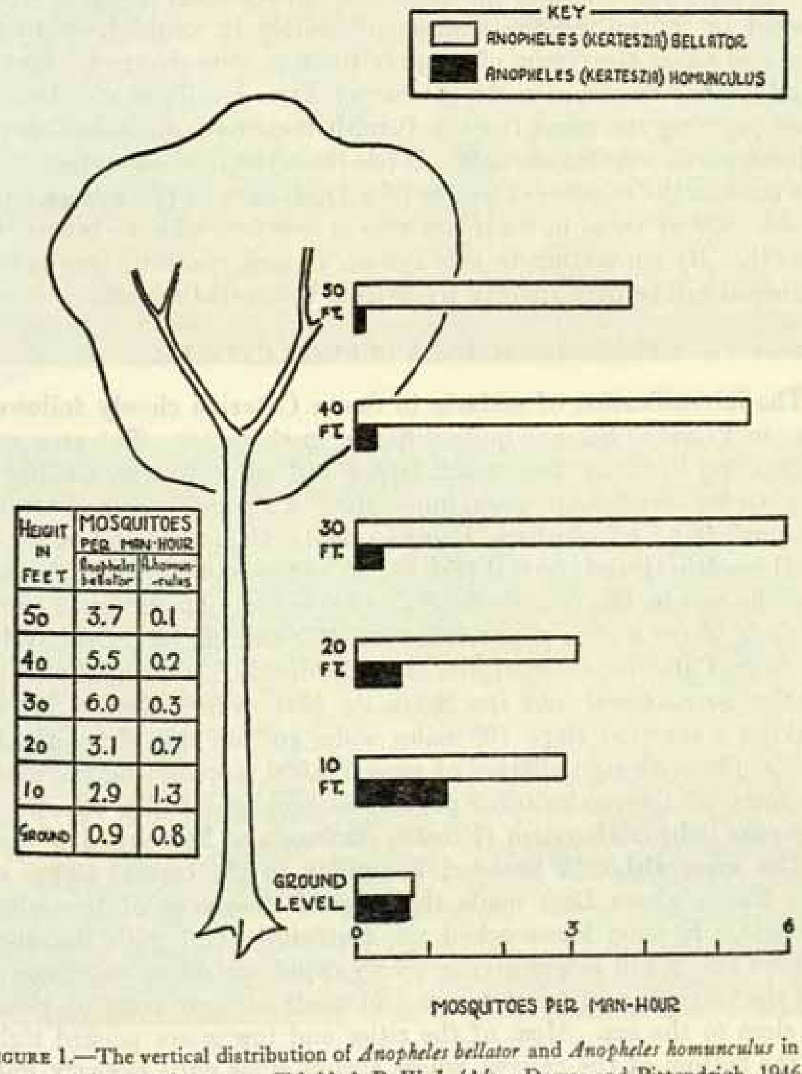

FIGURE 1.—The vertical distribution of *Anopheles bellator* and *Anopheles homunculus* in the seasonal forests of Tamana, Trinidad, B. W. I. (After Downs and Pittendrigh, 1946.)

The bromeliads absorb salts through the leaves instead of through the roots, like nearly all other plants. Thus they receive a maximum effect from any poison sprayed on them, while the tree roots are protected by the soil which neutralizes the chemical before it can reach them. The successful technique involved a 2-percent copper-sulfate solution applied with the same spraying equipment used in New England forests against gypsy moths. The pumps were moved along roads and lines of hose run from them to reach all parts of the plantations, the regular arrangement of the trees greatly facilitating the operation.

Although the killing of the bromeliads by chemical spray was successful in controlling the disease, ultimately it would have to be repeated unless the system of cacao cultivation were changed. Fortunately, other centers of cacao production have developed a system of close-planting the cacao trees to furnish their own shade and using other trees as windbreaks only. It has the additional advantage that the trees in the windbreak can be of a kind, such as the mango, that is not only of value in itself but also is less favorable to bromeliad growth. By converting to this system as new plantings are made, Trinidad can be permanently freed from bromeliad malaria.

BROMELIAD MALARIA IN SANTA CATARINA

The intensification of malaria in Santa Catarina closely followed that in Trinidad but was quite different in character. The area and population involved were much larger and more diverse, making a single solution of the problem impossible. This region comprises the seaward slope of southern Paraná, Santa Catarina, and extreme northern Rio Grande do Sul (fig. 2). The five municipios in Paraná and the two in Rio Grande do Sul are relatively insignificant parts of their states with a population of 60,000 and 22,000, respectively. In Santa Catarina, however, the drainage divide formed by the crests of the Serra Geral and the Serra do Mar swings deeply inland making a seaward slope 100 miles wide, and on this slope are 29 municipios with a population of some 829,000 representing the great majority of the agricultural population and practically all of the vigorous industrial system (Pinotti, Rachou, and Ferreira, 1947).

The area, although broader, is similar to the coastal slopes of São Paulo where Lutz made the original discovery of bromeliad malaria. Erosion has reached the maturity stage, with V-shaped valleys and sharp ridges giving a very rapid run-off to rains except for the retaining action of forests and small swampy areas by rivers or close to the sea. Most of the cities and towns are packed tight at the bottom of the valleys, whose abrupt sides until recently were

BROMELIAD TANKS AT GUARATUBA, PARANÁ

Upper: Epiphytic bromeliads, *Vriesia incurvata* in foreground.
Lower: Terrestrial bromeliads, mostly *Vriesia erythrodactylon* in foreground, and *V. philippocoburgii.*

1. PORTABLE TANKS USED IN SPRAYING METHOD OF CONTROLLING BROMELIAD MALARIA

2. A DEMONSTRATION OF THE TECHNIQUE OF SPRAYING

covered with dense forest with a profusion of bromeliads teeming with mosquitoes. As a consequence, malaria has been entrenched in the state and at intervals has reached great proportions.

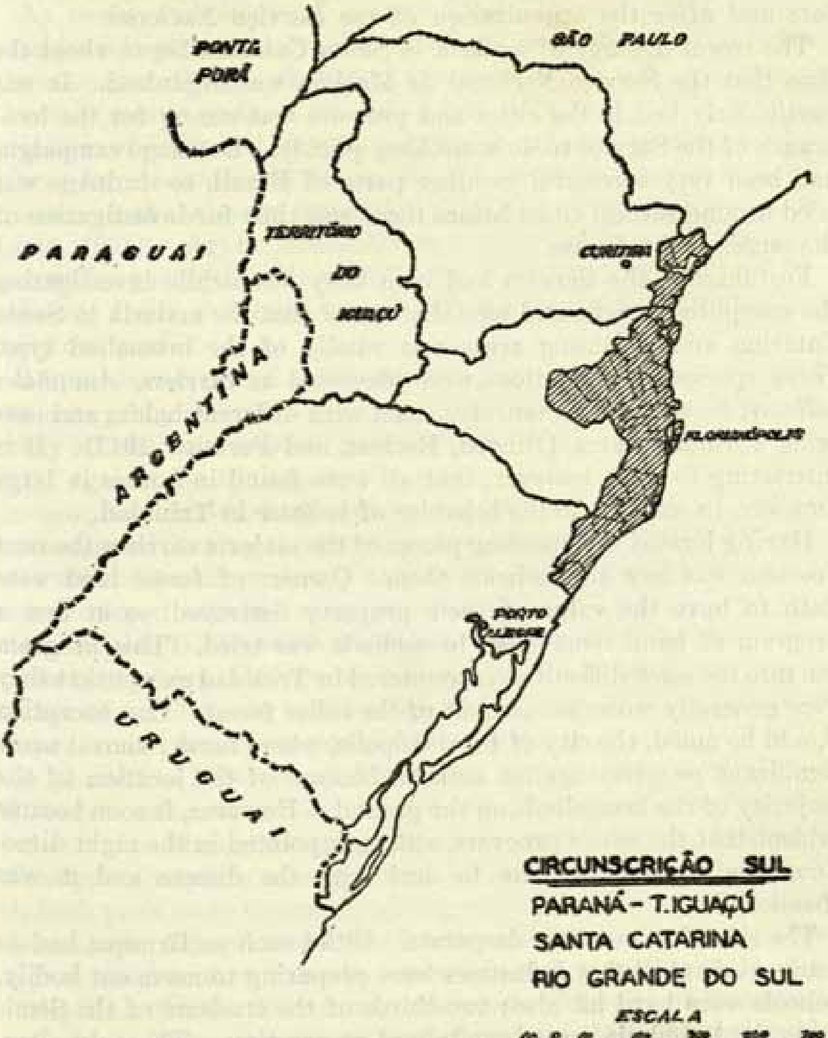

FIGURE 2.—Distribution of bromeliad malaria in southern Brazil. (After Pinotti, Rachou, and Ferreira.)

From the time of Lutz there has been a steady growth in malarial research in Brazil, and there have been some notable victories in its conquest such as the complete eradication of *Anopheles gambiae* after its accidental introduction from Africa led to a severe epidemic in the northeast. In 1941 the Brazilian Government raised the fight

against malaria to the national level by the formation of the Serviço Nacional de Malária, with Mário Pinotti as director. The Rockefeller Foundation, with its strong interest in the world-wide control of malaria, has been cooperating in the Brazilian campaigns both before and after the organization of the Serviço Nacional.

The recent upsurge of malaria in Santa Catarina began about the time that the Serviço Nacional de Malária was organized. It was particularly bad in the cities and pressure was strong for the local branch of the Serviço to do something quickly. Drainage campaigns had been very successful in other parts of Brazil, so drainage was tried around several cities before there was time for investigation of the causes of the disease.

Fortunately, the Serviço had been busy meanwhile investigating the mosquito carriers, and soon discovered that the malaria in Santa Catarina and adjoining areas was wholly of the bromeliad type. Three species of mosquitoes were identified as carriers, *Anopheles bellator*, *cruzii*, and *homunculus*, each with different habits and covering a different area (Pinotti, Rachou, and Ferreira, 1947). It is interesting to note, however, that all were found in houses in large numbers, in contrast to the behavior of *bellator* in Trinidad.

Having located the breeding places of the malaria carriers the next problem was how to eradicate them. Owners of forest land were loath to have the value of their property destroyed, so at first a program of hand removal of bromeliads was tried. This program ran into the same difficulties encountered in Trinidad except that they were generally worse on account of the taller forest. One exception should be noted, the city of Florianópolis, where hand removal made significant progress against malaria because of the location of the majority of the bromeliads on the ground. However, it soon became evident that the whole program, although pointed in the right direction, was quite inadequate to deal with the disease and it was abandoned.

The situation now was desperate. Cities such as Brusque had so many workers ill that industries were preparing to move out bodily. Schools were hard hit also; two-thirds of the students of the Seminario de Azambuja were hospitalized at one time. The only alternative was to deforest a belt around the cities, and this the Serviço proceeded to do under the direction of Mário Ferreira. Pittendrigh was called in to help formulate the plans and give the benefit of his experience in Trinidad (Ferreira, 1948).

The major part of the deforestation program required 3 years, but by the end of the first year there had been a sharp drop in the incidence of malaria. In the end, the program was a success, with malaria virtually eliminated from the cities. Early in 1952 I spent

a month in Brusque with neither screens on my bedroom windows nor net over my bed, and I found it very difficult to realize that only a few years ago my hosts of the Seminario de Azambuja had been on the point of moving out completely and abandoning their buildings.

As newer techniques of control have appeared, there has been considerable argument on the value and necessity of deforestation. On one score, though, there can be no argument: deforestation was the only means at the time and it was used very effectively. The principle of deforestation was simple. It sufficed to destroy breeding places for *Anopheles* as far as the nearest ridge crest, or rarely to the second if that were considerably higher (Ferreira, Rachou, and Lima, 1951). Again Azambuja is a good example, for there one can walk up over the ridge behind the Seminario and down the other side into forest and find a supply of mosquitoes sufficient to keep one fully occupied.[1]

Deforestation caused considerable hardship for landowners because the emergency did not allow time to lumber the forest properly, and many of the trees were a complete loss. The techniques of using DDT against the adult mosquito, aralen against the disease organism in man, and herbicide sprays against the bromeliads all have the advantage of leaving the forests intact, yet probably deforestation is still the best technique for protecting the cities. Herbicide spray has not developed sufficient range to cover any but the low forests along the coast, and DDT and aralen require constant reapplication in cities, while belts of deforestation can be maintained and even made a greater source of profit to the owners than the original forest. The gentler slopes can be turned into pasture or vegetable garden and the remainder planted to *Mimosa* and *Eucalyptus* with the help of the Serviço Florestal. *Mimosa* can be cut and sold for firewood in a few years before the slow-growing bromeliads can become established. *Eucalyptus* requires a longer time before it is ready to be cut, but its bark peels away constantly giving epiphytes no chance to establish themselves. The planted forest has the additional advantage of being a pure stand so that it can be lumbered much more efficiently at maturity than can the diverse original forest. The city of Brusque has voluntarily become a test case for deforestation by using that method alone and dispensing with the other means of protection. For over 5 years now deforestation has been sufficient.

However, as has been noted before, there was no universal solution to the problem in Santa Catarina. Deforestation worked in the city areas, but it was clearly impractical, if not impossible, for

[1] Note to cultivators of ornamental bromeliads: Cities are so widely separated in Santa Catarina that wholesale destruction of the plants in deforestation belts has made no appreciable inroad on the total supply.

small settlements and isolated farmhouses. The amount of deforestation necessary to protect one farmhouse would be the equivalent of what would protect scores of houses in a city area. The cost would increase astronomically. There is also the strong probability that further deforestration would have an adverse affect on the water supply.

In 1945 Pinotti imported a small amount of DDT and began experiments in mosquito control with it. By 1947 he was able to undertake a program for all Brazil, and by 1949 3 million houses a year were being treated. Thus as the cities in Santa Catarina came under control and the campaign shifted to the country districts, a technique was ready to apply to the new problem.

By itself DDT was not a complete solution since its use in the forest did not prove practical (Ferreira and Rachou, 1949). On the other hand, detailed investigation showed that the mosquito carriers in Santa Catarina were highly domesticated and preferred to dine indoors and at night (Rachou and Lima, 1950). Further research showed that they had a strong preference for resting on the walls at certain levels. They even tended to distinguish between light and dark bands. These peculiarities plus the regional climate were a great help to the DDT campaign. The spray had to be applied only to the upper part of the walls indoors and only once a year, because its 6 months' duration covered the rainy season and the mosquitoes were not a problem in the dry season.

The rural campaign was actually a double campaign because aralen was used against the malaria in its human hosts at the same time that DDT was used against the mosquitoes. The Brazilian Government bought a large supply of aralen, a drug that has largely succeeded the atabrine that was used against malaria in World War II. Clinics were established in all the municipios involved in bromeliad malaria and aralen administered to all persons who showed symptoms.

Probably it will never be possible to evaluate the effects of DDT and aralen separately, but the combination was eminently successful. Either the malaria organism lacked mosquitoes to carry it or the mosquitoes lacked malaria to carry. In either event the cycle was broken and the rural areas came under control like the cities.

One other type of control should be noted, that of herbicide sprays. So far, this method, which provided complete control in Trinidad, has been impractical except in the low coastal forest around cities like São Francisco (Veloso, Neto, and Chamarelli, in preparation). Even here a new technique was necessary because there were not enough roads to carry wheeled pumps within striking distance of all the forest area. Instead the Serviço crews cut trails and widened

them at suitable intervals to provide room for pumping stations. Tanks were made by assembling movable sections and lining them with canvas (pl. 2, fig. 1). Water was pumped into the tanks from the nearest watercourse and copper-sulfate powder added. The pumps were then reversed to spray the surrounding forest (pl. 2, fig. 2).

The value of herbicide control in Santa Catarina to date has not been so great as that of the other methods, but if it can be improved it promises to have certain advantages. It saves the trees, since only the epiphytes are killed, and thus it has a great economic advantage over deforestation. Owing to the slow recovery of the bromeliads, herbicide does not need to be applied oftener than every 5 years where DDT needs yearly application.

CONTINUATION OF CONTROL AND RESEARCH

At present Santa Catarina is freer from malaria than at any time in recent history. However, the people of the Serviço Nacional de Malária realize that what they have achieved is control and not eradication. As Rachou has pointed out (1951), eradication is possible only when the campaign can be carried out on all sides to strong natural barriers such as the shores of an island. On the other hand control, once established, can be made more and more efficient by continued research.

With this idea in mind, Pinotti set up a malaria research laboratory in Brusque in 1949 under the ecologist Henrique P. Veloso. The laboratory was equipped to study bromeliad malaria from all possible angles. Field crews have made a succession of surveys of the bromeliad population of the forests and of the mosquito population of the bromeliads. A card has been made out for each bromeliad listing 20 items of information, including the species of tree on which it grew, the species of the bromeliad, its height from the ground, the amount and temperature of the water in its tank, and the number and species of mosquito larvae in the water. To date 120,000 individual bromeliads from 200 localities have been studied and their importance as mosquito breeders evaluated (Veloso, in press), with the aim of making the attack more selective, more efficient, and consequently less expensive.

With the help of Padre Raulino Reitz, director of the Herbario Barbosa Rodrigues, a thorough systematic and ecological study of the bromeliads has been made and an illustrated monograph of all the Santa Catarina species has been prepared (Reitz, in preparation). I have contributed keys for the identification of such material (Smith, 1950) until more detailed works are ready, and have correlated all the Santa Catarina collections with those already in the Smithsonian

Institution. A duplicate series is on file here for the use of American investigators. It is now possible, by correlation with mosquito data, to distinguish potentially dangerous bromeliad populations from harmless ones.

A further refinement in control is the ecological study of the relation between the bromeliads and the trees upon which they perch. Veloso has accumulated the ecological data and is waiting while various systematic botanists, including myself, complete the identification of his trees. Until now Veloso has assembled data by using numbers and local popular names to designate his species. When complete, this report will help determine which types of forest are most rapidly invaded by bromeliads and where controls will need to be reapplied soonest, and its scientific names will make the information usable outside Santa Catarina should bromeliad malaria appear elsewhere in tropical America.

Studies of the mosquitoes will show at what height in the forest the principal carriers breed, and in turn prove whether it is necessary to reach all the forest or only certain levels when using herbicide.

Herbicide control technique has been the main research in the Brusque laboratory. To date, a way of controlling the low coastal forest has been found, but the laboratory is still experimenting to find a way to reach the high forest which predominates farther inland. Spraying from the ground does not reach the bromeliads in the tops of the highest trees effectively, and so far spraying from planes has been equally futile.

Ottis R. Causey, representative of the Rockefeller Foundation in Brazil, has developed a telescoped pole which is elevated by compressed air. It can be used to elevate the nozzle to the level of high trees and is capable of spraying bromeliads individually. In combination with ground spray for the lower levels it might provide the means for controlling some of the interior forests, but there has not been time to test it thoroughly yet.

At the same time the Serviço Nacional de Malária has been studying the data accumulated during the campaign with interesting results. Table 1, compiled from unpublished data, shows comparative statistics for five of the cities that were cleared of malaria. Note that Florianópolis controlled malaria by hand removal of bromeliads and that Brusque succeeded with deforestation. Blumenau and Joinvile used DDT in houses in addition to deforestation, and Itacorobí used only DDT in houses from 1948 on. Constant comparisons of the effectiveness and cost of these operations will point the way to further control or their adaption to fight possible epidemics elsewhere.

TABLE 1.—*New and total cases of malaria in various localities of Santa Catarina, 1944 to 1951*

Locality	Municipio	Year	Primary cases of local origin	Total
Florianópolis [1]	Florianópolis	1944	112	. . . . .
		1945	13	. . . . .
		1946	11	. . . . .
		1947	4	. . . . .
		1948	1	. . . . .
		1949	2	. . . . .
		1950	0	. . . . .
		1951	0	. . . . .
Blumenau [2]	Blumenau	1945	212	3, 106
		1946	112	2, 080
		1947	56	1, 874
		1948	58	2, 284
		1949	11	614
		1950	4	266
		1951	1	79
Itacorobí [3]	Florianópolis	1945	. . . . .	866
		1946	. . . . .	1, 255
		1947	. . . . .	1, 168
		1948	. . . . .	457
		1949	. . . . .	30
		1950	. . . . .	15
		1951	. . . . .	14
Joinvile [2]	Joinvile	1945	. . . . .	740
		1946	. . . . .	1, 239
		1947	. . . . .	4, 720
		1948	. . . . .	3, 639
		1949	. . . . .	2, 241
		1950	. . . . .	811
		1951	. . . . .	144
Brusque [4]	Brusque	1945	. . . . .	2, 011
		1946	. . . . .	1, 536
		1947	. . . . .	1, 289
		1948	. . . . .	441
		1949	. . . . .	95
		1950	. . . . .	44
		1951	. . . . .	18

[1] Florianópolis, only manual removal in 1944–45.
[2] Blumenau and Joinvile, manual removal and deforestation until 1948. DDT indoors beginning in 1949.
[3] Itacorobí, only DDT indoors beginning in 1948.
[4] Brusque, only deforestation and manual removal.

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Pharmacology of Antibiotics[1]

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The impetus given to the search for new antibiotics after the discovery of tyrothricin by Dubos in 1939 and the development of penicillin during World War II has resulted in the reporting of literally hundreds of new and untried antimicrobial substances. There has been compiled recently a dictionary of these substances in which are listed some thousands of antibiotics and, because of the large number of screening programs in progress, their number is increasing. It is significant, however, that of these thousands of antimicrobial substances less than ten have been found to be useful in the treatment of human or animal diseases.

The pharmacological study of a new antibiotic is usually not a simple one, particularly if the agent is impure. It will be remembered that both penicillin and streptomycin when first used clinically were relatively crude drugs, much more so in the case of penicillin than streptomycin. As a result, some of the toxicity first attributed to penicillin, such as irritation on injection and damage to nerve tissue, could not be immediately assigned to the pure crystalline substance per se. The purification of penicillin revealed that intramuscular irritation was related to purity while toxicity for nerve tissue was inherent in the drug itself. At the present time it is difficult, if not impossible, to determine whether the nephrotoxicity of bacitracin and neomycin is due to impurities or whether it is a quality inherent in the drugs themselves, though it appears that the latter is the case. The "broad spectrum" antibiotics—aureomycin, chloramphenicol, and terramycin—are crystalline drugs which contain few if any impurities. Thus any toxicity demonstrated for them can be attributed to the drugs themselves. It is perhaps unfortunate that, because of the need, it was necessary to use penicillin and streptomycin prior to their purification to the crystalline state. However, the progress made in

[1] Reprinted by permission from the Journal of the History of Medicine and Allied Sciences, vol. 3, 1951.

the antibiotics field during the past 10 years has been such that it is relatively unlikely that in the future we shall be required to determine the pharmacology of, or to use, many new antibiotics which have not been purified. In the following discussion of the pharmacology of antibiotics, only those chemotherapeutic substances that are currently in use will be discussed, keeping in mind that the pharmacology of some was determined on the impure drug, while others were studied in the pure state.

TYROTHRICIN

The tyrothricin available commercially consists of an impure defatted mixture containing approximately 20 percent gramicidin and 80 percent tyrocidine. Tyrothricin, gramicidin, and tyrocidine are highly active poisons. Both tyrothricin and tyrocidine hemolyze erythrocytes. Gramacidin has been shown to be hemolytic as well, but its action is delayed and the lytic activity of tyrothricin is usually ascribed to its tyrocidine content. The lysis caused by tyrocidine is prevented by the presence of serum. Gramicidin is more toxic than tyrocidine for cells in general, and the cytotoxicity of tyrothricin is largely due to its gramicidin content.

Injection of small amounts of these drugs in animals by the intravenous, intramuscular, intraperitoneal, or subcutaneous routes invariably causes death in a relatively short time. Death is apparently due to respiratory failure since the heart may continue to beat for some time after breathing ceases. Animals dying after lethal doses of these drugs show nonspecific degenerative changes. Acute congestion of the lungs and abdominal viscera, petechial hemorrhages of lungs, kidney, and myocardium, and diffuse hemorrhages of the spleen have been reported. Histopathological examination usually shows fatty degeneration of the liver with necrosis, cloudy swelling of the tubular epithelium of the kidney, and hemorrhage of the glomeruli. Orally tyrocidine and gramicidin are of relatively low toxicity.

In man, no appreciable toxicity of tyrothricin has been reported following local application. During the past 2 years, increased commercial availability of tyrothricin preparations has emphasized the need for cautious use of this drug. Following its use as nose drops with or without a vasoconstrictor, both parosmia and anosmia may occur. More serious, however, is the possibility of chemical meningitis following the use of solutions of tyrothricin for irrigation of cavities near the subarachnoid space. Fatal chemical meningitis has been reported after such use of tyrothricin solutions. Following injection of 1 cc. of 1:1,000 tyrothricin in alcohol into the cisterna magna of dogs, death occurred immediately or within a few hours in 50 percent of the animals so treated. The pathological process in the surviving animals was consistent with acute purulent chemical meningitis.

The final picture in those animals which survived revealed gross and microscopical thickening of the leptomeninges with or without hydrocephalus. One animal was observed to have a fully developed hydrocephalus involving all ventricles.

The observations in patients, together with the reproduction of the pathological processes in animals, indicate that tyrothricin solutions should not be used for the irrigation of sinus cavities in close proximity to the subarachnoid spaces and emphasize again the inherent toxicity of this drug.

PENICILLIN

Penicillin is by far the most widely employed of the antibiotics now available to the general practitioner and in many of the bacterial infections it remains the drug of choice. The toxicity of pencillin was shown early to be extremely low and, in general, the impressions gained at that time have been borne out in the extensive use of this drug. The original studies showed that even with relatively crude preparations there was little to indicate contraindication to its use in man. Further studies substantially confirmed the fact that crude amorphous penicillin had little, if any, true toxicity, although an occasional sensitization occurred with this material. As early as 1944, at which time only amorphous material was available, it was demonstrated that insofar as the calcium and sodium salts of penicillin were concerned, its acute toxicity appeared to be associated with the cation rather than with penicillin per se. Later studies of the sodium, lithium, ammonium, strontium, calcium, magnesium, and potassium salts showed conclusively that the toxicity of these penicillin salts was primarily associated with the cation. These studies were carried out with penicillin salts that were not pure although their potencies were on the order of 1,000 units per mg. The apparent toxicity of penicillin decreased as the purity of commercial preparations improved. Therefore it is important in discussing the pharmacology of penicillin to give consideration to the fact that all the reports concerning toxicity made prior to the advent of crystalline penicillin G were based on amorphous penicillin containing impurities, which may have been responsible for certain of the toxic effects ascribed to penicillin itself. It should be emphasized that the penicillin commercially available today is largely crystalline penicillin G. Amorphous penicillin is no longer produced. The presently manufactured penicillin approaches the theoretical potency—1,667 units of activity per mg. (60 mg. per 100,000 units).

One of the toxic effects observed with amorphous penicillin, an abrupt rise in temperature following injection, was due, without doubt, to pyrogenic impurities. The presence of these pyrogenic

substances in early commercial lots of penicillin resulted in specifications by the Armed Forces, who during World War II procured all of this drug, which required animal tests to demonstrate the absence of pyrogenic substances. Likewise, safety tests in mice were included to eliminate the possibility that chance contamination with solvents and other materials might render the product harmful.

The doses utilized, even in early clinical trials of penicillin, were relatively high and were a direct indication of the extremely low toxicity of this drug. At the present time, doses as high as 100,000,000 units daily of crystalline sodium or potassium penicillin G are given without untoward effects. There is little or no pain following intramuscular injection of crystalline penicillin. However, early lots of amorphous penicillin of low purity were quite painful on injection. As a matter of fact, there was a significant correlation between the purity (potency) of commercial sodium penicillin and irritation following intramuscular injection. With an increase in potency in units per mg., there was a corresponding decrease in the pain produced.

The early indications were that penicillin produced no serious toxic effect on the nervous system. However, there is no question now, that even with the pure crystalline drug, nerve tissue is vulnerable to its action. Convulsions may follow intraventricular administration of penicillin in man and can be induced in animals by direct application of penicillin to the cerebral cortex. Neurological complications in patients with pneumococcic meningitis have been noted after intrathecal administration of penicillin. In these cases, neurological symptoms were manifest between the tenth and twenty-third day after the institution of therapy. Both motor and sensory disturbances were observed although recovery was eventually complete. Peripheral neuritis has also been reported as a complication of intrathecal penicillin therapy. Localized peripheral neuritis with motor and sensory disturbances has been observed following intramuscular administration of penicillin. Recovery from the neuritis occurs in most cases. Symptoms following intrathecal administration of penicillin, such as listlessness, headache, nausea, vomiting, respiratory difficulty, cyanosis, fall in blood pressure, thready pulse, and muscular twitching, are apparently reduced or eliminated when the dosage is diminished. This is particularly true if barbiturates are used concomitantly with reduction in the dose. When 5,000 units of crystalline penicillin are applied to the occipital cortex in human beings, no clinical or electroencephalographic abnormalities occur, whereas 20,000 units of the same material produce definite encephalographic changes. Indications are that the intrathecal reactions are related to the size of the dose rather than to the concentration, acidity, or alkalinity of the solution used. The irritating effect of penicillin on the central nervous

system can be diminished directly in proportion to the destruction of the antibacterial properties of the drug.

Toxic reactions to oral therapy with penicillin have been reported on numerous occasions. Black tongue or glossitis may occur in patients treated with troches or with troches and sprays. Stomatitis following the use of penicillin as troches or by inhalation has been reported. There are other side effects resulting from penicillin therapy which may be classified as rather indefinite reactions. These include gastrointestinal disturbances, muscle cramp, flushing of the skin, and headache. These reactions are observed not infrequently and some have been described as being allergic in nature. The symptoms are difficult to explain but rarely, if ever, are they sufficiently severe to necessitate withdrawal of the drug. One of the serious reactions to penicillin in man is the Herxheimer reaction in syphilis. This "therapeutic shock" presumably represents a reactivation of the syphilitic process which sometimes follows the use of any potent antisyphilitic drug. The Herxheimer reaction has followed the use of penicillin in both early and late syphilis and alarming manifestations may occur in cases of cardiovascular and neurosyphilis. Deaths have occurred presumably following Herxheimer reactions during the use of penicillin therapy in syphilis. Fortunately, this type occurs infrequently.

Of more importance because of their possible universal occurrence are the allergic manifestations which may be observed following use of penicillin. The early belief that allergic reactions were connected exclusively with the impurities in penicillin has been thoroughly discredited by the mass of data to the contrary. Undoubtedly the impurities in amorphous penicillin increased the possibility of sensitization, but the pure crystalline drug itself is quite capable of causing an allergic reaction in man. Sensitization with crystalline penicillin approximating the theoretical potency of 1,667 units per mg. may occur in individuals who have never had previous contact with the drug. About 5 percent of individuals exhibit a positive reaction of the tuberculin type to penicillin, despite the fact that they have not had previous contact with the drug. In addition to those individuals who are sensitive on primary contact with penicillin, there is a group of probably 10 percent of the population that may become sensitive following brief or prolonged treatment. Certain individuals become sensitive following a few injections and others require many.

Probably the most common reaction to penicillin is urticaria. This may vary from a single or few transient erythematous wheals to the diffuse massive plaques of angioneurotic edema which may be localized on the hands, lips, eyelids, vulva, or larynx. Epidermal hypersensitivity to penicillin is more likely to occur following topical

application. The number of cases of contact dermatitis following topical application of penicillin makes one question the value of this drug for local therapy. In addition to contact dermatitis, an Arthus type of reaction and a condition resembling serum sickness are encountered. Reactions are seen most frequently after topical application of the drug but similar reactions have occurred following parenteral administration after initial topical use, and after parenteral or oral administration only. In some instances, reactions occur after initial exposure and in others after subsequent administration. In any case, the increase in frequency of reactions observed following penicillin therapy indicates that local application of the drug should be used with considerable caution. In addition, since bacitracin is as effective topically as penicillin, consideration should be given to its use because of its low incidence of sensitization following application.

Absorption and excretion.—When penicillin is injected intravenously, concentration in the blood reaches a "peak" almost immediately. The concentration in the blood decreases rapidly and after a few hours little, if any, can be detected by assay, although it may be detected in the urine for a longer period of time. The peak concentration of penicillin following intravenous injection as well as the duration of blood concentrations depends on the quantity of the drug administered. Since the first clinical trials were made in this country, it has been customary to consider that a maintained plasma concentration of 0.03 unit per ml. or better is satisfactory for most penicillin-susceptible infections other than the most severe. This is an arbitrary figure and it was chosen primarily because of limitations of the bioassay method utilized for determining blood concentrations of penicillin in man. Obviously, some bacterial strains are inhibited by lower concentrations of the drug while others require considerably higher ones to obtain the desired therapeutic result. Practically all the clinical evidence available on penicillin is based on a maintained plasma penicillin concentration and for general use this appears to be the most satisfactory procedure. There is, however, both laboratory and clinical evidence that a continuous plasma concentration is not essential for good therapeutic results.

After intramuscular injection, the highest penicillin concentration in the blood is reached usually within one-half hour with a slower fall than seen following intravenous administration. The peak concentration of penicillin in the blood is not so high as would occur with the same dose given intravenously. For intramuscular injection, the intermittent method is most generally used although under certain exceptional circumstances the drug is given by continuous intramuscular infusion. Subcutaneous injection is apt to be painful, and absorption is slow and uncertain. It has been shown that radioactive

penicillin, injected intramuscularly, is not stored in the body but is quickly excreted as penicillin or penicillin-decomposition products.

Early clinical trials with oral therapy were for the most part disappointing, and it was felt that this was due to inactivation of the drug by gastric secretions. During recent years, several investigators have shown that the oral route is effective for the treatment of many infections, provided sufficiently large doses are administered at proper midmeal periods. It is generally accepted that approximately five times as much penicillin is required orally as intramuscularly to obtain comparable plasma concentrations of the drug. These large doses are necessary because of the inactivating effect of gastric secretions and food, incomplete absorption, and inactivation by penicillinase-producing bacteria in the intestinal tract.

Penicillin may be administered by inhalation as an aerosol of finely micronized dust and by instillation in solution into the pleural, pericardial, peritoneal, or synovial spaces. By these methods of administration, a local or topical effect of the drug is obtained and although absorption may occur, it is erratic and unreliable where systemic therapy is needed. Soluble tablets of pencillin (containing nothing but the drug) are available for sublingual use. Satisfactory absorption by this route has been reported and this mode of administration may have a place in the treatment of patients who have difficulty in swallowing the larger penicillin tablets.

Diffusion of penicillin from the circulation into the tissues depends on the plasma concentrations, and the diffusion into the tissues will proceed as long as the concentration of diffusible penicillin in the plasma exceeds that in the tissues. The drug diffuses readily from maternal to fetal blood and into the abdominal cavity. Some diffusion also occurs into the pleural, pericardial, and synovial fluids, and bile. Very little of the drug penetrates into abscess cavities, brain and nerve tissues, bone, chambers of the eye, nor does it appear in any appreciable concentration in sweat, saliva, tears, or milk. Unless large doses are administered, very little diffusion into the cerebrospinal fluid will occur except where the meninges are inflamed.

As indicated above, after penicillin is absorbed most of it is rather rapidly excreted in the urine. The renal clearance of crystalline penicillin G approximates the total renal plasma flow. It is about four or five times greater than the renal clearance of inulin or sodium thiosulfate. As a matter of fact, the normal renal clearance of penicillin so closely approximates the renal plasma flow that it has been suggested as a possible substitute for para-aminohippuric acid or diodrast as a test for renal plasma flow and renal function. The soluble salts of penicillin are excreted in the greatest amounts during the the first hour, but diminishing quantities may be found for several hours thereafter.

Because penicillin is absorbed and excreted rapidly, numerous attempts were made to develop pharmaceutical forms of the so-called "repository types" which would allow a slow and more or less constant release of penicillin into the general circulation from a tissue depot. The first of these was a suspension of penicillin in peanut oil and wax. With the development of procaine penicillin, penicillin in oil and wax became less and less popular until at the present time practically none is available commercially. Procaine penicillin either in oil or in aqueous suspension is slowly absorbed from a tissue depot because of its insolubility. This drug has a solubility of only 0.67 percent. Further prolongation of blood concentrations of procaine penicillin in oil is obtained by the addition of 2 percent aluminum monostearate. The latter drug has been used in tremendous amounts during the past few years. Obviously the addition of peanut oil, sesame oil, beeswax, and other substances to penicillin increases the possibilities of sensitization. The occasional side reactions obtained with the so-called repository forms of penicillin, however, have not mitigated against their use.

In attempts to prolong the activity of penicillin in the body, agents that compete with penicillin for the same renal excretory mechanism have been proposed. These agents, para-aminophippuric acid, diodrast, and carinamide, act by retarding the excretion of penicillin, thus prolonging its presence in the blood. Recently a new, relatively nontoxic compound, p-(di-N-propylsulfamyl)-benzoic acid [2] has been shown to retard the excretion of penicillin with a daily dose of 2.0 grams (0.5 gram every 6 hours) to the same extent as a daily dose of 24 grams of carinamide (3 grams every 3 hours). This drug also delays the excretion of para-aminosalicylic acid, and because of this is under study in combination with para-aminosalicylic acid in the treatment of tuberculosis.

STREPTOMYCIN AND DIHYDROSTREPTOMYCIN

The speed with which streptomycin was demonstrated to be an effective weapon in the fight against infectious diseases was in part due to the great need for an agent active against the gram-negative organisms and the mycobacteria. Within a year of the announcement of the discovery of this drug, its in vivo activity was established and in spite of extremely short supplies, it had been shown clinically to be a safe and effective chemotherapeutic agent. It is the first and only drug of proven value that phthisiologists have had in the treatment of tuberculosis. Unfortunately, it is not the answer to definitive treatment of this disease although there is no question but that it is a most valuable adjunct to other forms of therapy.

[2] "Benemid"—trademark.

From the standpoint of the amounts injected, particularly in the treatment of gram-positive and gram-negative infections, streptomycin may be considered to be a drug of low toxity. In the process of the development of streptomycin, the organism *Streptomyces griseus* produces substances in addition to the antibiotic. Among these substances are histamine and histaminelike substances which in the early impure lots were carried over into the finished drug. These histaminelike substances were responsible for the reports of nausea, vomiting, headache, and flushing of the face following parenteral use of the drug. *Streptomyces griseus* not only produces unrelated chemical compounds that cause untoward reactions on injection, but produces also vitamin B_{12} and several other growth-promoting substances during the fermentation process.

Pyrogenic substances are produced in every batch of streptomycin, or for that matter in every batch of any antibiotic produced by the fermentation process. These pyrogens result from breakdown of the cell of the micro-organism, thereby releasing material that on injection raises the body temperature. The elimination of pyrogens from antibiotics has been a problem since their first use in man. It will be remembered that one of the first side reactions of penicillin was a pyrogenic response in man. Present-day penicillin rarely, if ever, contains pyrogenic substances since they are eliminated in the process of manufacture. Similarly, these substances are rarely found in present-day commercial lots of streptomycin. The presence of histaminelike substances and pyrogens in dihydrostreptomycin has been rarely noted also since in the case of this drug its clinical use came about only after relatively pure streptomycin was available. Some evidences of renal irritation occasionally accompanied by impairment of renal function have been reported, particularly with early lots of streptomycin. Similarly, intramuscular administration of partially purified streptomycin gave rise to some degree of soreness and induration at the site of injection. As the purity of the drug increased, however, reports of renal irritation and impairment of renal function decreased in number. It should be emphasized in any case that impairment of renal function ocurred in most instances during therapy in presence of a probable renal disease which had existed before streptomycin treatment was instituted. There appears to be no significant evidence that dihydrostreptomycin produces renal impairment with ordinary dosage regimens.

There is some evidence that streptomycin hydrochloride is more irritating than streptomycin sulfate on intramuscular administration, and this irritation seems to be related to the hydrochloride portion of the molecule. The apparent greater toxicity of the hydrochloride salt of streptomycin has been sufficient to result in the elimination

of this salt of streptomycin from the market, so that at the present time streptomycin sulfate and streptomycin calcium chloride trihydrochloride are the only salts available for clinical use. The only dihydrostreptomycin salt available is the sulfate salt.

In a general way, the toxicity of dihydrostreptomycin is similar to that of streptomycin, but this toxicity should be compared with relatively pure streptomycin only since dihydrostreptomycin is produced from relatively pure lots of streptomycin. The neurotoxicity of dihydrostreptomycin when tested in animals is approximately one-half that of streptomycin. The lower neurotoxicity of dihydrostreptomycin has been shown clinically in man by several investigators. A delayed neurotoxic effect of dihydrostreptomycin on the auditory system of patients evidenced by delayed deafness several weeks after treatment had been discontinued has also been reported. There is some question as to whether this "delayed deafness" is in reality delayed or whether it is actually a slow progressive increase in deafness. Studies are now in progress in an attempt to determine the facts in this unexpected toxic reaction in a relatively large group of patients.[3] In any case, careful investigation has failed to demonstrate a greater neurotoxicity of dihydrostreptomycin over streptomycin on the auditory system in cats. Indeed, in these animals dihydrostreptomycin appears to affect the auditory and vestibular systems to a lesser degree than does streptomycin.

As with the other antibiotic drugs, streptomycin causes skin eruptions during the course of treatment. These are relatively common but usually are transient and not considered to be an indication for the discontinuance of therapy. Although the impurities present in the early crude preparations of streptomycin may have been responsible for some of the skin reactions observed, the drug is capable inherently of producing sensitivity. Skin reactions occur in about 4 percent of the cases treated. Occasionally severe urticaria complicating streptomycin therapy occurs, and two deaths have been reported from dermatitis and stomatitis during streptomycin therapy. Contact dermatitis is caused by streptomycin more often than by penicillin. Not infrequently, individuals in industrial plants handling the drug become sensitive to it. In addition, nurses having intimate contact with the drug often show epidermal sensitization to streptomycin.

Absorption and excretion.—Following injection, streptomycin is readily absorbed and excreted. The usual method of administration is by the intramuscular route, and although intravenous administra-

[3] This study has now been completed (February 1953) and has shown dihydrostreptomycin to have a higher toxicity for the auditory branch of the eighth nerve than streptomycin, while the reverse is true for the vestibular branch of this nerve. Recent studies have also shown a marked reduction in toxicity for both branches of the eighth nerve through use of a mixture containing equal parts of these drugs.

tion has been used, it is no longer recommended, not only because of inconvenience to the patient but also because constant high blood concentrations are unnecessary. This is particularly true in the treatment of tuberculosis where prolonged high concentrations of the drug are not essential and in addition increase the possibility of neurotoxic reactions. The rapid disappearance of streptomycin from the blood can be accounted for by its early appearance in the urine. Following oral administration of the drug in animals relatively small amounts are found in the blood. This lack of absorption of streptomycin from the gastrointestinal tract is responsible for the low blood concentrations and is consistent with the large amount of drug recovered in the feces. In general, these results are similar to those found following oral use of streptomycin in man. The drug may be concentrated and excreted in the bile. It passes the placental barrier and is readily available to the fetal circulation.

Streptomycin cannot be demonstrated in the blood serum of patients following the administration of 0.5 gram per day by nebulization or by mouth and, furthermore, urinary excretion of streptomycin under these conditions is negligible. Injections of from 50,000 to 100,000 μg. per day intrathecally for meningitis show from 6 to 50 μg. per ml. in the spinal fluid 12 hours later. No significant amounts of streptomycin appear in the spinal fluid following intramuscular or subcutaneous injections of from 50,000 to 200,000 μg. In patients with tuberculous meningitis receiving streptomycin by continuous subcutaneous infusion for over 48 hours, streptomycin may be demonstrated in the spinal fluid in amounts varying from 4 to 18.5 μg. per ml. It would appear that the presence of an inflammatory reaction in the meninges increases the possibility of diffusion of streptomycin into the spinal fluid. In man, the serum concentration obtained within 1 hour after intramuscular injection of streptomycin approximates that obtained by intravenous injection of the same dose indicating a rapid absorption from the muscle. Streptomycin is absorbed more slowly following intramuscular or subcutaneous injection than is penicillin and similarly is excreted at a slower rate. Blood concentrations may be maintained for approximately 12 hours following the injection of 0.5 gram of streptomycin as the sulfate.

Most of the streptomycin injected parenterally is excreted through the kidneys and although rather broad variations in percent recovery of streptomycin in the urine of man have been reported, it appears that where normal kidney function is involved, between 50 and 60 percent of the streptomycin administered parenterally is excreted in the urine within a 24-hour period. Excretion of the drug is most rapid in the first 4 hours while the greater part of the antibiotic is excreted in the urine within the first 12 hours. Obviously in the

presence of renal damage, markedly different results may be obtained. The renal clearance in man is approximately 70 percent of the simultaneously determined glomerular filtration rate. In the dog practically all the streptomycin administered can be accounted for by excretion in the urine. In man, however, a considerable amount of the drug is frequently not found in the urine.

Several daily injections of streptomycin parenterally usually produce an equilibrium between the quantities administered and the amounts excreted. In the individual with normal renal clearance, a balance is reached rather rapidly and, as long as it remains normal, may be maintained for considerable periods of time. In the presence of renal damage, however, the blood concentrations may rise very rapidly. In any case, it is advisable and in some instances essential that the concentration of streptomycin in the serum be followed by laboratory assay. As has been indicated previously, the development of neurotoxic symptoms is related to the height of the blood concentration and duration of treatment. High concentrations of streptomycin in the serum for prolonged periods of time may result in evidences of neurotoxicity.

BACITRACIN

Although the bacitracin originally produced was made by the surface-culture method, the present material is produced by deep-tank fermentation. Production of this drug in the United States is largely by one manufacturer, but approximately five have produced small quantities during the past two years. There appear to be no differences in the antibacterial activity of that produced by surface culture and that produced by deep tank.

There is little doubt concerning the toxicity of the bacitracin now commercially available. It is produced fairly uniformly at a potency of 40 units per mg., and this is approximately 60 percent pure. Further purification beyond 45 units per mg. results in some instability which becomes pronounced at potencies much in excess of 45 units per mg. Animal tests invariably show the drug at these potencies to be nephrotoxic, producing damage to the renal tubules of mice and rats. Kidney damage is observed in dogs given 5,000 units per kg. twice daily for 3 days.

In man, bacitracin has been shown to produce local pain and injury on intramuscular injection. At the site of injection, petechiae of the skin and macular rashes have been observed. Some nausea and vomiting have also been noted, and occasionally tinnitus occurs. Of more importance, however, is the appearance of albuminuria and an increase in blood urea nitrogen in some patients. Most patients treated with bacitracin show some nephrotoxic phenomena. These vary in degree with different lots of bacitracin. The nephrotoxicity is re-

flected in the blood NPN, in the urinary albumin, and in low phenolsulfonphthalein excretion. Abnormal urinary changes are observed after the eighth or tenth injection with daily doses of 40,000 to 80,000 units and after the second injection of a single daily dose of 100,000 units for 2 days. Evidences of liver damage have not been reported and no significant effects have been noted on erythrocytes or white blood cells.

Absorption and excretion.—Bacitracin is absorbed readily following intramuscular injection but disappears from the blood less rapidly than does penicillin. Intramuscular injection of bacitracin in man produces higher and more prolonged blood concentrations than those observed after penicillin administration. The differences in the blood concentrations of penicillin and bacitracin have been shown to be due to their different rates of urinary excretion. In contrast to the mechanism of excretion for penicillin, bacitracin is cleared by the kidneys at a rate approximating that of glomerular filtration.

Following parenteral injection of bacitracin in animals, the drug is found in the urine, kidney, blood, bile, lung, bone marrow, skin, heart, muscle, skeletal muscle, liver, spleen, cerebrospinal fluid, and brain. In man, bacitracin readily diffuses into the pleural and peritoneal cavities. In general, following large intramuscular injections of this drug in man in the absence of inflamed meninges, bacitracin is not usually recovered in the cerebrospinal fluid.

When 50,000 units or about one-half of the maximum daily dose is administered intramuscularly, the peak concentration of the drug in the blood develops by the fourth hour, after which the concentration gradually declines. Individual variation in blood concentrations may be quite marked following intramuscular use. Blood concentrations following injection of 50,000 units may vary from 0.03 unit per ml. to 0.8 unit per ml.

The oral administration of bacitracin does not ordinarily result in measurable blood concentrations, the greater portion of the total dose being recoverable in the feces. Following unusually large oral doses or prolonged oral administration, however, a trace of activity may be observed in the blood and measurable amounts found in the urine, indicating that some absorption has occurred.

Bacitracin, after parenteral administration, is excreted mainly by way of the urine. Wide discrepancies exist concerning its excretion. In one experiment 10 to 30 percent of the injected dose was excreted in the urine within 24 hours and this suggested that the greater portion was either retained in the body or inactivated. Others have found that practically 100 percent of the dose administered could be accounted for by urinary excretion within 8 hours. The fact that in one case much smaller doses were used may account for this discrep-

ancy. Under experimental conditions, increasing the dose from 10 to 100 units per kg. results in a slightly decreased renal clearance. This agrees with the observation that after relatively large doses in animals, damage to the tubules of the kidneys occurs rapidly and this damage is reflected in the later excretion rate.

AUREOMYCIN

In aureomycin we have a chemotherapeutic agent that can be used without fear of serious toxic effects. Untoward side effects consist of anorexia, nausea, vomiting, epigastric distress, heartburn, and diarrhea, which occur more often in females than in males. The diarrhea often persists for several weeks but may be helped by the administration of kaolin, pectin, or bismuth. Sometimes patients complain of a bizarre desire for certain types of food, and occasionally there is a compelling and voracious appetite for any kind of food. Other side effects that have been reported following aureomycin are stomatitis, cheilosis, skin and mucous membrane eruptions, and vaginitis. In addition, a Herxheimer type of reaction has been observed in cases of brucellosis treated with aureomycin. These conditions usually do not interfere with treatment. Early commercial lots of aureomycin caused more nausea, vomiting, and diarrhea than those now available. It is certain that, although the drug itself may cause these symptoms in patients, a relatively large number of the early reports of toxic manifestations were due to the presence of impurities. Present-day aureomycin is recrystallized three times and, as a result, a product of extremely high purity is available for clinical use.

The diarrhea observed in patients treated with aureomycin for a period of three or more days may not be a toxic manifestation of the drug, but rather an expression of the profound effect this drug has on the intestinal flora. In this respect it is similar to terramycin or, for that matter, any combination of chemotherapeutic agents that are markedly active against both gram-positive and gram-negative aerobic and anaerobic bacteria of which the intestinal flora are comprised. Oftentimes, patients treated with these broad-spectrum antibiotics for a period of 3 days or more show nothing but pure cultures of yeast in their stools. Not infrequently the stools become loose, lose their normal odor, and the patient complains of pruritus ani. The latter is probably due to the abnormal shift of the bacterial flora to the acid-producing yeasts.

There is a relatively low incidence of vomiting in patients treated with aureomycin and this may be controlled quite readily with alkalies and, in some instances, milk. The use of aluminum hydroxide is not recommended since it interferes with proper absorption.

Although aureomycin is used in large part orally, the intramuscular and intravenous routes of administration have been explored. Intramuscularly, aureomycin causes considerable irritation and is extremely painful. There is no preparation commercially available at this time for intramuscular use. There is, however, an intravenous dosage form. This method of parenteral administration is very valuable, perhaps essential in certain types of cases. In comatose patients and those unable to swallow, intravenous aureomycin has been used with considerable success. Unfortunately, even when used with the special diluents, glycine and leucine, phlebitis occurs in approximately 10 percent of patients so treated. This reaction subsides promptly without serious residual effect as soon as this form of medication is stopped. Both nausea and vomiting have been reported following the intravenous use of aureomycin.

Aureomycin retards proliferation of fibroblasts, epithelial cells, and cells from explants of embryonal brain tissue at levels approaching those obtained in patients under treatment with this drug. At concentrations of 1,000 μg. per ml., inhibition of growth of these cells has been obtained. These toxic manifestations of aureomycin appear to be of little clinical significance.

Aureomycin, like all drugs, will sensitize some individuals. The evidence so far indicates that the incidence of patients who become sensitive to the drug is extremely low. Furthermore, it is rarely necessary to withdraw the drug from those patients who develop reactions to it.

In considering the toxicity of aureomycin, one should not forget its relative toxicity as compared to that of penicillin which for all practical purposes is considered atoxic. The average oral dose of crystalline penicillin G is 100,000 units (0.06 gram) every three hours. A million units of penicillin is 0.6 gram, yet doses of aureomycin as high as 30 grams orally have been used without serious toxic reactions. One must conclude that we have in aureomycin a drug practically free from toxicity.

Absorption and excretion.—Aureomycin is readily absorbed from the intestinal tract when administered orally in capsule form. Following absorption it diffuses into all body fluids and tissues. In single doses of from 0.75 to 1.0 gram, therapeutic serum concentrations are obtained quite rapidly and these are maintained for relatively long periods of time. These serum concentrations are maintained at therapeutic levels for 6 to 8 hours and complete disappearance from the circulation is not observed for from 24 to 30 hours. When doses of 0.5 gram to 1.0 gram are administered to patients every 6 to 8 hours, the serum concentration of the drug is maintained at from 2 to 4 μg. per ml., although the concentrations in some patients

may exceed 6 or 8 μg. per ml. From the circulation, aureomycin readily passes into the peritoneal fluid, spinal fluid, bile, urine, and milk. It passes into the fetal circulation through the placenta and has been found in the liver, kidney, lung, and spleen. Aureomycin probably passes the blood-brain barrier in therapeutic amounts and the presence or absence of inflammation is not a controlling factor as it is in the case of penicillin and streptomycin.

The concentration of aureomycin found in the urine following oral administration of this drug in either single or multiple doses is relatively high. Peak concentrations of from 50 to 250 μg. per ml. of urine are obtained following single doses of from 0.5 to 2.0 grams. For the most part these peak concentrations may be maintained by similar doses given every six hours. The successful use of this drug in certain types of urinary-tract infections, particularly those of the bladder, is in large part due to the relatively high excretion rate of this drug.

CHLORAMPHENICOL

Chloramphenicol was the first of the broad-spectrum antibiotics to be reported in the medical literature. The generic term "chloramphenicol" was derived from the now known structure of this drug which was first called "chloromycetin." The latter name, which incidentally is also descriptive of the drug, is the trade-mark name. Chloramphenicol is unique among the antibiotics. It is the first and only antibiotic ever synthesized on a commercial basis. The production of this drug, which today is measured in tons and produced largely by synthesis, was an extraordinary acomplishment.

Chloramphenicol is a drug of remarkably low toxicity. A review of its clinical history indicates that the great majority of investigators who have used this drug report "no untoward reactions." The nitrobenzene nucleus might suggest toxicity for man, yet in a relatively large number of patients on high dosages, no evidence of intolerance or toxicity has been observed.[4]

Although side reactions such as nausea, headache, skin eruptions, and enteritic symptoms are rare following the use of therapeutic doses of chloramphenicol, occasional untoward reactions, minor in character, have been recorded. In one case there was an altered sense of taste; food lost its savor and smoking was not pleasant. A second side effect was the appearance of a sensitivity response which occurred on the sixth day of treatment. At this time the patient felt somewhat dizzy, his face became flushed, and numerous red macular lesions appeared over his face. The pulse and respiratory rates were ac-

[4] At the present time (July 1952) evidence from both published and unpublished sources indicate that chloramphenicol has caused blood dyscrasias in certain individuals. While about half of the accumulated cases have been diagnosed as aplastic anemia, the over-all incidence of these blood dyscrasias appears to be quite low.

celerated. There was no associated pruritis. These symptoms persisted for about 30 minutes and then subsided spontaneously. The same syndrome occurred after the last dose of drug was given. Stomatitis may be a possible side reaction to chloramphenicol and some looseness of stools or diarrhea may occur. In the treatment of syphilis a mild Jarisch-Herxheimer reaction has been noted. This reaction is perhaps less frequent in patients treated with chloramphenicol than those treated with penicillin. In general, fewer cases of loose stools and diarrhea are reported with chloramphenicol than with either aureomycin or terramycin. An explanation of this, in part at least, may be the rapid absorption of the chloramphenicol from the gut and the rapid inactivation of that remaining in the intestine. In addition, little antibacterial effect is obtained on the intestinal flora in contrast to the rather profound antimicrobic effect of terramycin and aureomycin on these organisms. Yeasts are frequently found to make up a great proportion of the intestinal flora following extended treatment with either terramycin or aureomycin, while chloramphenicol has little or no such effect.

Proliferating epithelial cells and fibroblasts and cells from explants of embryonal brain tissue are retarded in their growth in vitro by concentrations of chloramphenicol of 10 μg. per ml. This, of course, is in the range obtained with certain dosage regimens of this drug. The cells are completely inhibited in their growth by concentrations of 1,000 μg. per ml. The latter amount is well beyond the blood concentration of the drug obtained in clinical use. In view of the large amounts of chloramphenicol that have been used clinically in man, it does not appear that its effect on the growth of proliferating cells is of clinical significance.

Absorption and excretion.—Chloramphenicol is very rapidly absorbed from the intestinal tract in man. It is metabolized readily and excreted by way of the kidneys. Present evidence indicates that approximately 90 percent of the administered dose may be accounted for in the urine in a period of 24 hours, although relatively low concentrations of active chloramphenicol are found. Probably less than 10 percent of the administered dose is excreted unchanged, while a great bulk of the drug is excreted in the form of an inactive nitro compound.

Although lower concentrations of active chloramphenicol are demonstrated in the urine following the oral use of this drug, the blood concentrations obtained with chloramphenicol are somewhat higher than those obtained following comparable oral doses of terramycin and aureomycin. The concentration of chloramphenicol in the blood drops off rapidly so that by the sixth hour its concentration is somewhat lower than that obtained with similar doses of either terramycin or

aureomycin. The more rapid disappearance of chloramphenicol from the blood may be explained by the fact that it is more rapidly metabolized into the inactive nitro compound. In spite of this, however, in some subjects chloramphenicol can be demonstrated in low concentrations at the twenty-fourth hour. In the therapeutic use of the drug, proper dosages at intervals of 6 to 8 hours have been shown to be clinically effective. As with single doses, the blood concentrations obtained are much higher than those obtained with comparable oral doses of aureomycin and terramycin.

TERRAMYCIN

The first report on terramycin, the third of the broad-spectrum antibiotics to be isolated, gave an indication of its wide clinical possibilities. This drug has an acute and chronic toxicity comparable to the other broad-spectrum antibiotics. Although daily intramuscular injections of the drug were well tolerated by dogs for a period of 2 months or more, it was indicated that intramuscular use of the drug would probably cause local irritation. In high doses (75 to 225 mg. per kg.) sodium terramycin in dogs resulted in impaired renal and liver functions. Dogs dying from these large intramuscular doses of sodium terramycin showed cloudy swelling of the liver and fatty metamorphosis of the kidneys.

Terramycin, as the hydrochloride, is administered largely in capsule form by the oral route. Patients treated by this mode of administration rarely show untoward reactions although there is evidence that terramycin causes gastrointestinal irritation in some patients. This is manifested by nausea, vomiting, and diarrhea. This is usually minor in character. The nausea and vomiting can be controlled by giving the capsules with milk. The use of milk does not interfere with the absorption of terramycin; however, the use of aluminum hydroxide gel is contraindicated as it is with aureomycin. Other reactions reported include proctitis, vaginitis, and pruritis, usually of a mild degree.

Terramycin is now available for intravenous administration. This preparation, however, should not be used except in those patients who, for one reason or another, are unable to take the drug by mouth. The relatively high alkalinity of the preparation may cause phlebitis on intravenous administration and patients receiving this type of medication should be given the drug by the oral route as promptly as possible. The low toxicity of terramycin by mouth is evident from the fact that doses of at least 15 grams per day over a period of 10 to 15 days have been given without evidences of serious toxic effects.

Absorption and excretion.—The close relationship between terramycin and aureomycin is readily demonstrable in the absorption and

excretion of these drugs following oral administration. Both drugs are readily absorbed from the gastrointestinal tract and are readily demonstrable in the blood and urine. In addition, appreciable amounts are excreted in the feces and thereby alter the intestinal flora of the patient. As with aureomycin, complete disappearance of terramycin from the blood may occur as late as the twenty-fourth to thirtieth hour after single doses. There is, however, a definite diminution in the amount of terramycin in the blood 6 to 8 hours after single doses of 0.5 to 2.0 grams. In contrast to aureomycin, which is not very stable in solution, terramycin is quite stable in the presence of serum, urine, and other body fluids. Terramycin does not readily traverse the blood brain barrier as aureomycin does although in cases where the meninges are inflamed, terramycin has been demonstrated in the cerebrospinal fluid. Terramycin diffuses readily into the pleural fluid and passes through the placenta and is present in the fetal circulation. The drug is also excreted readily in the bile. The serum concentrations of terramycin after oral administration are relatively high and prolonged. As the dose is increased from 0.5 to 2.0 grams there is a tendency for the serum concentration to increase correspondingly at any given time. However, the increase in serum concentrations of this drug following single oral doses of from 1 to 2 grams is not quite as great as one would expect, and furthermore the serum content of terramycin is not significantly increased by increasing the size of a single dose from 1 to 3 grams. It appears that only a certain amount of terramycin is absorbed from the circulation regardless of the size of the oral dose. Blood concentrations of terramycin can be maintained at a relatively high level by oral administration every 6 hours. Following oral administration of 0.25 gram, 0.5 gram, and 1.0 gram given at 6-hour intervals for a period of 24 hours, serum concentrations rise sharply with increased dosage.

Urinary excretion of terramycin is relatively high following both single and multiple doses. Indeed, considerably more terramycin is found in the urine than aureomycin after similar doses. The differences in recovery of terramycin and aureomycin in the urine following the same dose do not appear to be fully explained on the basis of the instability of aureomycin in urine.

SUMMARY

Pharmacologically, the clinically useful antibiotics are a unique group of drugs. Penicillin is nearly nontoxic but may cause annoying allergic manifestations especially when given topically. Both streptomycin and dihydrostreptomycin are essentially nontoxic when given over short periods of time, although repeated dermal exposure to either drug may give rise to allergic phenomena, and both drugs may

cause vestibular and auditory pathology when given over long periods. The polypetide antibiotics possess somewhat more toxicity. Tyrothricin and its constituents gramicidin and tyrocidine have a systemic toxicity that precludes their parenteral use or makes their application into body cavities and other sites where absorption is likely undesirable. Bacitracin is nephrotoxic and its parenteral use is justified only under exceptional circumstances. The broad-spectrum antibiotics, aureomycin, chloramphenicol, and terramycin are essentially nontoxic but they may give rise to sensitization reactions and are apt to induce minor gastrointestinal disturbances.

As one would expect, the presently employed antibiotics are readily absorbed following one or more standard routes of administration, are able to diffuse into the various tissues, are considerably more active against the parasitic cells than against the host cells and, once their work has been completed, they are destroyed by normal metabolic processes or are excreted from the body by natural routes.

Many of the other antibiotics are of no clinical value because of their adverse pharmacological activity. These substances, although highly bacteriostatic, are either too toxic for use in man or are slowly absorbed, poorly diffusible, or inactive in the body. These properties can only be determined after thorough pharmacological study and serve to emphasize the importance of pharmacological techniques in the final evaluation of any new antibiotic.

An Anthropologist Looks at Lincoln

By T. D. Stewart
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[With 4 plates]

"Do you often see Professor Henry?" inquired the President, as soon as the door had closed.

I smiled, for it was the identical question which the professor had asked me about the President.

"My visits to the Smithsonian, to Dr. Henry, and his able lieutenant, Professor Baird, are the chief recreations of my life," I said. "These men are missionaries to excite scientific research and promote scientific knowledge. The country has no more faithful servants, though it may have to wait another century to appreciate the value of their labors."

"I had an impression," said Mr. Lincoln, "that the Smithsonian was printing a great amount of useless information. Professor Henry has convinced me of my error . . ." (L. E. Chittenden, *Recollections of President Lincoln and His Administration*, p. 238, 1901. Harper & Bros., New York.)

Famous men, by virtue of outstanding traits of character and personality, often impart an impression of physical bigness regardless of their actual size. The physiques of such men, being easily visualized, as compared to the intangible traits, even after the men themselves are dead, tend to grow in remembrance, feeding as it were on the increasing fame of their intellectual accomplishments. Sculptors carry on this idea by representing these great men in heroic proportions.

Abraham Lincoln is one of the best examples of this type of admiration. Rarely has a man, sprung from such humble surroundings, self-taught, and self-advanced, been the subject of such intensive study. His strength of character and clarity of thought need no comment. In the physical sense he was very tall and seemed even taller because of his leanness. Is it any wonder, then, that his appearance stuck and grew in the minds of those who, immediately after his death, began to assemble their recollections; and that with more

recent recompilations and reanalyses he has continued almost literally to grow in stature? And in the case of his sculptures, the figure in the Lincoln Memorial in Washington, for example, is truly heroic, being, although seated, 19 feet from the top of the head to the sole of the boot.

There are very few measurements made during Lincoln's lifetime that help to bring these soaring concepts of his size nearer to reality or to give perspective on the man himself in his population milieu. There is, of course, his own recollection of height and weight: 6 feet 4 inches and 180 pounds, respectively. Then there is a chiropodist's record of his foot size. And some idea of his head size has been gained from hats. That is about all.

The lack of life measurements is somewhat offset, fortunately, by the existence of other records of Lincoln's physique that as such have been largely overlooked. I refer to the casts of his face and hands made in life by the sculptors Leonard W. Volk and Clark Mills. Since probably the best copies from the original molds are preserved in the United States National Museum, I was urged by Dr. Milton H. Shutes, a Lincoln scholar, to study them from the standpoint of physical anthropolgy. This paper is the result.[1] However, in setting about this task I found that I needed to know something about the history of the casts themselves. Not only is their story interesting, but it is important to the understanding of the use I have made of them. This is my reason for now taking the reader back in time and introducing him directly to the principals involved.

LINCOLN AND VOLK

"Mr. Volk, I have never sat before to sculptor or painter—only for daguerreotypes and photographs. What shall I do?"

With this modest but forthright statement, Volk later (1881) recalled, Lincoln covered his uncertainty as he seated himself in the model's chair that Friday morning early in April 1860, the year of the 51-year-old Lincoln's nomination and election to the Presidency.

Volk was becoming well known as a sculptor. He had been wanting to make a bust of Lincoln ever since he had met him 2 years before, during the Lincoln-Douglas senatorial contest, when he had been working on a likeness of Douglas. Something in Lincoln's appearance at that time undoubtedly fascinated Volk as it was later to fascinate

[1] Dr. Shutes brought this problem to my attention during his visit to Washington in the summer of 1950. My manuscript was finished in November 1952. In the meantime, Dr. H. L. Shapiro, of the American Museum of Natural History in New York, had become interested in the same subject and had agreed to supply an article along much the same lines for the February 1953 issue of *Natural History*. When, in December 1952, he began to write, he learned of my completed manuscript and graciously curtailed the scope of his article (see bibliography).

others. When Volk had asked Lincoln to pose for a bust sometime when he would be in Chicago, the great man had replied promptly and simply, "Yes, I will, Mr. Volk—shall be glad to, the first opportunity I have."

Now, almost 2 years later, the opportunity had come. Lincoln was in Chicago on legal business and was to stay there from March 23 to April 4. Volk had chanced to see his name in the newspaper and had arranged an appointment. In preparation for the sittings, and over Volk's protest, Lincoln had had his hair cut.

After Lincoln had seated himself in Volk's studio that Friday morning, only measurements were taken. Except for stature, which Volk seems to have remembered incorrectly, we are not told of what the measurements consisted. Probably they represented the main diameters and circumferences needed by the sculptor for building into clay the body masses; probably also they were taken over the clothing without any attempt at real accuracy.

At the second sitting, on Saturday, Volk made a cast of Lincoln's face. In those days sculptors often resorted to this means of securing an exact likeness. They could, of course, modify the expression of the mask as they chose, but it gave them something to refer to in the sitter's absence. Reporting the episode 20 years later, Volk said:

He sat naturally in the chair when I made the cast, and saw every move I made in a mirror opposite, as I put the plaster on without interference with his eyesight or his free breathing through the nostrils. It was about an hour before the mold was ready to be removed, and being all in one piece, with both ears perfectly taken, it clung pretty hard, as the cheekbones were higher than the jaws at the lobe of the ear. He bent his head low and took hold of the mold, and gradually worked it off without breaking or injury; it hurt a little, as a few hairs of the tender temples pulled out with the plaster and made his eyes water.

A less calm and courageous person might have become panicky during such an ordeal. The hair pulling, and the realization that the mold was hard to get off, were discomforts of which probably Lincoln had been warned. In addition, well before the end of the hour, surely the setting plaster had begun to generate heat. Volk's efforts at assurance might not have been so successful if Lincoln had known that, years before, the aged Jefferson had almost succumbed to the effects of Browere's moldmaking (Hart, 1899). Nevertheless, even if Lincoln had been discouraged thereby from further sittings, an accurate record of his face had been obtained, for which we are grateful to Volk.

Of course Lincoln was not so easily discouraged. Volk got the sittings required for a bust and ultimately for a full-length figure (Durman, 1951). But we will pass over these proceedings, for our interest here is in the life mask alone. In this mask the physical an-

thropologist sees more than the sadness, the compassion, and other such emotions that sculptors delight in portraying; he sees such characteristics as the bold cheekbones that held the mold tight, the clear lines of the nose, the long ears—all features that he has come to recognize as typical of that segment of our population now known as "Old Americans." But let us postpone the considerations of physical anthropology until we have finished our story about the surviving records of Lincoln's physique.

Two months after taking the face mold Volk arranged to cast Lincoln's hands. The appointment was for Sunday morning, May 21, in Springfield. This was the day after Lincoln had been officially notified of his nomination and when he had shaken hands with the great crowd intent on congratulating him. Therefore his right hand was somewhat swollen.

Before making the first cast, that of the right hand, Volk had Lincoln saw off a piece of broomstick. The cast was made with him holding this stick. The left hand was cast without the stick and with the fingers naturally flexed. In the course of the work Lincoln called attention to a scar on the left (?) thumb resulting from a glancing blow of the ax years before. We are not told anything further about the casting of the hands.

Like the face mask, the hands are records of Lincoln's physique. Were they large in proportion to his height and angular build? If we can trust what people have said about his hands, they must have been huge. For example, Volk makes a special point of describing Lincoln's handshake, using the following expressions: "Grasping my hand in both his large hands with a viselike grip" and "Those two great hands took both of mine with a grasp never to be forgotten." Again we may ask, Was it the size of the hands, the strength of the grip, or a reflection of the Lincoln personality? We will take up the answer later and now go on with the story.

Volk's original casts of Lincoln's face and hands, so valuable alike to sculptor, historian, and physical anthropologist, together with bronze copies thereof made by Volk in 1866, became national property in 1888 (U.S.N.M. acces. No. 20084). Quite fittingly, their preservation and public display in the National Museum in Washington were aided by another notable Lincoln sculptor—Augustus Saint-Gaudens. The latter arranged for Thomas B. Clarke, Richard Watson Gilder, and Erwin Davis to serve with him on a committee to raise funds and purchase the relics from Douglas Volk, the sculptor's son. The committee solicited subscribers, offering to furnish sets of the casts for sums from $50 to $85, depending on whether they were made of plaster or bronze. Ultimately the committee paid Volk $1,500, raised through the following 33 subscribers:

Benjamin Altman
Boston Athenaeum
J. L. Cadwalader
William Carey
The Century Co.
George W. Childs
Thomas B. Clarke
Erwin Davis
Alex. W. Drake
George M. Eddy
Fairmont Park Association, Philadelphia
Richard Watson Gilder
J. J. Glessner
John Hay
E. W. Hooper
Walter Howe
Henry E. Howland
B. Scott Hurtt
Henry Irving
P. J. Koonz
Enoch Lewis
R. J. Lyle
J. W. Mack
Payson Merrill
S. Weir Mitchell
Allen Thorndyke Rice
Jacob Schiff
Bram Stoker
F. M. Stimson
Augustus Saint-Gaudens
William Thomson
Alexis Turner
J. Q. A. Ward

It was the desire of this group that these important relics should be preserved and no longer tampered with. This wish has always been carefully respected. Incidentally, the authenticity of the mask is attested by Leonard Volk's affidavit as well as by the presence of a few hairs still embedded in the plaster at the temples.

As has been said, Volk cast the face in April and the hands in May 1860. On June 3 of the same year, the Chicago photographer Alexander Hessler made his famous portraits of Lincoln in Springfield. One of these, according to Jesse Weik (1922), was "pronounced by Mr. Herndon [Lincoln's law partner] to be the best and most lifelike portrait of Lincoln in existence." Two of the surviving Hessler glass negatives, both unfortunately damaged, recently have been deposited in the National Museum. These negatives have been described and illustrated by the former Secretary of the Smithsonian Institution, Dr. Alexander Wetmore (1936). The casts and the photographs together provide the finest original records of Lincoln at the time of his nomination.

LINCOLN AND MILLS

The last 5 years of Lincoln's life—1860-65—were devoted to the Nation's highest political office and were spent largely in Washington. The Civil War added to the usual strain of this office. During these years, as Shutes has remarked (1933), "he aged with great rapidity." We have Volk's word that already during the Presidential campaign of 1860—that is, between the time he sat to Volk for his bust and when he left Springfield for Washington—he had lost 40 pounds. His average weight was only 180 pounds; his stature 6 feet 4 inches. After the election he began to grow a beard. Although the greater number of pictorial representations of Lincoln relate to this period, there is only one other three-dimensional record com-

parable in accuracy to Volk's casts. In February [2] 1865, just before Lincoln's fifty-sixth birthday and only 2 months before his assassination, another face mask was made. Clark Mills, who was well known at this time in Washington, was the sculptor. His equestrian statue of Andrew Jackson in the square in front of the White House had been unveiled in 1853 (Rutledge, 1942).

Unfortunately, the circumstances surrounding the making of the second face mold are unknown. Quite likely Lincoln told Mills the story of his sitting for the first mold and of the discomforts involved. Lincoln could tell a story well. Also, it seems probable that Mills countered with assurances that such discomforts were largely avoided by his technique. Perhaps he listed some of the famous men whose faces he had cast.

Mills was largely self-taught, so far as a knowledge of the sculptor's art is concerned. In casting the face he showed much of the same independence of tradition that he exhibited in his other art work. As witnessed in Charleston, S. C., in 1845, his casting method was as follows:

> He first encases the head in a tight cap and then (the hair being thus put out of the way) spreads the paste [plaster] over the casing, thereby obtaining the head and forehead with all their phrenological developments. Removing, for a while, the segment thus formed that it may harden and cool (for, although the paste is at first cool, yet it goes under a phase of temporary heat) he soon replaces it, and proceeds to the completion of the work by spreading the paste over the entire face, closing eyes, mouth and ears, and leaving only the nostrils open for breath. The paste is inodourous and insipid, and produces no unpleasant sensation; but, on the contrary, with the thermometer at 90, is actually agreeable and refreshing by reason of its original coolness. It soon hardens around its nucleus, forming a facsimile of every feature and muscle and before the heating stage commences, by a gentle movement of the facial muscles, it is broken into more or less fragments, which are caught in a towel and recombined at the leisure of the artist. The whole operation is over in 15 minutes (Rutledge, 1949).

This is a very different method from the one used by Volk. Whereas the latter built up the plaster over the face and allowed it to harden for an hour so that it could be removed in one piece, Mills kept the plaster thin over the face, allowed it to set for only 15 minutes, and then had the sitter break the mold into pieces by movement of the facial muscles. These factors, combined with the defects necessarily introduced by the recombination of the fragments, would diminish the accuracy of the reproduction.

Available copies of Mills's life mask of Lincoln suggest that Mills was still using in 1865 the method here described as witnessed 20 years earlier. For instance, the whole top of the head is included

[2] If we can reply on the inscription carved on the Fisk Mills bust of Lincoln now in the Lincoln Museum in Washington, the date was February 11. Fisk was one of Clark Mills's sons.

with the face, but without any detail (is this the effect of the tight cap?), the closed eyes are in detail, but much of the face, together with the hair and beard, are somewhat blurred (is this the effect of reassembling the fragments?). In spite of such defects, the fact remains that Mills's cast is a unique relic deserving of closer attention than it has received.

In 1889, the year after the Volk casts were presented to the Government, Clark Mills's son, Theodore A. Mills, presented a plaster copy of the second Lincoln mask to the National Museum (U.S.N.M. acces. No. 21843). The original plaster copy is said to have been owned by John Hay, at one time Lincoln's assistant private sercetary; its present whereabouts is uncertain.[3] R. R. Wilson stated (1935, p. 263), without giving his source of information, that the plaster mask in the Lincoln Museum in Washington is the one once owned by Hay, and hence the original. The records of the Lincoln Museum have nothing to say on this point. Thus, so far as now clearly established, the mask in the National Museum has as good a claim as any to being the earliest copy in existence.

THE CASTS COMPARED

Out of these historical considerations the following question naturally arises: How do these two life masks, taken only 5 years apart, compare in details? In answering this question we must remember what has been said about the different techniques used by the two sculptors. Also that Lincoln was clean-shaven when the first cast was made but later had a beard covering his chin and side cheeks.

Comparisons of the accompanying photographs reveal these facts—and more: They show the same gauntness, the same pattern of skin creases, the same prominent right lower lip; in other words, an assemblage of details in each case producing the same well-known expression. Actually, the beard and the differences in the casting techniques seem to have contributed the main modifications.

On the negative side it is interesting to note the absence of any signs indicating that the original molds had been divided along the midline of the face. Sculptors sometimes cut the mold into two equal parts before making the first positive impression, so that the mold can be taken off easily and used over again. When this has been done the crack between the two parts of the mold leaves a slight ridge along the midline of the mask which usually can be detected even though the

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[3] After this was written Dr. H. L. Shapiro illustrated in *Natural History* a bronze replica of the Mills cast now owned by Clarence Hay of New York. He has told me also that another member of the Hay family has a plaster replica. Lacking still, unfortunately, is the documentation to show the sequence in which these copies were made. We know only that after the death of Clark Mills in 1883 his sons parted with two or three copies of the Lincoln mask, one (two?) going to Colonel Hay (1886), and another to the U. S. National Museum (1889). The sequence of the gifts does not necessarily indicate the sequence of manufacture.

sculptor has tried to obliterate it. Probably, therefore, Volk and Mills destroyed their original molds in the course of making the first positive impressions.

When we next compare the details in the two versions of Lincoln's face by anthropometric caliper, we are confronted again by the masking effect of the beard and by the limitations of the sculptor's art. For example, the beard in the Mills mask interferes with the taking of the length and width of the face; and the incomplete casting of the ears makes it difficult to locate the borders of the ears.

To these difficulties must be added another, namely, the scarcity of natural metrical landmarks on unyielding plaster casts. Whereas the measurer, in working with the living face, is guided by the feel of the underlying bone, in working with the mask he cannot get below what was the surface of the skin. For this reason measurements made on masks are larger than the same diameters taken in life; they are subject also to the measurer's judgment as to where to place the caliper.

These considerations should be taken into account in assessing the following standard facial measurements, which I have obtained on the National Museum's precious masks:

Measurements (defined in Stewart, 1952)	*Volk's mask (1860) mm.*	*Mills's mask (1865) mm.*
Total face height (menton-crinion)	194	?
Lower face height (menton-nasion)	122	?
Face breadth (bizygomatic)	148	?
Nose height	54	56
Nose breadth	38	38
Mouth breadth	55	59
External ocular width	102?	102
Ear length (right)	77?	78?
Ear length (left)	78	?
Ear breadth (right)	43	46?
Ear breadth (left)	39	37?

To appreciate better the difference between measuring the living face and a cast thereof we may take the two figures for mouth breadth in the above list. This measure is the extreme distance between the corners of the mouth. In life the measuring point at each corner of the mouth can be identified readily by the color change that marks the edge of the mucous membrane. Of course, this color guide, like the bone guide, is lost in the masks. The resulting metrical difference may be due to my faulty judgment, seconded by the blurring of detail in the Mills mask.

Attention has been called already to the fact that the Mills mask includes, in addition to the face, most of the vault of the head. If this is a cast of the head taken over a cloth cap, a practice attributed to Mills, the surface texture of this part of the cast does not supply verification. My examination of the specimen, before I had read about

Mills's technique, led me to believe that he had modeled this part of the head from measurements. I can believe now that, if a head cast actually was taken, Lincoln's coarse and unruly hair might have imparted a lumpy effect to the cast and Mills might have been forced to modify the surface. Also, whether he reduced the diameters of the head beyond the surface of the compacted hair there is no sure way of telling. Thus, the following head measurements, which I have taken from the cast in the National Museum, are subject to this uncertainty:

	Mm.	*Inches*
Maximum length from glabella	210	8¼
Maximum breadth (above ears)	170	6$\frac{11}{16}$
Head height (position of poria and bregma estimated)	165	6½
Circumference (as for hat)	578	22¾
Arc between ear openings over bregma	370	14½
Cephalic index	*81.0*	

For comparison with these figures we have Herndon's statement (Angle, 1949, p. 472): "The size of his hat measured at the hatter's block was seven and one-eighth, his head being, from ear to ear, six and one-half inches, and from the front to the back of the brain eight inches. Thus measured it was not below medium size."

Commenting on Herndon's figures, Nicolay reported (letter of 1895) that he and Colonel Hay "made as careful measurement [of the cast owned by Hay] as we could, with the result that from ear to ear it measures 6¾ inches, and from the front to the back of the brain 7¾ inches. It is difficult to arrive at exact measurements, but the ones we took applied to hatter's block would give 7¼ or 7⅜ as the size of his hat. So you see it was fully as large as stated by Herndon."

We come now to the hands, and here again we are confronted with difficulties. In addition to those mentioned already, which for the most part apply here also, we have to deal with flexed fingers. Presumably Volk regarded this form of hand as being both artistic and easy to cast. However, the flexion of the fingers makes it hard to evaluate hand size. All the standard measurements of the hand are planned for the extended position of the fingers. This being the case, we must improvise.

The distance across the second to fifth knuckles (metacarpophalangeal joints) amounts to 95 mm. on the left hand. The equivalent distance is not readily obtained on the right, but seems to be no more than 94 mm. The circumference of the right wrist on the hand side of the styloid process (the bony prominence on the same side of the wrist as the little finger) is 188 mm.; that of the left wrist is 194 mm. The difference possibly is accentuated by the extension of the left wrist and the flexion of the right.

A measure of the length of the fingers was obtained by stretching a steel tape along the back of each finger from the edge of the nail

to the apex of the metacarpophalangeal knuckle. The results (in mm.) follow:

	Digits				
	I	*II*	*III*	*IV*	*V*
Right	88	133	143	139	115
Left	77?	137	148	141	117

To this may be added the dimensions of the nails of the left hand. Only on this side are the details clear enough to yield accurate results. The nails had been cut moderately short.

	Nails				
	I	*II*	*III*	*IV*	*V*
Length	17	15	15.5	13	14
Breadth	16	12	13	11.5	10.5

So far as the hands have been compared, there seems to be a consistent difference in size in favor of the left hand. Yet we are told that the right was temporarily swollen. In a right-handed individual, which I am assuming Lincoln to be, it is unusual for the left hand to predominate in size. Nor am I able to account for this difference in the somewhat contrasting positions of the two hands. Probably the asymmetry, although unusual, was natural.

LINCOLN AND THE POPULATION OF HIS TIME

Up to this point we have been examining these unique casts and comparing them one with the other, simply as isolated records. Because our first objective was to check one cast against another, the scale provided by the casts themselves was sufficient. Now, however, we want to see how Lincoln's physical dimensions rank in the population from which he arose. For this we need population figures to serve as a scale. Accordingly, at this point we will consider Lincoln's place in the American population of his time.

It is hard to realize that Lincoln was born 144 years ago—in 1809; it is harder still to realize that his was the first white generation born in Kentucky. In 1775, only about 35 years prior to Lincoln's birth, Daniel Boone had successfully opened up the Kentucky area. Then toward the end of the eighteenth century the Lincolns and the Hankses had followed their friends the Boones and others down the Shenandoah Valley, through the Cumberland gap in the Shenandoah Mountains, and up the Wilderness Road into the heart of Kentucky.

The people who participated in this movement were predominantly English and Scotch by national extraction. We know this, of course, not only from the history of American colonization but also from an analysis of their names. As a matter of fact, most of the schedules of names recorded in the First Census of 1790 are still in existence (Rossiter, 1909). From this source we learn that the names "Lincoln" (in all its various spellings) and "Hanks" are recorded for heads of

families 210 and 35 times, respectively; and that for all other members of families these names are recorded 987 and 177 times, respectively. There is every reason to believe, therefore, that our Lincoln was a product of the seventeenth-century Anglo-Saxon migration to the New World. The later descendants of this group have been called "Old Americans."

The physical characteristics of the Old Americans were first described in 1925 by my predecessor in the National Museum, the late Dr. Aleš Hrdlička. His sample was drawn partly from Virginia and Tennessee and includes both mountain and lowland people. More specifically he felt justified in including in this group—

> those Americans whose ancestors on each side of the family were born in the United States for at least two generations—in other words, all those whose parents as well as all four grandparents were born in this country. The third native generation of adults means roughly an ancestry on each side of the family of at least 80 to 150 years American. As a matter of fact the mean "nativity" of those examined was nearer the latter than the former figure and for the whole series it probably surpassed an average of 150 years, for there were many who on one or both sides exceeded the minimum requirement of three generations. In a large majority of cases the American ancestry of the one examined, while only three or four generations on one side, extended to from four to eight generations on the other; and there were fairly numerous instances where the ancestry was pure native on both sides for four generations, while occasionally it was five, six and in a few cases even seven generations (Hrdlička, 1925, pp. 4–5.)

Hrdlička's sample of Old Americans dates from the 1920's. Thus it comprises elements of at least the second and third generations after Lincoln's generation. Although there is good reason to believe that the American population at large has been changing in its average physical characteristics over the years, probably not much change has taken place in this particular group. On the other hand, Hrdlička's sample—less than 1,000 individuals—leaves much to be desired by way of adequate inclusion of all elements of this widespread population. This deficiency perhaps is reflected especially in the ranges of characters. In spite of this defect, Hrdlička's Old Americans is as near as we can get now to the population from which Lincoln arose. Therefore, we will rely upon his figures for our main comparisons.

Stature.—Lincoln gives his height as "6 feet 4 inches, nearly" (letter to J. W. Fell, Dec. 20, 1859; for facsimile see Oldroyd, 1883, p. 482). That he was well above average in height is evident from Brady's photographs of the President with his generals at the battlefield (Meserve and Sandburg, 1944). Also, there are personal recollections of "his great height towering head and shoulders above them all" (Rankin, 1916, p. 207).

Lincoln probably came by this great stature naturally, as the saying goes. His father was 5 feet 10 inches; his mother, 5 feet 7 inches

(Angle, 1949, pp. 12–14; Hertz, 1940, pp. 353–354). These figures (in inches) compare with the Old Americans as follows:

Thomas Lincoln	*Abraham Lincoln*	*Average for Old American males (737)*	*Nancy Lincoln*	*Average for Old American females (811)*
70	76	68. 6	67	63. 7
		Range		*Range*
		60. 5–76. 0		57. 3–69. 7

In addition we have the stature figures for 364 Civil War soldiers from the then Fourth Congressional District of Kentucky, which includes Larue County where Lincoln was born (Baxter, 1875). These soldiers, born about 30 years after Lincoln, averaged 68.2 inches and were among the tallest in the northern army. Unfortunately the range of their statures is not given. We are justified in concluding, however, that Lincoln's stature was at the upper end of the range of his fellow Old Americans.

Another interesting, but less direct, comparison is provided by the Old American members of the National Academy of Sciences (Hrdlička, 1940). The Academy was established by President Lincoln during the Civil War to advise the Government on scientific matters. Between the years 1926 and 1933, Hrdlička, himself a member of the Academy, measured 150 members, including 100 who met his requirements, quoted above, for Old Americans. These 100 scientists had a mean stature of 68.4 inches, with a range from 61.7 to 74.7 inches. Lincoln's height would not have been very conspicuous among the taller members of this select company!

Weight.—Lincoln's usual weight was around 180 pounds (Oldroyd, 1883, p. 482). Like most people of slender build, he did not get much heavier than his usual weight, although, as we have seen, he lost weight under stress. His father is described as having a "compact build" and is said to have weighed 195 pounds in the latter part of his life. His mother, from whom he seems to have inherited his slender build, weighed about 130 pounds at the age of 23 years when she married (Angle, 1949, pp. 12–14; Hertz, 1940, pp. 353–354). Here obviously our comparison is complicated by the fact that individuals may put on weight with age. However, of the three Lincolns probably only the father, Thomas Lincoln, was of a build subject to considerable weight change. Here again is how they compare (in pounds) with the Old Americans:

Thomas Lincoln	*Abraham Lincoln*	*Average for Old American males (838)*	*Nancy Lincoln*	*Average for Old American females (805)*
195	180	150. 3	130	127. 3
		Range		*Range*
		111. 0–219. 5		86. 0–206. 0
		Weight-height (gram-centimeter) index		
497. 5	453. 6	390. 8	346. 5	356. 8

By this comparison both Abraham and Thomas Lincoln were above average for their weight/stature. On the same basis Nancy Lincoln was below average in weight/stature. All were well within the ranges of their contemporaries.

Vault of head.—Because of uncertainties regarding Mills's casting of this part of the head, as already mentioned, I will point out merely that the figures for maximum length and breadth are possible, but extreme as compared with the Old Americans. Thus the figures for length and breadth, 210 and 170, compare with maximums for the group of 216 and 170, respectively. On the other hand, the cephalic index derived from the Lincoln head diameters, 81.0, is near the middle of the range for Old American males—69.7–90.9. The general shape thus represented may be fairly accurate.

Face.—Measurements taken on the Lincoln face masks have been given already. However, as explained in that connection, such measurements are larger than the corresponding ones taken in life on the same individual. So in order to compare our figures with Hrdlička's Old Americans, the former must be corrected.

There is no need here to go into detail about deriving the corrections. As it happens, the National Museum has a collection of face masks of individuals who were measured at or near the time the masks were made. By comparing the series of measurements made on the masks with those made in life, some average differences are obtained which constitute the corrections to be used here. In addition, I have used my judgment in selecting the most reliable figures from those taken on the Lincoln masks.

With this explanation I present a comparison of my estimated measurements of Lincoln's face (in mm.) with those of the Old Americans:

Diameter	Lincoln (corrected measurements from life mask)	Old Americans (at large)			Old Americans (National Academy)		
		Number	Average	Range	Number	Average	Range
Total face height (menton-crinion)	186	443	188.1	161–212	25	189.0	168–216
Lower face height (menton-nasion)	116	594	121.9	103–141	100	120.7	104–142
Height of forehead (nasion-crinion)	70	510	65.9	----------	25	65.7	----------
Face breadth (bizygomatic)	142	594	139.2	128–158	100	139.6	128–152
Nose height	55	247	53.5	43–63	100	55.0	45–64
Nose breadth	38	247	36.1	30–43	100	36.9	31–45
Mouth breadth	55	247	53.7	45–66	92	56.6	47–67
Ear height, left	78	247	67.0	55–81	92	70.2	61–84
Ear breadth, left	40	247	37.9	30–46	92	39.4	34–46

In viewing these figures the matter of age should be kept in mind. Lincoln was 56 at the time the second mask was made. The Academicians were older when measured; on the average, 59 years. But the Old Americans in general tended to be younger. The effect of age appears mainly in the dimensions of the mouth and ears, parts that are not supported by bone. The result is that these features usually get larger as age increases. However, age alone cannot be the cause of Lincoln's relatively long ears, or of his rather wide mouth.

Lincoln's face was large in other respects, but, as figure 1 demonstrates, always well within the range of the population with which

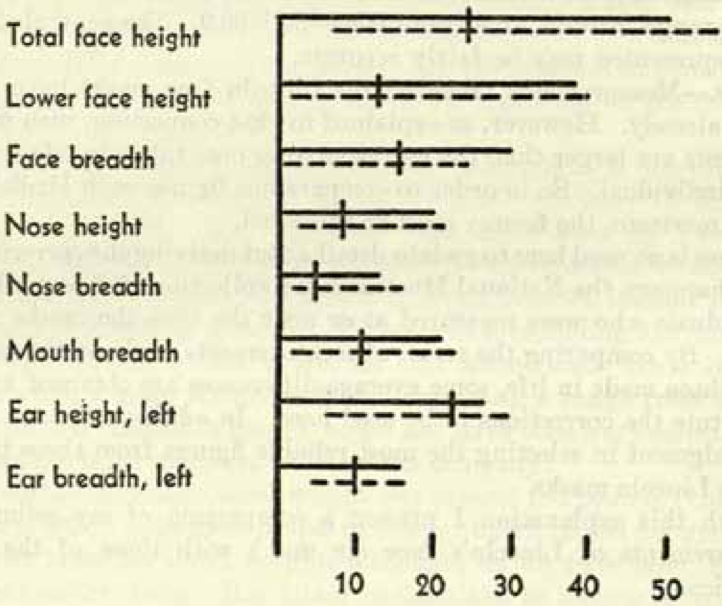

Figure 1.—Estimated position of Lincoln's face dimensions in the ranges of the Old Americans. Solid horizontal lines=Old Americans at large; interrupted lines=Old Americans in National Academy of Sciences.

he is identified. His large forehead height and face breadth across the cheekbones are especially noteworthy. Perhaps, though, these dimensions appear exaggerated because the face heights are slightly below average.

It is interesting to note also that whereas Lincoln's ear size is in the upper part of the range of the Old Americans, his nose size, and especially nose breadth, is in the lower part of this range.

One other point should be mentioned in this connection. Nose height, lower face height, and forehead height have one landmark in common—so-called "nasion" at the root of the nose. The location of this landmark depends upon trying to estimate the position of the nasofrontal suture in the underlying skull. When the observer lo-

cates nasion below its true position, he increases the height of the forehead and correspondingly decreases the height of the nose and lower face. Of course, the reverse is the case when the observer locates nasion above its true position. Obviously, these circumstances undermine the reliability of all measurements based on nasion.

Now the above figures suggest that, as compared to Hrdlička, I have placed nasion low. Whether this is so, or whether Lincoln did have a lower-than-average face height and nose height with a relatively high forehead, must remain in doubt. In spite of this and other points of uncertainty, it is remarkable how nearly modal in position Lincoln's face measurements turn out to be when plotted as in figure 1.

Hands.—The difficulty of comparing Lincoln's hands metrically has been explained. Although we cannot tell directly how big his hands were on the scale of the Old Americans, we can get some idea of their relative size by using another hand for intermediate comparisons. My own will serve as well as any other. I am a little under 6 feet in height and my hand falls well within the Old American range as the following figures (in mm.) show:

	Author's left hand	*Old Americans (left)*
Length	198	(247) 192.8 Range: 172–223
Breadth	90	(247) 91.8 Range: 77–110

When I hold my hands in the positions of the cast hands of Lincoln, the distance across the second to fifth knuckles is 89 mm. on both sides. This is only 5 or 6 mm. less than on the casts and probably would scarcely be noticed in visual comparisons. A comparable measure of Lincoln's finger length—that is, from nail edge to the apex of the metacarpophalangeal knuckle—gives him an advantage amounting perhaps to 20 mm., as shown in the following figures:

Digits	Lengths of Lincoln's fingers		Lengths of author's fingers	
	Right	Left	Right	Left
I	88	77?	72	78
II	133	137	116	115
III	143	148	129	129
IV	139	141	120	121
V	115	117	101	100

Although the apex of the knuckle is not an exact landmark for linear measurement, the general metrical difference brought out in this table can hardly be due to observational error. It seems quite likely, therefore, that Lincoln had a hand which, like the rest

of his body, was long and narrow. As compared with the Old Americans his hands must have been in the upper part of the range in length (perhaps 218–220 mm.) and close to the average in breadth (perhaps 95 mm.). This relationship is shown graphically in figure 2.

Feet.—Drawings and "measurements" of Lincoln's feet were made on December 13, 1864, by Dr. Peter Kahler, the surgeon-chiropodist who later developed a fashionable practice in New York City. The drawings look as if they had been traced from stockinged feet. The "measurements" are inscribed on the drawings without any indication of how they were determined. The figure "12" appears in the toe of the outline of the left foot and the figure "12¼" in the right. It has been assumed that these are maximum lengths in inches. If so, they

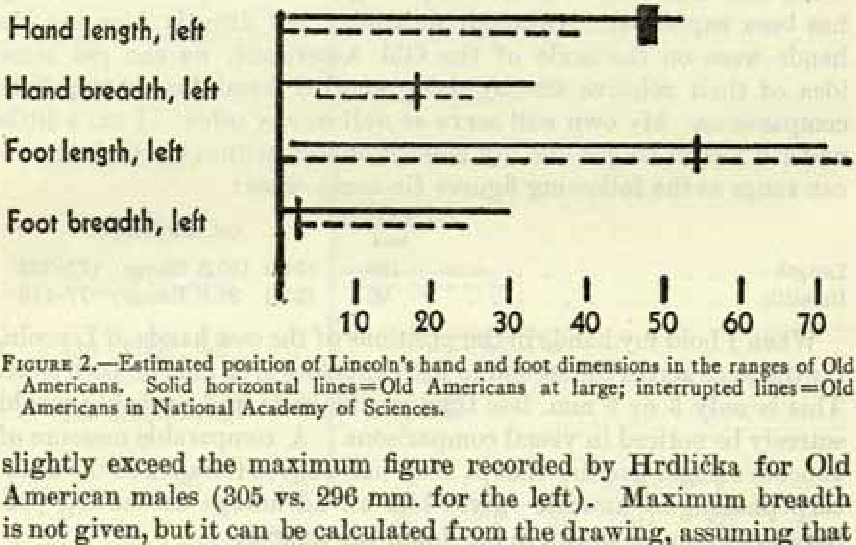

FIGURE 2.—Estimated position of Lincoln's hand and foot dimensions in the ranges of Old Americans. Solid horizontal lines = Old Americans at large; interrupted lines = Old Americans in National Academy of Sciences.

slightly exceed the maximum figure recorded by Hrdlička for Old American males (305 vs. 296 mm. for the left). Maximum breadth is not given, but it can be calculated from the drawing, assuming that for the left foot 12 inches, or 305 mm., is maximum length. In this way we arrive at a figure of 92 mm., which is well under the maximum (111 mm.) recorded by Hrdlička for the left foot in Old Americans. The foot index (breadth × 100/length) derived from these figures, 30.2, is slightly below the range (30.7–41.1) of Old American males. Although Lincoln's feet thus may have been relatively narrow, these comparisons leave room for doubt that his feet were absolutely as long as Dr. Kahler's figures indicate.[4]

[4] After this was written, I arranged to have the Lincoln boots, preserved in the Lincoln Museum, Washington, examined by an expert shoe fitter. This was made possible through the courtesy of Stanley W. McClure, assistant chief, National Memorial and Historic Sites, U. S. Department of the Interior. In the opinion of J. W. Rogers, buyer for Julius Garfinckel & Co. of Washington, the Lincoln boots are size 12B, according to the present sizing standard. This means that Lincoln's foot length was little if any more than 11 inches. Mr. Rogers is of the opinion also that the numbers on the Kahler diagrams refer to external shoe dimensions. This seems to be borne out by the dimensions of this particular pair of shoes. I can report also that the beaded moccasins, which the Chicago Historical

CONCLUSIONS

The picture that emerges from these anthropological comparisons is the well-known one of Lincoln: a man of tall and slender build. But we see a little more clearly that only in the linear dimensions was he unusual. He may have been long-bodied, long-armed, and long-limbed, but he was not otherwise an overly big man. Even his well-remembered handshake was not so much the result of his "great hands" as of his long hands. This bears out William Herndon's description of Lincoln's physique (Hertz, 1940, p. 413):

> In sitting down on a common chair or bench or ground, he was from the top of his head down to his seat no better than the average man; his legs and arms were, as compared with the average man, abnormally, unnaturally long, though when compared to his own organism, the whole physical man, these organs may have been in harmony with the man. His arms and hands, feet and legs, seemed to me, as compared with the average man, in undue proportion to the balance of his body. It was only when Lincoln rose on his feet that he loomed up above the mass of men. He looked the giant then.

A stature of 6 feet 4 inches is not generally thought of in the United States as extraordinary; yet statistically it is fairly uncommon, for it is to be found in only a small fraction of 1 percent of the male population. To Lincoln, the politician, this meant that he would be conspicuous in any ordinary assembly. During the Lincoln-Douglas debates, for example, an audience might not have recognized Douglas immediately, but they could not miss Lincoln—or forget his height and build. From this remembrance of linear bigness it was easy to slip into exaggerations of other body proportions, especially if one had come under the spell of Lincoln's personality and mind.

The precious replicas of Lincoln's face provided by Volk and Mills, and preserved in the Nation's Capital for all to see, are the most reliable of all such reproductions so far as now known. Unquestionably they provide sure evidence that from the physical standpoint Lincoln was a fairly typical member of the American pioneer stock.

The meaning of other details of these masks, as, for instance, the skin folds and facial asymmetries, may be read with less certainty and even with more or less conscious bias. In this connection atten-

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Society obtained recently at the sale of the Barrett-Lincoln collection, have been measured for me by Dr. Paul M. Angle, secretary and director. By inserting wooden strips cut to different lengths, Dr. Angle decided that 11 inches was the length of foot most likely to have been comfortably accommodated in the left moccasin. (Personal communication dated November 13, 1952.)

Substituting the figure 11 (or 279 mm.) in the calculations outlined above, we get a foot breadth of 84 mm. and a foot index of 30.1 for Lincoln's left foot. This foot breadth, as shown in figure 2, is just above the minimum (82) for Hrdlička's Old Americans.

Dr. Louis A. Warren, director of the Lincoln National Life Foundation, Fort Wayne, Ind., has called my attention to newspaper clippings in the collection of the Foundation showing rather different outlines (claimed to be originals) of Lincoln's feet. This suggests that the outline published by Kahler may be a somewhat smoothed-out version of the original tracing.

tion is called to a recent (1952) study of the Volk mask by Dr. Edward J. Kempf in which the following statement appears (p. 4): "There is an unusual depression in the forehead of the mask, with a palpable edge, near the midline above the left eye. This deformation indicates the place of fracture of [Lincoln's] skull." On this subjective and hence shaky premise is then erected an elaborate neuropsychiatric edifice in explanation of Lincoln's appearance, habits, and character. We are not told how far removed from the original mold was the particular mask which was examined, or why irregularities in the skin surface can only represent a fracture of the underlying bone. For my part I am unable to detect anything in the copies of the Volk and Mills masks in the National Museum that I would interpret as evidence of fracture.

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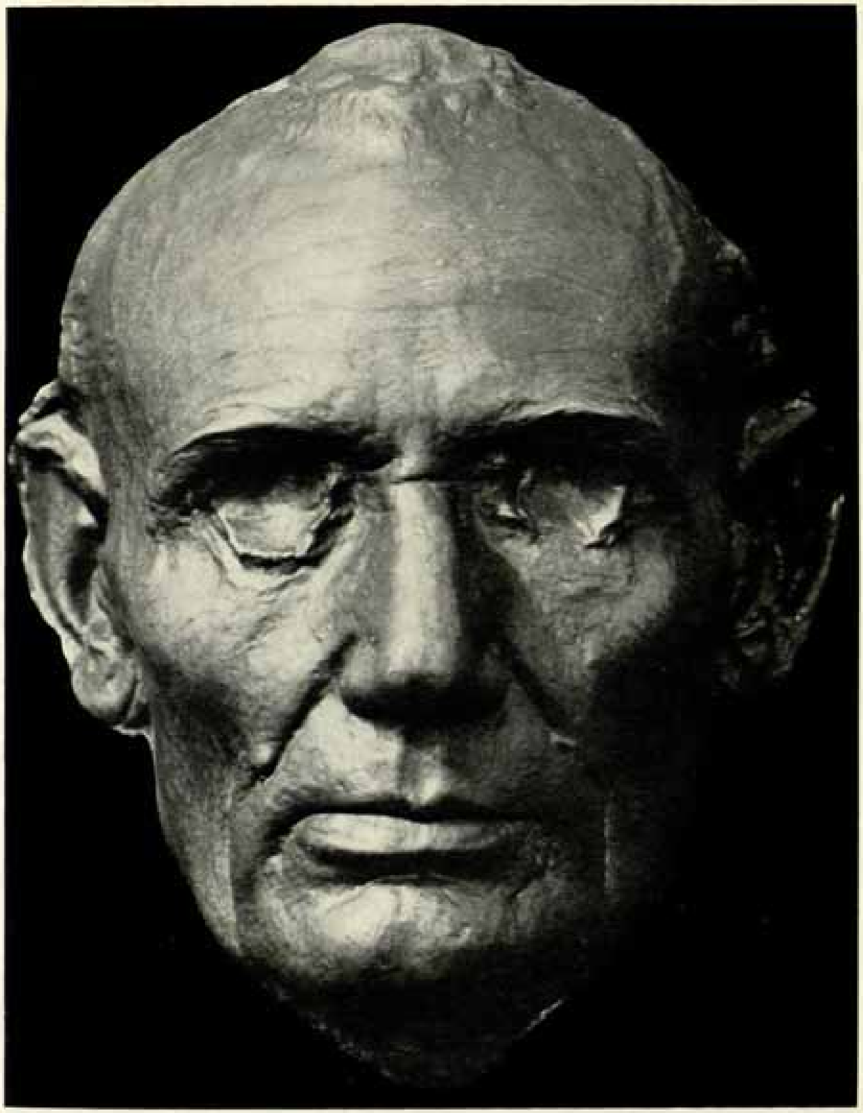


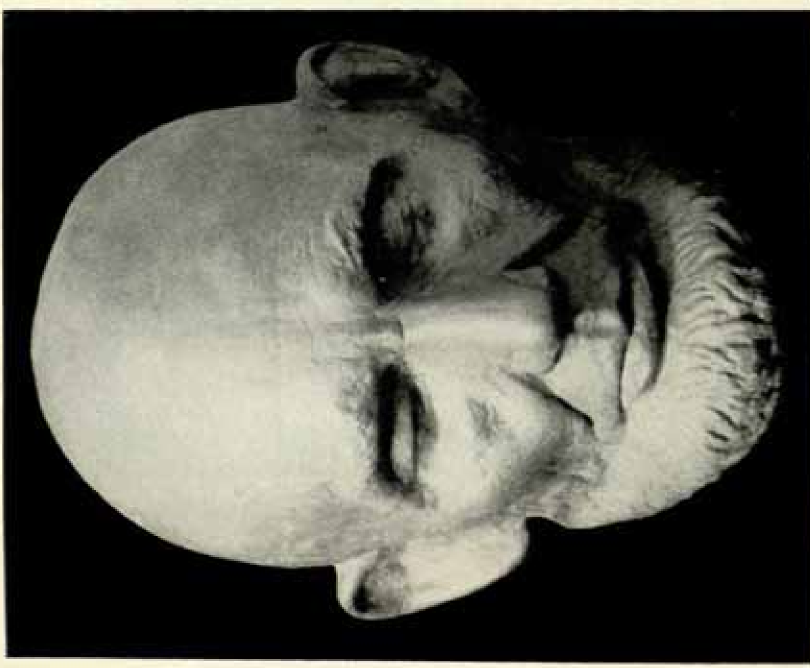
FULL-FACE VIEW OF THE NATIONAL MUSEUM'S BRONZE COPY OF THE VOLK LIFE MASK OF LINCOLN

This version was made by Volk in 1886 from the original plaster copy. Note the artifact in the left nasolabial fold. Photograph (copyrighted) reproduced through the courtesy of Lloyd C. Henbest.

LEFT PROFILE VIEW OF THE SAME BRONZE MASK AS SHOWN IN PLATE 1
Photograph (copyrighted) reproduced through the courtesy of Lloyd G. Henbest

THE NATIONAL MUSEUM'S BRONZE COPIES OF VOLK'S CASTS OF LINCOLN'S HANDS

These versions were made by Volk in 1886 from the original plaster copies. Photograph (copyrighted) reproduced through the courtesy of Lloyd G. Henbest.



FULL-FACE AND PROFILE VIEWS OF THE NATIONAL MUSEUM'S PLASTER COPIES OF THE MILLS LIFE MASK OF LINCOLN

This version was donated by Mills's son in 1889. Photographs (copyrighted) reproduced through the courtesy of Lloyd G. Henbest.

The Use of Music in the Treatment of the Sick by American Indians[1]

By Frances Densmore
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[With 4 plates]

Two methods of treating the sick were used by the American Indians in early days and are continued to some extent at the present time. One method involves the private ministrations of a doctor or medicine man and the other a public ceremony, conducted by a number of doctors, attended by many people, and often continued for several days. Music is an important phase of each method and consists of singing by the doctor or his assitants and the shaking of a rattle or beating of a drum. The songs used in these treatments are said to come from supernatural sources in "dreams" or visions, and with them come directions for procedure and a knowledge of the herbs to be used.

Both methods were seen and described by the White men who first went among the Indians, but a study of the songs was made possible only by the recording phonograph, which came into use about 1890. The study of recordings of Indian songs may be compared to the work of a chemist in his laboratory. By this means the structure of the melody can be determined and the song transcribed as nearly as possible in musical notation.

Another factor contributing to our understanding of Indian medical practice is the development of educated interpreters with a knowledge of both English and Indian idioms. The missionaries were the first teachers of the Indians, and among the first English words learned by Indians were those connected with the religious teaching of the period. Such words were applied to many Indian customs that the White men did not understand, and the terms "superstition" and "witchcraft," as well as words of highest spiritual import, were attached to Indian customs. These terms became permanent and, to a

[1] Reprinted by permission from "Music and Medicine," Henry Schuman, New York.

large extent, have influenced the White man's opinion of the Indian. Similiarly the terms "music" and "singing" were applied to Indian performances. These did not please the White man, and there is still a reluctance to regard music as an important phase of Indian culture worthy of our consideration.

Early ethnologists attended the healing ceremonies of the Indians but did not write of individual treatment by the Indian doctors. The first ethnologist we shall quote is the Rev. Clay MacCauley,[2] who went among the Seminoles in the winter of 1880–81. He attended the annual Green Corn Dance and heard a "medicine song" which was sung as a certain medicine was drunk; the belief was that unless one drank of it he would be sick at some time in the year. MacCauley's Seminole informant refused to sing the song for him after the feast, saying that he would "certainly meet with some harm" if he did so. This refusal shows an early connection between music and health. MacCauley stated clearly that he did not know what part incantation or sorcery played in the healing of the sick. One of the most important papers by early ethnologists is "The Mountain Chant: a Navajo Ceremony,"[3] by Dr. Washington Matthews. The author selected the mountain chant from among other Navajo ceremonies because he witnessed it the most frequently. Like other great rites of the Navajo, it was of 9 days' duration. The shaman, or medicine man, who was master of ceremonies, was known as the chanter, and the ceremony was "ostensibly to cure the sick." The myth concerning the origin of the mountain chant (Dsilyídje Qaçàl) relates that "many years ago . . . the Navajo had a healing dance in the dark corral; but it was imperfect, with few songs and no kethawns or sacrificial sticks." Dr. Matthews describes a ceremony that he attended on October 1, 1884, at a place on the Navajo Reservation about 20 miles northwest of Fort Wingate, N. Mex., and he presents descriptions and illustrations of the four wonderful pictures on sand (drypaintings) that were used on that occasion. The patient was a middle-aged woman and the treatment included "prayer, song and rattling." No information concerning the songs or the form of the rattle is presented.

A remarkable study of the individual treatment of the sick, in contrast to the ceremonial, was made by James Mooney,[4] who collected in 1887 and 1888 about 600 sacred formulas of the Cherokees. The original manuscripts were transferred to the Bureau of American Ethnology. These manuscripts "were written by the shamans of the tribe, for their own use, in the Cherokee characters invented by Skiwâ'ya

[2] MacCauley, C., The Seminole Indians of Florida, 5th Ann. Rep. Bur. Amer. Ethnol. (1883–84), pp. 469–531, 1888.

[3] 5th Ann. Rep. Bur. Amer. Ethnol. (1883–84), pp. 379–467, 1888.

[4] Mooney, J., The sacred formulas of the Cherokees, 7th Ann. Rep. Bur. Amer. Ethnol. (1885–86), pp. 301–397, 1892.

(Sequoyah) in 1821. Some of these manuscripts are known to be at least thirty years old, and many are probably older." Eleven of the formulas are for the treatment of the sick, and the use of songs is mentioned in connection with the treatment of snake bite, "the great chill" (intermittent fever), and an ailment which "from the vague description of symptoms . . . appears to be an aggravated form of biliousness." The formula for the treatment of chill "begins with a song of four verses, in which the doctor invokes in succession the spirits of the air, of the mountain, of the forest, and of the water." In a serious case the doctor follows the song with a prayer to the whirlwind "which is considered to dwell among the trees on the mountain side, where the trembling of the leaves gives the first intimation of its presence." The doctor directs the whirlwind "to scatter the disease as it scatters the leaves of the forest, so that it shall utterly disappear."

Mooney found that "like most primitive people the Cherokees believe that disease and death are not natural, but are due to the evil influence of animal spirits, ghosts or witches." He quotes Haywood,[5] who stated that "in ancient times the Cherokees had no conception of anyone dying a natural death," and presents a Cherokee myth concerning the origin of both disease and medicine. According to this myth, the animals and all living creatures were happy together until man came and began killing them for food and clothing. They then held a council for their safety and protection. The decision was that each group of animals should inflict a disease upon man. The deer resolved to inflict rheumatism upon every hunter who killed one of their number without asking pardon for the offense. They sent notice of this resolution to the nearest settlement of Indians and told them how to avoid giving offense when necessity forced them to kill one of the deer tribe. The plants were friendly to man and determined to defeat the evil design of the animals. "Each tree, shrub, and herb, down even to the grasses and mosses, agreed to furnish a remedy for some one of the diseases . . . When the doctor is in doubt what treatment to apply for the relief of a patient, the spirit of the plant suggests to him the proper remedy."

To such beliefs the student finds parallels in recent times in widely separated tribes and in customs that the Indians follow without giving any reason for their observance. The Papago in southern Arizona told the writer of their belief that every disease is caused by an animal or spirit which imparts the secret of its cure to a favored doctor. A song is taught to him as an essential part of the treatment. Among the Algonkins it is still customary for a doctor to put tobacco in the ground when he digs a medicinal herb and to "talk a little," asking the herb to help the sick person. In the old days a hunter apologized

[5] Haywood, John, Natural and aboriginal history of Tennessee, pp. 267–268, 1823.

to an animal before killing it, saying its flesh was needed for food. The belief in a nature that was friendly to man has always been strong. The Indians did not have the White man's idea of "conquering nature." Many offerings have been construed by White men as propitiation when, to the Indians, they were simply gifts to a friend. An exchange of gifts is a common custom, and the Indians acknowledged thus the bounty of nature. Careful interpreters have explained to the writer that the native term did not suggest anger on the part of the spirit to whom the gift was offered. This harmony between man and nature may seem apart from our subject, but it is important to an understanding of Indian therapy. It was the desire of the Indian doctor to restore what he believed to be a natural condition of health, strength, and long life, such as he saw in the natural world. The Indians believed in the existence of evil spirits but also believed that the medicine men had power over them. The laity did not attempt to deal with evil spirits.

Both the individual and ceremonial methods of treating the sick were studied among the Chippewa (Ojibwa) of Minnesota by Dr. W. J. Hoffman.[6] Singing and the shaking of a rattle or beating of a drum were essential parts of both methods of treatment. The sick man was first treated in his home. A member of the Midewiwin would give him a medicinal broth, singing and shaking his rattle as the patient drank. The songs of the Midewiwin are represented by mnemonics, or song pictures; 150 of these were collected by Hoffman with translations of the words, and 18 were transcribed in musical notation. Typical of the words are "The spirit saw me and gave me medicine from above" and "It is also on the trees, that from which I take life." If this first treatment was not successful, the sick man would be carried to the lodge of the Midewiwin and treated by a number of its members in a ceremonial manner. If his condition became hopeless, the singing was generally continued until life was extinct. Since health and long life, as well as a right mode of living, were among the teachings of the Midewiwin, this extensive use of music is important to our subject.

The writer began her study of the Midewiwin and its songs in 1907 by attending a ceremony at Onigum on Leech Lake, Minn. This ceremony was conducted for Flat Mouth, the last hereditary chief of the Pillager band of Chippewa, who was very ill. His condition had been pronounced hopeless by the government physician, and he had asked that the native treatment be permitted. The request was granted. Eight members of the Midewiwin were summoned and sang in Flat Mouth's wigwam for several days and nights. As he

[6] Hoffman, W. J., The Midē'wiwin or "Grand Medicine Society" of the Ojibwa, 7th Ann. Rep. Bur. Amer. Ethnol. (1885–86), pp. 143–300, 1892.

showed no improvement, a ceremony of the Midewiwin was instituted. Flat Mouth was carried outdoors and placed in the center of an enclosure formed of low branches of trees. There the doctors of the Midewiwin moved around him, singing their songs and ministering to him. The writer stood outside the enclosure listening to the songs for many hours. As the end approached, Flat Mouth was carried into his wigwam, and in a short time the firing of a gun announced the passing of his spirit.

FIGURE 1.—Chippewa healing song, recorded by Ge′ miwûnac′.

Words

Kimanidó′ wihé′	You are a spirit.
Kimanidó′ wiīn′	I am making you a spirit.
Ĕndá′ nabiyan′	In the place where I sit.
Kimanidó′ wiīn′	I am making you a spirit.

A few weeks later the writer returned to Leech Lake with a phonograph to begin her work of recording Indian songs for the Bureau of American Ethnology. There she met Ge′ miwûnac′ (bird that flies through the rain), the aged member of the Midewiwin who had charge of the ceremony for Flat Mouth. She asked whether he would record some of the songs heard at that time. He replied that he was so over-

come during the last hours of Flat Mouth's life that he could not recall exactly what songs were sung, but he did record a song that he generally sang under such circumstances (fig. 1).

The writer's study of the Midewiwin and the treatment of the sick was continued at White Earth, Minn., where Hoffman had witnessed a ceremony of the society in 1889. Certain Chippewa remembered him and aided the later work which continued to some extent his earlier research on the subject (Cf. p. 454.)

A certain class of Chippewa doctors are not of necessity members of the Midewiwin. They claim to summon spirits and commune with them. Such men do not administer remedies but rather impress their patients by exhibitions of various sorts intended to show their magic power. They are commonly called jugglers and are here designated as medicine men. The Jesuit Fathers met them early in the seventeenth century and called them "magiciens et consulteurs du manitou" (spirits). In their demonstrations they are tightly bound and placed in a small conical tipi. They sing, the structure sways as though in a tempest, and strange sounds are heard; these sounds are said to be the voices of spirits communing with the medicine man. Nor has this custom entirely passed away. The writer witnessed it in 1930 at Grand Portage, an isolated Chippewa village on the north shore of Lake Superior, where for about two hours in the quiet of a summer evening the little tipi swayed as though a mighty wind were blowing. The next day the medicine man said that he had summoned the spirits to learn whether they would help him cure a certain sick man. Without that assurance he was unwilling to take the case. He added that the spirits "spoke loud and clear" so he was sure his treatment would be successful. A day or two later a "beneficial dance" was held under his direction for the man, whose illness had been diagnosed by a physician and a nurse as "apparently typhoid fever." They told the man to keep quiet and remain in bed. The dance was held in an enclosure at his door, and a generous feast was cooked and served. The writer attended the dance and listened to the songs, and about two weeks afterward she was informed that the man had recovered.

At Santo Domingo Pueblo, N. Mex., as among the Chippewa, the private treatment of the sick may be followed by treatment in a public ceremony. The healing customs of this pueblo were described and 10 of its healing songs recorded in Los Angeles by a man from the pueblo. He said, "If the doctors who give herb remedies fail to help a patient, the medicine men of the Flint society may be summoned." This is a medicine society which goes into retreat before a communal rabbit hunt and follows the retreat with a ceremony much like that used to bring rain or secure good crops. The members of the society, usually

15 or 16 in number, go to the house of the sick man, arriving early in the evening. They shake their black gourd rattles and sing until about midnight, with pauses for relaxation and smoking at intervals of about eight songs. If the patient is a woman they may question her and ask her friends what she has done to bring on the sickness. Then they consult among themselves as to her condition and chances of recovery. There is much ceremonial procedure, including the making and effacing of a meal-painting ("altar") on which certain ceremonial articles are placed. The medicine men "call on the birds and animals," whose voices are distinctly heard. They look in a crystal ball and make use of a special song with these words:

I am fighting to cure you.
I will suck out what is hurting you, to cure you.
The things I shall take out are the things that are causing your sickness.
Now I shall take Mother-bear and put her under my arm
As I get ready to look in the crystal, and I will help you.
Help us all.
Thank you.

"Mother-bear" refers to the "bear-paws" or "mittens" which the medicine man puts over his hands. They consist of the skin of the forelegs of the bear, with the paws. It is said that the people "never deny what a medicine man says he sees in the crystal."

We have dwelt somewhat at length of the circumstances under which the Indians sing their healing songs. Let us now consider the men and women who sing them and the characteristics of the songs.

I have known the Indian doctors in many tribes, from British Columbia to Florida, and the acquaintance in some instances has continued for several years. Without exception they were quiet, conservative men and women, constituting a definite type and respected in their several tribes. They prepare themselves for their calling by a fast in which they receive their "dream" or vision, and they live strictly in accordance with the requirements of that dream. They do not take part in social affairs, but they are not antagonistic toward them. Doctors do not expect to be understood, nor do they seek companionship. A doctor's wife is usually his principal helper. Through this isolation comes a deepened sense of companionship with all living creatures and an awareness of nature in all its manifestations.

Three women who were engaged in the practice of medicine told me of their work. These were Owl Woman, the Papago (cf. p. 450), Susie Tiger (a Seminole of the northern or Cow Creek group living in the cabbage-palm country), and Mrs. Washington, of the Northern Ute. Susie Tiger recorded five songs which she was using in her treatment of the sick. These included songs for lumbago, for a sick baby, for bringing a child into the world, a song addressed to the

"white sun-lady," and a song addressed to the dying in which she besought the spirit to turn back before reaching nine different places in the journey. Mrs. Washington gave no material remedies, for she claimed to have supernatural power. Her specialty was the treatment of illnesses caused by an evil influence proceeding from some person. She recorded six of her songs and said that she usually sang them when the sun was at a height corresponding to its position at about 10 o'clock on a summer morning.

Indian doctors were primitive psychologists. They studied their patients and did not always consider it necessary to give medicine. In Santo Domingo Pueblo it was believed that personal jealousy might cause illness, and in a certain northern tribe the patient was sometimes told to "get up a dance and have a big time" and he would be well again. There has been also a distinct feeling that such treatment deserved a fee. Natawika, a Menominee doctor, said, "The medicine will not work unless they pay for it." She had no fixed fee but required the patient to give what he was able—perhaps a little tobacco, a handkerchief, or about four yards of calico. Natawika died in 1918 and this information was supplied by her daughter. Eagle Shield, a Sioux doctor, described a case for which he received a large fee consisting of $100, a new white tent, a revolver, and a steer.

It has been said that primitive treatment of the sick is characterized by affirmation. I have found this practice less frequently in the words of the songs than in the doctor's speech before beginning the treatment. At that time he often tells the source of his power and sometimes relates his former successes. The source of his power is generally a bird or animal known to have great strength, or something in nature that is connected with vibration, such as the wind or the "great water" when it is seething and in motion, or a mountain shaken with mysterious "spirit power." An example of affirmation occurs in a ceremonial song of the Chippewa Midewiwin containing these words:

> You will recover, you will walk again.
> It is I who say it. My power is great.
> Through our white shell (emblem of the Midewiwin)
> I will enable you to walk again.

There are differences of custom between tribes and between individual doctors, but the prevailing characteristic of Indian healing songs is irregularity of accent. Sometimes this takes the form of unexpected interruptions of a steady rhythm and sometimes there is a peculiar rhythmic pattern throughout the melody. It is my custom to transcribe the phonograph records of Indian songs in musical notation, using ordinary indications. Thus the transcriptions contain frequent changes of measure lengths. Indians never "sing with ex-

pression"; the singing of an Indian doctor is entirely monotonous. By this manner of presentation the rhythm is impressed on the mind of the patient. The rhythmic pattern holds his attention and, in some instances, may be somewhat hypnotic in effect. Certain healing songs are sung many times, while others are sung a definite number of times, usually three, four, or five. Some doctors have songs for beginning and ending a treatment, and others have special songs for each of the four divisions of the night. Such details of procedure are in accordance with the instructions received by the doctor in his dream.

Songs used for treatment of the sick have been recorded by the writer in the following tribes and in British Columbia: Cheyenne, Chippewa, Makah and Clayoquot (at Neah Bay, Wash.), Menominee, Papago, Seminole, Sioux, Northern Ute, Winnebago, and Yuma. Healing songs were also recorded by Tule Indians from Panama and by Indians from Acoma and Santo Domingo Pueblos.[7] Except for a few British Columbian and Tule songs, the recordings were made by doctors who were using the songs in their treatment of the sick. Many songs of the Chippewa Midewiwin are connected with ceremonies believed to benefit or cure the sick but are not songs of individual doctors, related to the treatment of specific diseases, accidents, or physical conditions. They are accordingly omitted in the following analysis, which is limited to songs used definitely in treating the sick. The total number of such songs recorded and transcribed in musical notation is 197; many others have been studied and were found to be similar in structure.

Mention has been made of a change of accent, or irregular rhythm, in many Indian songs for the sick. A tabulation of these 197 songs, from 14 localities, shows that such a change occurs in 173, or about 88 percent of the number. In a similar analysis of 1,510 songs of all classes, from many tribes, only 83 percent contain a change of accent. In many Indian performances there is a difference in the

[7] The writer's study of music in the following tribes did not include songs for the sick: Arapaho, Alabama, Choctaw, Cocopa, Hidatsa, Maidu, Mandan, Omaha, Yaqui, and Zuni and Cochiti Pueblos. Nor were songs of this class included in recordings of Indian songs secured at Anvik, Alaska, by Dr. Aleš Hrdlička and transmitted to the Bureau of American Ethnology. Iroquois ceremonial songs were recorded by J. N. B. Hewitt. The study of Cheyenne, Arapaho, and Maidu music and that of Santo Domingo Pueblo was under the auspices of the Southwest Museum of Los Angeles, Calif. A portion of the records made for the Southwest Museum were presented to the Bureau of American Ethnology after being transcribed. The remainder, and also the records made for the State Historical Society of North Dakota, were retained by the sponsors of the undertakings after the records had been transcribed and copies made for the Bureau. The writer's recordings, comprising more than 2,500 songs, constitute the Smithsonian-Densmore collection of Indian song recordings. They were transferred to the National Archives in 1940, where they were cataloged and where she wrote a handbook of the collection. In 1948 they were transferred to the Library of Congress, and she has selected songs that are now being issued in a series of 10 long-playing records, each accompanied by a descriptive pamphlet. These are available to the public.

metric unit, or tempo, of the voice and accompanying instrument, but this does not characterize the songs for the sick. Only 34 of these songs were recorded with accompaniment, but the metric unit of voice and accompaniment was the same in 24, constituting about 70 percent of the number. The accompaniment was faster than the voice in six and slower in four songs. A small drum was substituted for the usual rattle when recording these songs. As one purpose of Indian healing songs is to quiet the patient, a tabulation was made also of the tempo of the 197 recorded songs. This shows that 59 songs were sung slowly (♩=40 to ♩=104) constituting 30 percent of the number. In a previous tabulation of 710 songs of all classes in three tribes, the largest groups have a more rapid tempo (♩=76 to ♩=104). The latter may be considered the general tempo of Indian songs, though many are much more rapid.

The foregoing analysis shows that the characteristics of recorded Indian songs for the sick are irregularity of rhythm in the melody, a slow tempo, and a coincidence of voice and accompaniment. As the songs under consideration are typical, it is believed that the results would be the same if the analysis included a larger number of such songs.

The ownership of a song, as indicated, was with the man or woman who received it in a dream. Others might know the song and be asked by the owner to sing with him in order to add their power to his in a case of serious illness, but they could not use such songs with authority unless granted that privilege by the original owner. He did not relinquish his own use of the song by this action. Among the Menominee and in some other tribes there was a rule that a man seeking to buy a song and its manner of use must make the request four times, on consecutive nights, and that each request must be accompanied by a gift. The owner would then teach the song, explain its use, and show a specimen of the herb to be employed with it. He did not transfer the plant; this the inquirer had to identify from memory and find for himself.

Two types of Cheyenne doctors in Oklahoma have recorded their songs for healing the sick. These are Bob-tailed Wolf, who received his songs and power direct from supernatural sources, and Turtle, who obtained most of his songs from an older doctor, and received only one song himself. That song was taught to him by a spirit buffalo.

Bob-tailed Wolf treats all forms of illness. Power has come to him in many dreams, but the first manifestation was connected with an experience in a thunderstorm. He was traveling on horseback when the storm arose. A bolt of lightning knocked him unconscious and killed his horse. On the fourth night after this occurrence he

had a dream in which he was told how to treat the sick. The day was clear when he recorded that song for the writer, but within an hour the rain was falling heavily. He said this always happened when he sang this song. The word "grandfather" occurring in the song refers to the thunderbird. The song may be translated:

My grandfather has come to see me and taken pity on me and given me this power.

Another song recorded by Bob-tailed Wolf refers to the sun as "my grandfather." With his songs he uses a rattle made of stiff rawhide; a face is painted on one side, the handle is wrapped with deerskin, and formerly a buffalo tail was attached to it. Bob-tailed Wolf is a prominent member of the Peyote organization (Native American Chuch) and was photographed in his costume as a leader in its ceremony.

It is interesting to learn that a man holding such a high position and allied to such sources of supernatural power is also a man who "understands what babies say" and treats their small ailments. Bob-tailed Wolf says that when he is treating sick babies they tell him where they feel bad. He received his power with them in the following manner: One day he came upon a covey of little plovers hardly old enough to walk. He was about to take them away when the mother came and said, "Indian, don't take them; I love them and they are so pretty. If you will spare them I will give you power to treat sick babies." He accordingly refrained from taking the tiny birds and their mother told him to use water in treating sick babies, instructing him to apply it to their bodies and to use it without herbs. What appear to be words in his song for the babies are not real words and cannot be translated. He uses the rattle described above.

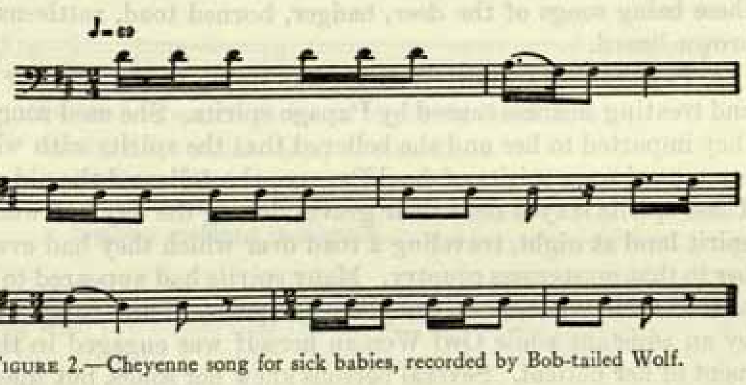


FIGURE 2.—Cheyenne song for sick babies, recorded by Bob-tailed Wolf.

Turtle, the other Cheyenne doctor, learned his songs from Dragging Otter, who had received them from an older doctor. His personal song, received from a buffalo, is sung "when the spirit of a sick

person is in danger of departing." He says that when he sings this song, "a young buffalo stands in the way and tries to keep the spirit from going away." After recording the song he made a sound of violent blowing in imitation of the buffalo; he always does this after singing the song for a sick person.

The Omaha treatment of a boy wounded by a pistol shot was witnessed by Francis La Flesche in his own boyhood.[8] The "buffalo doctors" were summoned, and four leading doctors in succession sang their personal songs and administered their personal remedies. About 20 doctors, including 2 women, then joined in the songs. The treatment continued over a period of 4 days and was followed by a ceremony of recovery and the distribution of many gifts. It is said that the boy recovered in about a month. Two of the songs used on this occasion were published by La Flesche in musical notation.

Mention has been made of the Indian belief that spirit-animals cause various illnesses. This belief was found in a particularly interesting form among the Papago of southern Arizona, who included among causes of sickness the spirits of dead Papago and of Apache slain in war. About 50 healing songs were recorded in this tribe. The bird, animal, or spirit which causes a disease is thought to impart songs and instruction for its cure to a certain doctor. It is the duty of a sia′ticum, or diagnostician, to decide the cause of the illness and refer the patient to the proper doctor. Songs are so closely connected with the illness that the diagnostician may say to a man with sore eyes, "Your trouble is caused by the quail. You had better go to So-and-so who knows the quail songs." If the patient does not improve, the diagnostician is held responsible and sends the sick man to another doctor. Sixteen diseases and ailments attributed to birds and animals were described, and songs used in the treatment of five were recorded, these being songs of the deer, badger, horned toad, rattlesnake, and brown lizard.

A Papago doctor, Owl Woman, was living at San Xavier in 1921 and treating sickness caused by Papago spirits. She used songs which they imparted to her and she believed that the spirits with whom she communed were spirits of dead Papago who followed the old customs. These spirits stayed near their graves during the day but went to the spirit land at night, traveling a road over which they had even taken her to that mysterious country. Many spirits had appeared to her, described their experiences, and given her songs. These songs were sung by an assistant while Owl Woman herself was engaged in the treatment of her patient. Several persons knew her songs, but she depended on Sivariano Garcia, also a doctor, who lived near her and could

[8] Fletcher, Alice C., and La Flesche, Francis, The Omaha tribe, 27th Ann. Rep. Bur. Amer. Ethnol., pp. 17-672, 1911.

be summoned at any time. For an entire day Owl Woman directed him in recording her songs for the writer.

Owl Woman always began a treatment with two songs given her by the spirit of a man who was killed near Tucson. As in many of her songs, the words are highly poetic. The first song ran:

> Brown owls come here in the blue evening.
> They are hooting about,
> They are shaking their wings and hooting.

and the second:

> How shall I begin my song in the blue night that
> is settling?
> I will sit here and begin my song.

After four songs had been sung she treated the sick man by stroking his body with a bunch of owl feathers on which she sprinkled ashes from his fire. The night was divided into four parts, each with its own songs.

Jose Panco, a Papago doctor, has treated the sick for 12 years, each year represented by a notch in the handle of the gourd rattle with

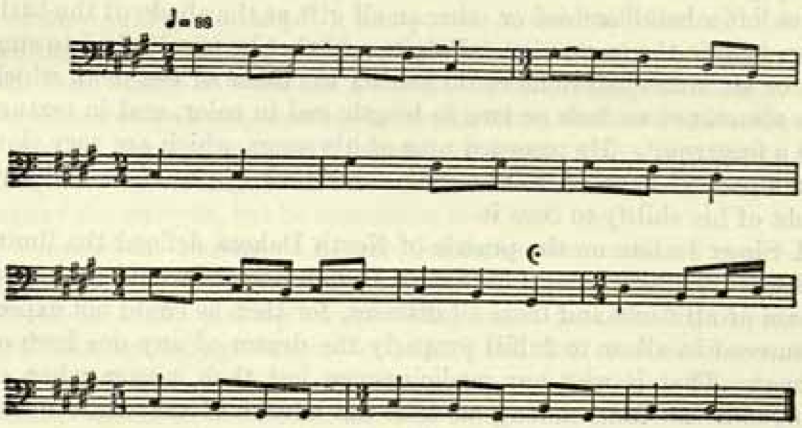


FIGURE 3.—Papago healing song, recorded by Jose Panco.

> Sandy Loam Fields, on top of these Elder
> Brother (Montezuma) stands and sings.
> Over our heads the clouds are seen, downy white
> feathers gathered in a bunch.

which he accompanies the songs. Panco recorded several songs, among them a song with two verses that he received from his grandfather. A deer gave this song to a hunter from Sandy Loam Fields, a native village. It is a gentle, pleasing melody and an excellent example of irregular rhythm.

Not far from the Papago Reservation, to the west, is the reservation of the Yuma and Cocopa. Charles Wilson, the leading Yuma doctor,

recorded four songs that he used in treating men suffering from gunshot wounds in the chest. Each song has a special purpose. With the singing of the first song he expects the patient to regain consciousness. With the second he calls upon a small insect that lives in the water and is believed to have power over the fluids of the body; the purpose is to check the hemorrhage. The third mentions a lively insect, and with this song Wilson expects the patient to regain the power of motion. The fourth mentions a certain kind of buzzard that has white bars on its wings and flies so high that it cannot be seen by man. Wilson said, "Each of these insects does his best, but it is the buzzard whose great power gives the final impetus and cures the sick man."

A unique explanation of the cause and cure of sickness was given by Pa′gits, a doctor of the Northern Ute tribe, living on the high plateau at the base of the Uinta Mountains. He claimed to receive his power from "a little green man who lives in the mountains and shoots arrows into those who speak unkindly of him." Pa′gits said, "He tells me when he has shot an arrow. Then the man sends for me and pays me to get it out." In return for this cooperation he sometimes left a handkerchief or other small gift at the abode of the little green man in the mountains. Pa′gits said that he usually had to sing five or six times before he could extract the cause of the pain, which was sometimes an inch or two in length, red in color, and in texture like a fingernail. He recorded nine of his songs, which are very slow in tempo and have no words. He never took a case if he had any doubt of his ability to cure it.

A Sioux Indian on the prairie of North Dakota defined the limits of Indian therapy by saying that an Indian doctor "would not try to dream of all herbs and treat all diseases, for then he could not expect to succeed in all or to fulfill properly the dream of any one herb or animal. That is why our medicine-men lost their power when so many diseases came among us with the advent of the white men." Sioux songs were recorded in 1911–14.

Brave Buffalo was one of the most powerful doctors on the Standing Rock Reservation in Dakota. He related a dream in which a pack of wolves formed a circle around him; as they stood looking at him he noticed that their nostrils and paws were painted red, and then he lost consciousness. When he regained his senses, the wolves took him to a den on top of a high hill. The details of his dream are not of present interest, but the wolves gave him a song that he used in treating the sick. The words reflect the high regard which Indian doctors, who usually treat the sick at night, have for the owl:

Owls hooting in the passing of the night,
Owls hooting.

Another prominent doctor on this reservation was Eagle Shield, who had treated fractures for more than 40 years; he also treated wounds and general illnesses, and he ascribed his power to the bear and badger. He recorded 11 of his healing songs and brought specimens of the herbs used with them. Eagle Shield was also a warrior and had the right to wear the crowskin "necklace" which is the insignia of the Kangi′yuha, or Crow-owners society, an important military society of the Plains tribes.

A primitive form of socialized medicine was found among the Makah and Clayoquot, two seafaring tribes living in northwest Washington and on the west coast of Vancouver Island. These tribes had an organization called the Sai′yûk society to which "everyone had to belong in order to have any standing in the tribe." One of its functions was to supply musical therapy to its members. A group of men and women would go to the house of the sick person, where they danced and sang. The songs were in pairs, the first accompanied by very rapid pounding on planks (a native form of percussion instrument) and the second by a measured beat on small drums, in the same tempo as the song. "Sometimes a pretty song would soothe the sick person and he would go to sleep." The power of the Sai′yûk included the healing of physical ills, and it was said that they cured a cripple who had been unable to walk for at least 10 years. They came and sang for him, and he lived in excellent health to an advanced age. He was a whaler, a vocation which requires strength and endurance. His daughter, Sarah Guy, said, "His reliance was on the songs and meetings of the Sai′yûk, but he sometimes took herb tea."

Songs of the Indians of British Columbia were recorded near Chilliwack, British Columbia, where about a thousand Indians were employed in a hop-picking camp. They came from widely separated localities, including Vancouver Island and the reservations on the west coast, Fort Simpson and the regions of the Nass, Skeena, and Babine Rivers in the north, and the country adjacent to the Fraser and Thompson Rivers. Many songs were recorded, and among them were 26 songs used in the treatment of the sick. These were recorded by eight singers from various parts of British Columbia and Vancouver Island. John Butcher and Tasalt recorded songs that they were using in their treatment of the sick, and other songs were recorded chiefly by sons and grandsons of old men who treated the sick. The younger men had learned the songs when singing with them. One of these songs contains the words, "The whale is going to help me cure this sick man."

John Butcher, whose native name may be translated Dawn, lives at Lytton, on the Thompson River, and treats illnesses of a general character. The four songs he recorded are those he uses in a confine-

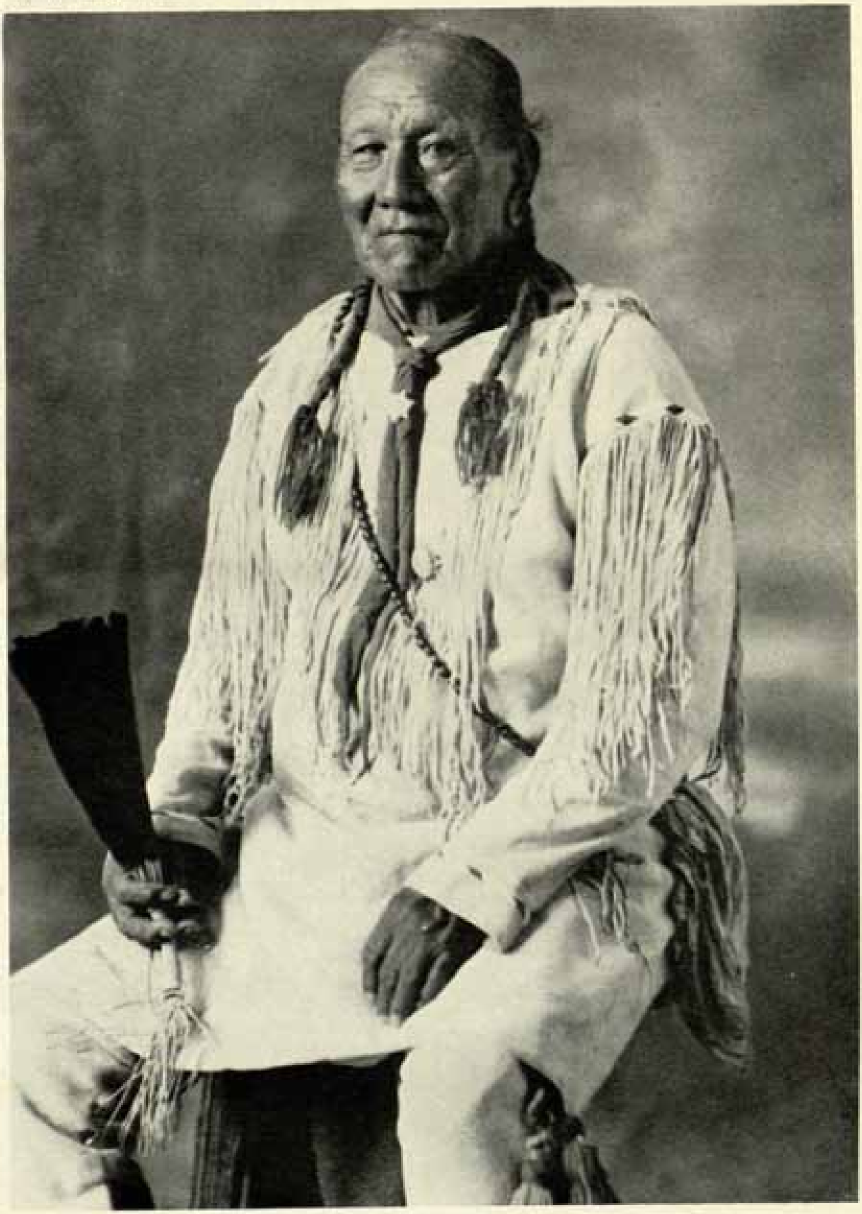
ment case. In one song he talks to a sturgeon and a bird, and in the others to the seal, grizzly bear, deer, and eagle.

Tasalt has inherited his name from a remote past and does not know its meaning. He lives on the Fraser River and is commonly known as Catholic Tommy. When the writer's work was explained, he said that he would record his four songs for the treatment of smallpox, fever, palsy, hemorrhage from the lungs and pneumonia. These were preceded by a long introductory song. The songs were ascribed to mythical spirits; one was said to live in the water and to resemble a dog. It had a golden breast and golden eyes. Another was received from a "wild spirit" that he could not describe. He said these spirits went away when the White men came. Each song has its own characteristics and the rhythms are varied. The tempo is slowest in the song for pneumonia and most rapid in the song for palsy.

The members of the Chippewa Midewiwin continue the treatment which they were using for the sick when Hoffman heard their songs in 1889. The writer talked with one of these men in August 1945. He was Joe Pete of Lac Vieux Desert, Mich. Two of his recent cures, with singing, were related. (Cf. pp. 442–444.)

These examples will suffice to show the close relation between music and medicine among the Indians and the deep faith of these primitive peoples in the healing power of music. The White man has developed his own methods of musical therapy, but in isolated places the Indian doctor still sings the songs that come to him in dreams, while his patients listen and recover.

Reprints of the various articles in this Report may be obtained, as long as the supply lasts, on request addressed to the Division of Publications, Smithsonian Institution, Washington 25, D. C.



BOB-TAILED WOLF, CHEYENNE
Courtesy Southwest Museum.

OWL WOMAN, PAPAGO
Courtesy Bureau of American Ethnology.

EAGLE SHIELD, SIOUX
Courtesy Bureau of American Ethnology.

BRAVE BUFFALO, SIOUX
Courtesy Bureau of American Ethnology.

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