Annual Report of the Board of Regents

of the

SMITHSONIAN INSTITUTION

PUBLICATION 4272

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

1956

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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 28, 1956.

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, 1956. I have the honor to be,

Respectfully,

LEONARD CARMICHAEL, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1956

Presiding Officer ex officio.—DWIGHT D. EISENHOWER, President of the United States.

Chancellor.—EARL WARREN, Chief Justice of the United States.

Members of the Institution:

DWIGHT D. EISENHOWER, President of the United States.
RICHARD M. NIXON, Vice President of the United States.
EARL WARREN, Chief Justice of the United States.
JOHN FOSTER DULLES, Secretary of State.
GEORGE M. HUMPHREY, Secretary of the Treasury.
CHARLES E. WILSON, Secretary of Defense.
HERBERT BROWNELL, JR., Attorney General.
ARTHUR E. SUMMERFIELD, Postmaster General.
FRED A. SEATON, Secretary of the Interior.
EZRA TAFT BENSON, Secretary of Agriculture.
SINCLAIR WEEKS, Secretary of Commerce.
JAMES P. MITCHELL, Secretary of Labor.
MARION B. FOLSOM, Secretary of Health, Education, and Welfare.

Regents of the Institution:

EARL WARREN, Chief Justice of the United States, Chancellor.
RICHARD M. NIXON, Vice President of the United States.
CLINTON P. ANDERSON, Member of the Senate.
LEVERETT SALTONSTALL, Member of the Senate.
H. ALEXANDER SMITH, Member of the Senate.
OVERTON BROOKS, Member of the House of Representatives.
CLARENCE CANNON, Member of the House of Representatives.
JOHN M. VORYS, Member of the House of Representatives.
ARTHUR H. COMPTON, citizen of Missouri.
EVERETTE L. DEGOLYER, citizen of Texas.
ROBERT V. FLEMING, citizen of Washington, D. C.
CRAWFORD H. GREENEWALT, citizen of Delaware.
CARYL P. HASKINS, citizen of Washington, D. C.
JEROME C. HUNSAKER, citizen of Massachusetts.

Executive Committee.—ROBERT V. FLEMING, *chairman*, CLARENCE CANNON, CARYL P. HASKINS.

Secretary.—LEONARD CARMICHAEL.

Assistant Secretaries.—J. E. GRAF, J. L. KEDDY.

Administrative assistant to the Secretary.—MRS. LOUISE M. PEARSON.

Treasurer.—T. F. CLARK.

Chief, editorial and publications division.—PAUL H. OEHSER.

Librarian.—MRS. LEILA F. CLARK.

Superintendent of buildings and grounds.—L. L. OLIVER.

Chief, personnel division.—J. B. NEWMAN.

Chief, supply division.—A. W. WILDING.

Chief, photographic laboratory.—F. B. KESTNER.

UNITED STATES NATIONAL MUSEUM

Director.—A. Remington Kellogg.
Assistant Director.—F. A. Taylor.
Planning officer.—J. C. Ewers.
Chief exhibits specialist.—J. E. Anglim.
Chief exhibits preparator.—W. L. Brown.
Registrar.—Helena M. Weiss.

Department of Anthropology:
F. M. Setzler, head curator.
Division of Archeology: W. R. Wedel, curator; Clifford Evans, Jr., associate curator.
Division of Ethnology: H. W. Krieger, curator; C. M. Watkins, associate curator; R. A. Elder, Jr., G. C. Lindsay, assistant curators.
Division of Physical Anthropology: T. D. Stewart, curator; M. T. Newman, associate curator.

Department of Zoology:
W. L. Schmitt, head curator.
Division of Mammals: D. H. Johnson, acting curator; H. W. Setzer, C. O. Handley, Jr., associate curators.
Division of Birds: Herbert Friedmann, curator; H. G. Deignan, associate curator.
Division of Reptiles and Amphibians: Doris M. Cochran, curator.
Division of Fishes: L. P. Schultz, curator; E. A. Lachner, associate curator.
Division of Insects: J. F. G. Clarke, curator; O. L. Cartwright, W. D. Field, Grace E. Glance, associate curators.
Division of Marine Invertebrates: F. A. Chace, Jr., curator; F. M. Bayer, T. E. Bowman, C. E. Cutress, Jr., associate curators.
Division of Mollusks: H. A. Rehder, curator; J. P. E. Morrison, associate curator.

Department of Botany (National Herbarium):
J. R. Swallen, head curator.
Division of Phanerogams: A. C. Smith, curator; E. C. Leonard, L. B. Smith, E. H. Walker, Velva E. Rudd, associate curators.
Division of Ferns: C. V. Morton, curator.
Division of Grasses: Ernest R. Sohns, associate curator.
Division of Cryptogams: C. V. Morton, acting curator; P. S. Conger, associate curator.

Department of Geology:
G. A. Cooper, acting head curator; J. H. Benn, museum geologist.
Division of Mineralogy and Petrology: G. S. Switzer, E. P. Henderson, associate curators.
Division of Invertebrate Paleontology and Paleobotany: G. A. Cooper, curator; A. R. Loeblich, Jr., David Nicol, associate curators.
Division of Vertebrate Paleontology: C. L. Gazin, curator; D. H. Dunkle, associate curator.

Department of Engineering and Industries:
R. P. Multhauf, acting head curator.
Division of Engineering: R. P. Multhauf, curator.
Section of Civil and Mechanical Engineering: R. P. Multhauf, in charge.
Section of Tools: R. P. Multhauf, in charge.

DEPARTMENT OF ENGINEERING AND INDUSTRIES—Continued

Division of Engineering—Continued

Section of Marine Transportation: K. M. Perry, associate curator.

Section of Electricity: W. J. King, associate curator.

Section of Physical Sciences and Measurement: R. P. Multhauf, in charge.

Section of Horology: S. H. Oliver, associate curator.

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

Division of Crafts and Industries: W. N. Watkins, curator; E. C. Kendall, associate curator.

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

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

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

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

Division of Medicine and Public Health: G. B. Griffenhagen, curator.

Division of Graphic Arts: Jacob Kainen, curator.

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

DEPARTMENT OF HISTORY:

M. L. Peterson, acting head curator.

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

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

Division of Numismatics: M. L. Peterson, acting curator.

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

BUREAU OF AMERICAN ETHNOLOGY

Director.—M. W. STIRLING.

Associate Director.—F. H. H. ROBERTS, Jr.

Anthropologist.—H. B. COLLINS, Jr.

Ethnologist.—W. C. STURTEVANT.

RIVER BASIN SURVEYS.—F. H. H. ROBERTS, Jr., *Director.*

ASTROPHYSICAL OBSERVATORY

Director.—F. L. WHIPPLE.

Assistant Director.—J. S. RINEHART.

Table Mountain, Calif., field station.—F. A. GREELEY, A. G. FROILAND, S. L. ALDRICH, physicists.

DIVISION OF RADIATION AND ORGANISMS:

Chief.—R. B. WITHROW.

Plant physiologists.—W. H. KLEIN, MRS. ALICE P. WITHROW, LEONARD PRICE, V. B. ELSTAD, C. C. MOH.

Biochemist.—J. B. WOLFF.

NATIONAL COLLECTION OF FINE ARTS

Director.—T. M. BEGGS.

Curator of ceramics.—P. V. GARDNER.

Chief, Smithsonian Traveling Exhibition Service.—MRS. ANNEMARIE H. POPE.

FREER GALLERY OF ART

Director.—A. G. Wenley.
Assistant Director.—J. A. Pope.
Assistant to the Director.—B. A. Stubbs.
Associate in Near Eastern art.—Richard Ettinghausen.
Associate in technical research.—R. J. Gettens.
Assistant in research.—H. P. Stern.

NATIONAL AIR MUSEUM

Advisory Board:
Leonard Carmichael, *Chairman.*
Maj. Gen. John P. Doyle, *U. S. Air Force.*
Rear Adm. James S. Russell, *U. S. Navy.*
Grover Loening.
Head curator.—P. E. Garber.
Associate curator.—W. M. Male.

NATIONAL ZOOLOGICAL PARK

Director.—W. M. Mann.
Assistant Director.—E. P. Walker.
Veterinarian.—T. H. Reed.

CANAL ZONE BIOLOGICAL AREA

Resident Naturalist.—C. B. Koford.

INTERNATIONAL EXCHANGE SERVICE

Chief.—D. G. Williams.

NATIONAL GALLERY OF ART

Trustees:
Earl Warren, Chief Justice of the United States, *Chairman.*
John Foster Dulles, Secretary of State.
George M. Humphrey, Secretary of the Treasury.
Leonard Carmichael, Secretary of the Smithsonian Institution.
F. Lammot Belin.
Duncan Phillips.
Chester Dale.
Paul Mellon.
Rush H. Kress.
President.—Chester Dale.
Vice President.—F. Lammot Belin.
Secretary-Treasurer.—Huntington Cairns.
Director.—John Walker.
Administrator.—Ernest R. Feidler.
General Counsel.—Huntington Cairns.
Chief Curator.—(vacancy).
Assistant Director.—Macgill James.

Honorary Research Associates, Collaborators, and Fellows

Anthropology

Mrs. Arthur M. Greenwood
N. M. Judd
T. W. McKern
Betty J. Meggers
W. W. Taylor, Jr.
W. J. Tobin

Zoology

Paul Bartsch, Mollusks
A. G. Böving
L. L. Buchanan, Coleoptera
M. A. Carriker, Insects
R. S. Clark, Zoology
R. A. Cushman, Hymenoptera
D. C. Graham, Biology
C. T. Greene, Diptera
A. B. Howell, Mammals
W. L. Jellison, Insects
W. M. Mann, Hymenoptera
J. P. Moore, Marine Invertebrates
C. F. W. Muesebeck, Insects
Benjamin Schwartz, Helminthology
Mrs. Harriet Richardson Searle, Marine Invertebrates
C. R. Shoemaker
R. E. Snodgrass, Insects
Alexander Wetmore, Birds
Mrs. Mildred S. Wilson, Copepod Crustacea

Botany

Mrs. Agnes Chase, Grasses
E. P. Killip, Phanerogams
F. A. McClure, Grasses
J. A. Stevenson, Fungi

Geology

R. S. Bassler, Paleontology
R. W. Brown, Paleobotany
Preston Cloud, Invertebrate Paleontology
J. B. Knight, Invertebrate Paleontology
Mrs. Helen N. Loeblich, Invertebrate Paleontology
S. H. Perry, Mineralogy
J. B. Reeside, Jr., Invertebrate Paleontology
W. T. Schaller, Mineralogy

Engineering and Industries

F. L. Lewton, Crafts and Industries

History

P. A. Straub, Numismatics

Bureau of American Ethnology

Frances Densmore
J. P. Harrington
R. F. Heizer
Sister M. Inez Hilger
R. S. Solecki
R. J. Squier
J. R. Swanton
A. J. Waring, Jr.

Astrophysical Observatory

C. G. Abbot

Freer Gallery of Art

Grace Dunham Guest
Max Loehr
Katherine N. Rhoades

Canal Zone Biological Area

C. C. Soper
James Zetek

Report of the Secretary of the Smithsonian Institution

LEONARD CARMICHAEL

For the Year Ended June 30, 1956

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit a report showing the activities and condition of the Smithsonian Institution and its branches for the fiscal year ended June 30, 1956.

GENERAL STATEMENT

Botanists have learned in their study of the rings in the cross sections of trees that all years are not equally favorable for growth. When sun and moisture are just right, development is best. In the life of the Smithsonian Institution, the one hundred and tenth ring, which is covered by this report, shows what is probably an unparalleled period of healthy growth in this old and honored institution.

Museum of History and Technology Assured

Last year it was possible to report that $2,288,000 had been appropriated to plan the already authorized new Museum of History and Technology building for the Smithsonian. This year the additional $33,712,000 has been appropriated to make possible the building of this great and most urgently needed new museum structure.

The established site for this building is an admirable one. It is in the Mall area of the Capital, near other Smithsonian buildings, and is bounded on the north by Constitution Avenue, on the east by 12th Street, on the south by Madison Drive, and on the west by 14th Street. It is expected that the construction of the foundation of the building will begin in the spring of 1957, and it is hoped that the building will be completed in 1960.

The Smithsonian Regents selected the New York firm of McKim, Mead & White as architects for the building. Under its direction the development of the necessarily elaborate plans for the structure is progressing in a most promising manner. These plans are being worked out so as to meet the requirements for the new building that have been set by the staff of the Smithsonian Institution on the

basis of detailed study of similar buildings and especially on the basis of the knowledge of the objects to be displayed in it.

The Joint Committee on Construction of a Building for the Museum of History and Technology for the Smithsonian Institution, of which our Regent Senator Clinton P. Anderson is chairman, and our Regent John M. Vorys, House of Representatives, is secretary, has devoted much careful attention to the architectural problems presented by the building. When the new structure becomes a reality, the Nation will owe a deep debt of gratitude to the wisdom and effective assistance that this committee has provided in the development of the new museum. The full membership of the committee is as follows:

Clinton P. Anderson, Senator from New Mexico.
Leverett Saltonstall, Senator from Massachusetts.
H. Alexander Smith, Senator from New Jersey.
Stuart Symington, Senator from Missouri.
Edward Martin, Senator from Pennsylvania.
Clarence Cannon, Representative from Missouri.
Overton Brooks, Representative from Louisiana.
Robert E. Jones, Jr., Representative from Alabama.
John M. Vorys, Representative from Ohio.
Laurence Curtis, Representative from Massachusetts.

Now that the Museum of History and Technology building is becoming a reality, we must remember that even this great structure is but one step, although a very important one, in providing our Nation with suitable modern buildings in which to house and display its unequaled collections that tell the story of the rise to greatness of the United States of America.

Other Buildings Needed

Of all the urgent additional building needs of the Smithsonian, that which has highest priority is the expansion of the Natural History Museum. In 1930 the two wings needed for this building were authorized by the Congress. This was done because at that time—a quarter of a century ago—the crowding of the Nation's great Natural History Museum had come to seem intolerable. In the intervening years, conditions in this building have become progressively worse. Now world-famous study collections must be piled to the ceiling in the hallways of certain parts of this building. It is most sincerely to be hoped that during the present year funds may be appropriated for this long-delayed, although already authorized, addition to the plant of the Institution.

As indicated in my report a year ago, by a special gift of private funds an architectural study of an adequate building for the National Air Museum was made last year. The site that had been tentatively allocated to the Smithsonian for this building, on Independence Avenue at 10th Street, near other Smithsonian structures, now has

been declared unavailable to the Institution. Other promising locations, however, are ready for consideration. The National Air Museum today maintains, mostly in storage for the future, effective displays of the world's most comprehensive collection of historic aircraft, including innumerable devices and pieces of scientific apparatus that are related to this important phase of modern life. It is hoped that funds may soon be provided to make possible a suitable building for the National Air Museum in close proximity to the other units of the Smithsonian.

The Congress, in 1846, authorized the establishment, within the Smithsonian organization, of an art gallery, which later was designated as the National Collection of Fine Arts. The important works of art in the custody of this bureau are now inappropriately housed in the Natural History Museum. A new and proper building to accommodate this notable collection and to make possible the acceptance of other available collections in the fine and decorative arts was authorized by the Congress in 1938. In spite of many efforts, however, the private funds that were expected to finance the planning and erection of this building have not been secured. Each year pressure from the public to make this building a reality becomes greater. Soon some positive action in regard to this problem must be taken.

Congressional proposal has been discussed in the public press for the establishment, possibly as a new and separate bureau of the Smithsonian Institution, of a National Portrait Gallery. It has been suggested that this collection be housed in the old Patent Office Building. This handsome building is now occupied by offices of the Civil Service Commission, but it is not too well suited for a modern office building. It is believed that this architectural monument of early Washington could be transformed without too great cost into an admirable gallery to house collections of portraits of Americans who have contributed importantly to our country. The possibility that the National Collection of Fine Arts could also be housed in this building deserves study.

Besides the buildings mentioned above, additional structures are urgently needed by the Smithsonian Institution at the National Zoological Park. There is also continued discussion by interested members of the public of the need for the erection of a National Planetarium in connection with the Smithsonian's Astrophysical Observatory. Such a building would have great educational value for the millions of citizens who come each year to Washington.

Rebuilding of Exhibits Continues

The program for the renovation of the exhibits in the old existing Smithsonian buildings, which has been discussed previously, continued

during the period covered by this report. On March 22, 1956, the new Bird Hall of the Natural History Museum was opened to the public. It has been described by one internationally known ornithological expert as the most effective and most instructive museum display of birds in the world. Dr. Herbert Friedmann, curator of birds in the United States National Museum of the Smithsonian Institution, is an artist as well as a scientist, and he and his associates developed this hall in such a way as to make it not only beautiful and eye-arresting but also instructive. The notable success of this hall, with its many new display features, illustrates a function of the Smithsonian Institution that is not always remembered. This is an age in which museums are becoming very common throughout the country. Leadership at the Smithsonian in the development of effective museum displays is thus especially important because, as the world's largest museum in number of cataloged objects, it almost automatically sets for many other museums a pattern for guidance in developing new and small museums throughout the country. There is broad advantage, therefore, when the Smithsonian leads the way in new museum display ideas as it has done in the Bird Hall and in the other recently opened halls that are transforming the old exhibitions of the Institution.

During the year progress was made in the renovation of the second secion of the American Indian Hall, the Engineering Power Hall, and the Health Hall. The notable artistic work required for the backgrounds of the new North American Mammal Hall was produced under special contracts. Part of the Printing Art Hall in the old Smithsonian Building was renovated and is now open to the public. The lights that have been installed in this hall are, so far as is known, the first artificial illumination of any kind ever to be used in this section of the Institution. Progress was also made in preparing a hall displaying the style of life of the early American colonies.

Under the difficult conditions already referred to, improvements in displays were made both in the National Collection of Fine Arts and in the National Air Museum. Many of the plaster casts, which were in far too great a variety of scales and which have long confused the visitor on entering the Rotunda of the Natural History Museum, have been placed on exhibit elsewhere or are in storage.

Rehabilitation of the structures of the older Smithsonian buildings went on during the year covered by this report. Painting of the remaining halls and courts in the Arts and Industries Building, started last year, was completed. It is believed that some of this painting, such as that on the underportions of the roofs, is possibly the first since the building was completed in 1878. New and safer entrance and exit doors were installed in this building.

Nine halls of the Natural History Building were also repainted, and a contract was let for the urgently needed repair of the roof of this great structure. The ancient so-called "converter" heating system of this building was modernized and made more economical. Steam lines in various buildings, which were in a dangerous condition, were replaced.

Work on the air-conditioning of the Freer Gallery of Art was begun. The air-conditioning of this building will protect the priceless objects of art contained in the Freer collections which were deteriorating under the extremes of temperature and humidity of Washington. Also, possibly for the first time since this building was opened, the gallery has been completely repainted, and its library has been renovated and provided with adequate lighting fixtures. Modern rest rooms for the public were opened in the Natural History Building and in the old Smithsonian Building.

Research in Astrophysics

It is always important to remember that Smithson, in establishing his institution, and the Congress, in founding it, directed that it should not only "diffuse knowledge" but also "increase knowledge." During the current year, effective research has continued in all the scientific and artistic departments of the Institution. A particularly notable development, as is indicated in the detailed report that follows (p. 65) has taken place in the program of the Smithsonian Astrophysical Observatory.

Astrophysics has long been one of the principal research activities of the Institution. With the retirement a year ago of Loyal B. Aldrich as head of this bureau, it became clear that, because of the growing importance of astrophysics in national defense as well as in pure science, the future program of this bureau required careful study. With the assistance of Mr. Aldrich, authorities in this field were consulted and it was agreed that the time was ripe to expand both the bureau's facilities and programs. The Smithsonian was fortunate in securing as director Dr. Fred L. Whipple, then chairman of the Department of Astronomy at Harvard University. The scientific headquarters of the Observatory have been moved from temporary buildings behind the old Smithsonian Building to more adequate quarters in immediate association with the Harvard College Observatory in Cambridge, Mass. By this physical change, the Astrophysical Observatory of the Smithsonian Institution, without compromising its independence, has gained the advantage of close association with an active group of scientists in the mathematical and physical as well as astronomical sciences. Without such association, modern advances in astrophysics are severely handicapped.

Dr. Finley Retires

The National Gallery of Art, a bureau of the Smithsonian, has had a notable year. The art world has been saddened by the fact that at the close of June, the Director of the National Gallery, Dr. David E. Finley, whose unremitting labor has done so much to make this institution world famous, reached retirement age. It is most gratifying to announce, however, that this important post has been filled by the promotion of John Walker, Chief Curator of the Gallery, to the post of Director. Mr. Walker has been connected with the Gallery from its beginning and brings to his new post an outstanding international reputation as a student of art.

Financial Support

Grants continue to be made to the Smithsonian by private foundations, by individuals, and by other agencies in support of specific service functions, such as the Bio-Sciences Information Exchange, and many research projects. One of the most interesting of these grants names the Smithsonian Institution as the agency to organize throughout the world the program of observing the artificial earth satellites that are to be launched under the auspices of the International Geophysical Year. The fact that the Smithsonian Institution was selected for this important function attests the recognition accorded to it by the scientists who are responsible for this great and novel project.

Detailed reports of all the ten bureaus under the direction of the Smithsonian Institution follow. In addition, there are included a report on the Smithsonian Library (p. 193) and a report of the Editorial and Publications Division (p. 197) with a complete list of the publications issued during the year. These publications have had a most enthusiastic reception by the scientific and learned world.

In concluding this general introduction to the 1956 Smithsonian Annual Report, it is impossible to resist an expression of deep appreciaton to the Regents of the Institution for all that they have done during the current year to advance the welfare of the Smithsonian. The executive committee of the Board of Regents has been most active and effective in the difficult tasks of managing the details of the private funds of the Institution. In many other ways the Regents, not only as a corporate body but also as individuals, have made possible the really memorable advances in the Smithsonian that are recorded in this report of the operations of its one-hundred and tenth year.

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 Eng-

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

THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice of the United States, and three members of the Senate, and three members of the House of Representatives; together with six other persons, other than members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected Chancellor of the Board. In the past the selection has fallen upon the Vice President or the Chief Justice.

The past year brought the resignation of a highly valued member of the Board, Dr. Vannevar Bush, who had been a Regent since April 5, 1940. He was also a member of the executive committee of the Board and in this capacity, too, rendered distinguished and outstanding service to the Institution.

The Board is honored to welcome as new members the following: Everette Lee DeGolyer, to succeed Harvey N. Davis, deceased; Crawford Hallock Greenewalt, to succeed Vannevar Bush, resigned; and Caryl Parker Haskins, to succeed Owen Josephus Roberts, deceased.

The annual informal dinner meeting of the Board was held in the main hall of the Smithsonian Building on the evening of January 12, 1956, amid various exhibits showing phases of the work being carried on at present. Brief talks on their special fields of research and activities were made by two staff members: Dr. T. Dale Stewart and Dr. Fred L. Whipple.

The regular annual meeting of the Board was held on January 13, 1956. At this meeting the Secretary presented his published annual report on the activities of the Institution and its bureaus; and Robert V. Fleming, chairman of the executive and permanent committees of the Board, presented the financial report for the fiscal year ended June 30, 1955.

The roll of Regents at the close of the fiscal year was as follows: Chief Justice of the United States Earl Warren, Chancellor; Vice President Richard Nixon; members from the Senate: Clinton P. Anderson, Leverett Saltonstall, H. Alexander Smith; members from

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the House of Representatives: Overton Brooks, Clarence Cannon, John M. Vorys; citizen members: Arthur H. Compton, Everette Lee DeGolyer, Robert V. Fleming, Crawford H. Greenewalt, Caryl P. Haskins, and Jerome C. Hunsaker.

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 204.

APPROPRIATIONS

Funds appropriated to the Institution for its regular operations for the fiscal year ended June 30, 1956, total $4,166,000, obligated as follows:

Management	$77,906
United States National Museum	1,386,023
Bureau of American Ethnology	59,248
Astrophysical Observatory	121,102
National Collection of Fine Arts	47,635
National Air Museum	120,334
International Exchange Service	90,946
Canal Zone Biological Area	14,326
Maintenance and operation of buildings	1,826,376
Other general services	422,104
Total	4,166,000

In addition, the Institution received an appropriation of $2,288,000 for the preparation of plans and specifications for the new Museum of History and Technology.

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

From the District of Columbia for the National Zoological Park	$690,900
From the National Park Service, Department of the Interior, for the River Basin Surveys	92,360

VISITORS

Visitors to the Smithsonian group of buildings during the year reached an all-time high of 4,145,591, which was approximately a quarter of a million more than the previous year. April 1956 was the month of largest attendance, with 667,752; May 1956 second, with 597,566; June 1956 third, with 489,999. Largest attendance for a single day was 54,466 for March 31, 1956. Table 1 gives a summary of the attendance records for the five buildings. These figures, when added to the 3,788,229 estimated visitors at the National Zoological Park and 1,013,246 recorded at the National Gallery of Art, make a total number of visitors at the Smithsonian of 8,947,066.

TABLE 1.—*Visitors to certain Smithsonian buildings during the year ended June 30, 1956*

Year and month	Smithsonian Building	Arts and Industries Building	Natural History Building	Aircraft Building	Freer Building	Total
1955						
July	72,782	191,975	93,645	62,162	10,392	430,956
August	79,521	195,036	100,443	62,002	11,021	448,023
September	47,146	110,582	64,918	37,020	7,914	267,580
October	39,978	107,259	70,290	29,331	6,553	253,411
November	33,959	76,639	59,150	26,801	5,371	201,920
December	20,632	44,485	40,088	20,058	3,209	128,472
1956						
January	22,059	54,566	43,515	21,325	3,604	145,069
February	30,761	66,471	58,645	26,793	4,756	187,426
March	52,088	148,340	84,211	36,145	6,633	327,417
April	132,642	284,232	155,494	82,412	12,972	667,752
May	101,112	281,049	135,286	69,102	11,017	597,566
June	83,368	235,846	101,839	58,058	10,834	489,999
Total	716,048	1,796,480	1,007,578	531,209	94,276	4,145,591

A special record was kept during the year of groups of school children visiting the Institution. These figures are given in table 2:

TABLE 2.—*Groups of school children visiting the Smithsonian Institution, 1955–1956*

Year and month	Number of groups	Number of children
1955		
July	37	1,054
August	139	4,379
September	94	2,585
October	313	10,559
November	389	12,392
December	167	4,717
1956		
January	190	5,086
February	369	10,621
March	1,231	41,655
April	2,501	94,569
May	3,833	152,961
June	1,194	44,609
Total	10,457	385,187

LECTURES

In 1931 the Institution received a bequest from James Arthur, of New York City, 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 twenty-third Arthur lecture was delivered in the auditorium of the Natural History Building on the evening of April 26, 1956, by Dr. Donald H.

Menzel, director of the Harvard College Observatory, Cambridge, Mass. This illustrated lecture, on the subject "The Edge of the Sun," will be published in full in the general appendix of the Annual Report of the Board of Regents of the Smithsonian Institution for 1956.

John K. Marshall, of the Peabody Museum, Cambridge, Mass., showed his color film "The Hunters—African Bushmen" before a large audience in the Natural History Building auditorium on the evening of February 9, 1956. This showing was under the joint sponsorship of the Smithsonian Institution and the Anthropological Society of Washington.

Prof. Millar Burrows, chairman of the Department of Near Eastern Languages, Yale University Graduate School, delivered his lecture on "The Dead Sea Scrolls" before an overflow audience in the Natural History Building on the evening of February 29, 1956. This lecture was sponsored jointly with the Archaeological Institute of America.

Dr. Gunnar Thorson, of the Zoological Museum, Copenhagen, Denmark, on the evening of May 10, 1956, lectured on the subject "The Relationship Between Prey and Predator on the Sea Bottom" in the auditorium of the Natural History Building. This was one of a series of lectures that this distinguished foreign scientist delivered in America that season.

Several lectures were also sponsored by the Freer Gallery of Art and the National Gallery of Art. These are listed in the reports of these bureaus.

BIO-SCIENCES INFORMATION EXCHANGE

The Bio-Sciences Information Exchange continued during the year under the directorship of Dr. Stella L. Deignan. This agency operates within the Smithsonian Institution under funds made available to the Institution by other governmental agencies. By performing the unique function of effecting an exchange of information on work just beginning or not yet published, it serves as a clearinghouse for current research in the biological, medical, and psychological sciences. Its services are provided, free of charge, to investigators associated with recognized research institutions in the United States and abroad.

The body of information within the Exchange now consists of brief abstracts of over 10,000 active research projects and of a somewhat greater number of summary statements on investigations which are no longer current. The studies registered with the Exchange are for the most part being carried out in laboratories in the United States.

Requests for information on work in scientific fields come to the Exchange from granting agencies, committees, and from individual investigators. For the first two groups, detailed surveys of current work in broad fields are provided; for the individual investigator the service is limited to information on work on one or a series of specifi-

cally defined problems. The purpose is not that of a reference library to provide guidance to publications, but to place investigators in contact with others having immediate and similar interests.

During the fiscal year 1956 replies to over 900 requests for subject information were supplied by the Exchange. Among these were requests for rosters of scientists to be used in planning symposia, conferences, and international scientific meetings, and calls from scientists abroad who were planning itineraries for visiting United States laboratories, as well as from investigators planning problems and wishing to know of others in related fields.

A primary purpose of the Exchange is to prevent the inadvertent duplication of support by granting agencies of a field of research or of an investigator. To carry out this responsibility, the Exchange prepares, at the request of government and nongovernment granting agencies, résumés of the support of men, research institutions, and departments of such institutions. Approximately 7,500 such reports were prepared during the year.

Because a large proportion of the research registered is supported by grants and contracts, the Exchange prepares for its cooperating agencies and, within the limits of its charter, for other qualified groups, statistical information on the amount and distribution of research support. As a correlation to liaisons with granting agencies, it provides also a considerable body of information on the general policies of granting agencies. As staff and time permit, this information is employed to aid scientists in locating possible sources of support.

JUNIOR LEAGUE DOCENT ACTIVITIES

In the fall of 1955, through the cooperative assistance of the Junior League of Washington, a program was inaugurated for a volunteer docent or educational guide service in Smithsonian exhibition halls for elementary school children in the Greater Washington area. Such a service has long been needed at the Institution. The project is one of many voluntary programs undertaken by members of the Junior League.

This program is under the immediate supervision of Frank M. Setzler, head curator of the National Museum's department of anthropology, who undertook the task in addition to his regular duties. Representing the Junior League are Mrs. Robert Nelson, Jr., chairman of the project, and Mrs. Alexander Chilton, vice chairman. They organized the volunteers and met frequently with the Secretary, Mr. Setzler, and other Museum officials concerned with procedures and scripts.

To begin the program, two of the recently modernized exhibition halls were selected—the Hall of American Indians and the First

Ladies Hall. The professional staff of the Smithsonian Institution prepared the scripts used by the docents. All the drudgery of organizing the tours, notifying the various elementary school systems in the District and those in the adjoining counties of Maryland and Virginia, and making all tour arrangements with the school teacher and respective docent, was graciously assumed by Mrs. Nelson and Mrs. Chilton.

On January 25, 1956, the first trial was held in the American Indian Hall, and the first official scheduled tours began February 20. The following Junior Leaguers served as docents in the American Indian Hall: Mrs. George Goodrich, Mrs. William McClure, Mrs. Robert McCormick, Miss Mary McNeil, Mrs. John Manfuso, Mrs. John Mashburn, Mrs. Robert Nelson, Mrs. Bolling Powell, Mrs. Walter Slowinski, and Mrs. George Wyeth.

During the final stages of completing the First Ladies Hall, a script was prepared emphasizing in this unique display graphic portrayals of interesting episodes in our American history. The program for fifth- and sixth-grade pupils was inaugurated on March 29, 1956. The following served as docents in the First Ladies Hall: Mrs. Alexander Chilton, Mrs. William Evers, Mrs. Walter Graves, Mrs. Harold Hull, Mrs. John W. Kern, III, Miss Mary L. Krayenbuhl, Mrs. Peter MacDonald, Mrs. Jay B. L. Reeves, and Mrs. John Schoenfeld.

In reviewing the number of tours and children accommodated in this short period, I am extremely pleased with the response and yet somewhat chagrined that the Institution has not been able in the past to offer more of this kind of service. The numerous requests for it only accentuate the acute need for this type of educational program. Moreover, it becomes especially desirable as we continue to modernize our exhibition halls. During the 3-month period in the American Indian Hall the Junior League completed 58 tours, escorting over 3,000 third- and fourth-grade pupils. During the 2½-month period in the First Ladies of the White House Hall, 44 tours guided over 1,500 elementary school classes.

One of the most encouraging features resulting from a final conference before the summer vacation period began was the manifest enthusiasm on the part of the Junior Leaguers to continue this school guide service in the aforementioned two halls and to extend the program to other new halls as they are completed and opened to the public.

In many ways the project has been the culmination of several years of hopes, desires, and plans for assisting school children in understanding the Smithsonian's new and modernized exhibition halls. I feel confident that the members of the Board of Regents join with me in expressing gratitude to the members of the Junior League

Docent Service and those members of our professional staff who participated in the establishment of one more educational program within the Smithsonian Institution.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE INSTITUTION

National Museum.—Accessions to the national collections showed a normal growth, slightly more than 900,000 specimens being added during the year. The total catalog entries in all departments now number 43,756,010. Some of the year's outstanding accessions included: In anthropology, collections of ethnological material from the Sudan, Peru, and New Zealand, fine lots of pottery and ceramic tiles, a collection of Mexican jadeite, a series of pathological human bones from Illinois, and a group of early Eskimo skeletons; in zoology, valuable collections of mammals from Siam and Africa, a Ross seal from the Antarctic, a giant sea bass from the Marshall Islands, a collection of over 230,000 termites, and more than 10,000 invertebrates from the Antarctic; in botany, the James Smith Memorial Collection of fossil diatoms from the Philippines and important lots of plants from Brazil, New Guinea, Australia, Idaho, and Alaska; in geology, an exhibit of synthetic diamonds, 11 meteorites new to the Museum, several thousand miscellaneous but important invertebrate fossils including many type specimens, a notable collection of fossil fishes and reptiles from Kansas, and an example of a very rare Middle Eocene bowfin from Wyoming; in engineering and industries, an unusual number of turbine and other power machines; and in history, additions to the collection of White House state china, more than 30,000 philatelic specimens lent by former Postmaster General James A. Farley, including original, autographed sketches of stamps made by President Franklin D. Roosevelt.

Members of the staff conducted fieldwork in Peru, Europe, Canada, Palau Archipelago, Libya, West Indies, Panama, and many parts of the United States.

The exhibits-modernization program was successfully continued, and the new Bird Hall was opened to the public.

Bureau of American Ethnology.—The staff members of the Bureau continued their researches and publication in ethnology and archeology: Dr. Stirling his Panamanian studies, Dr. Roberts his work as Director of the River Basin Surveys, Dr. Collins his archeological fieldwork in the Hudson Bay area, and Dr. Drucker his Mexican studies.

Astrophysical Observatory.—Scientific headquarters of the Observatory were moved to Cambridge, Mass., at the beginning of the year. Broadened research programs of the agency now include not only strictly solar research but also meteoritic studies and studies of the

higher atmosphere. The Observatory is also participating in the new Satellite Tracking Program of the International Geophysical Year. The division of radiation and organisms continued its research on the role of light in regulating growth in higher plants.

National Collection of Fine Arts.—The Smithsonian Art Commission accepted for the Gallery 1 oil painting, 3 miniatures, a German antique cabinet, a collection of 31 pieces of glassware, 2 ceramic pieces, and 3 bronze busts. The Gallery held 13 special exhibits during the year, while the Smithsonian Traveling Exhibition Service circulated 72 exhibitions, 71 in the United States and 1 abroad.

Freer Gallery of Art.—Purchases for the collections of the Freer Gallery included Chinese bronzes, paintings, and pottery; Japanese lacquer work, metalwork, and painting; Indian and Syrian metalwork; Coptic painting; and Persian pottery. The Gallery continued its program of illustrated lectures in the auditorium by distinguished scholars in Eastern art.

National Air Museum.—All the Museum's stored materials have now been moved to the storage facility at Suitland, Md. During the year 118 specimens in 45 separate accessions were added to the aeronautical collections, including the first Pitcairn autogiro constructed in America, a Stearman-Hammond airplane of the 1930's, the Curtiss Robin monoplane *Ole Miss*, which established an endurance record in 1935, an original amphibious aircraft of 1909–12, and a Bell P-39 Airacobra, besides many scale models and other aeronautical accessories and equipment.

National Zoological Park.—The Zoo accessioned 1,710 individual animals during the year, and 2,155 were removed by death, exchange, or return to depositors. The net count at the close of the year was 2,965. Noteworthy among the additions were a pair of European wisents, a rare dwarf Bolivian armadillo, an olingo from Colombia, fine examples of gelada baboons, and a Guianan crested eagle. In all, 252 creatures were born or hatched at the Zoo during the year—77 mammals, 43 birds, and 132 reptiles. Visitors totaled 3,788,229.

Canal Zone Biological Area.—Mr. Zetek, longtime resident manager, retired at the end of May. He is succeeded by Dr. Carl B. Koford. The year's visitors to the island totaled 440, of whom about 50 were scientists using the station's facilities for special researches.

International Exchange Service.—As the official United States agency for the exchange of governmental, scientific, and literary publications between this country and other nations, the International Exchange Service handled during the year 1,161,855 packages of such publications, weighing 803,056 pounds, about the same as last year. Consignments were made to all countries except China, North Korea,

Outer Mongolia, Communist-controlled areas of Viet-Nam and Laos, and the Haiphong Enclave.

National Gallery of Art.—The Gallery received 477 accessions during the year, by gift, loan, or deposit. Ten special exhibits were held, and 23 traveling exhibitions of prints from the Rosenwald Collection were circulated to other galleries and museums. Exhibitions from the "Index of American Design" were given 42 bookings in 20 States and the District of Columbia. Nearly 46,000 persons attended the various tours conducted by Gallery personnel, and the 42 Sunday-afternoon lectures in the auditorium attracted 9,470. The Sunday-evening concerts in the east garden court were continued.

Library.—A total of 78,715 publications were received by the Smithsonian library during the year. In all, 237 new exchanges were arranged. Among the gifts were several private collections of valuable material, both of books and periodicals. At the close of the year the holdings of the library and all its branches aggregated 956,157 volumes, including 586,447 in the Smithsonian Deposit in the Library of Congress but excluding unbound periodicals and reprints and separates from serial publications.

Publications.—Seventy-four new publications appeared under the Smithsonian imprint during the year (see Report on Publications, p. 197, for full list). Outstanding among these were "The Bromeliaceae of Brazil," by Lyman B. Smith; "The Last Cruise of H. M. S. *Loo*," by Mendel L. Peterson; "Chazyan and Related Brachiopods" (2 vols.) by G. Arthur Cooper; "The Honey-Guides," by Herbert Friedmann; "The Dîné: Origin Myths of the Navaho Indians," by Aileen O'Bryan; and "Chinese Porcelains from the Ardebil Shrine," by John Alexander Pope. In all, 424,389 copies of printed matter were distributed during the year.

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, 1956:

COLLECTIONS

During the year 905,473 specimens were added to the national collections and distributed among the six departments as follows: Anthropology, 19,371; zoology, 409,127; botany, 32,616; geology, 48,900; engineering and industries, 4,292; history, 391,167. This increase is smaller than last year, when the unusual increase resulted from the accession of several million small fossils. This year's total is a more normal annual accretion. Most of the accessions were received as gifts from individuals or as transfers from Government departments and agencies. The Annual Report of the Museum, published as a separate document, contains a detailed list of the year's accessions, of which the more important are summarized below. Catalog entries in all departments now total 43,756,010.

Anthropology.—Among the outstanding accessions received in the division of ethnology is a collection of specimens from the environs of Nasir on the Sabat River in South Sudan, East Africa, presented by Rev. A. MacRoy, an American missionary. These come from an area hitherto unrepresented in the national collections. An interesting object is a much-worn leopard skin, a traditional court accessory, on which the witness sits while giving evidence during a trial. A perjurer would be subject to dire consequences if he gave false evidence while sitting on this leopard skin. Rings perforating one corner indicate the number of occasions the skin has been used by witnesses. Another item, significant of the culture of the Nuer, is a fighting bracelet of brass, generally worn on the right wrist by men and women alike.

While building a railroad in about 1910, Alexander J. Norris collected objects used in the daily life of the Arawak Indians living in the colony of Perené in the watershed of the Río Perené (upper Ucayali River), and from the Quechua Indians in the vicinity of Cuzco, Peru. These ethnological specimens consist of hunting and fishing weapons, woven ponchos, and various objects of personal adornment,

presented by Mr. and Mrs. Joseph C. Green. Another acquisition of note, a stylistically carved wooden treasure box, "waka," originally presented to President Calvin Coolidge by the assembled chiefs of the Arawa, was transferred from the Department of State. The Arawa, a federation of Maori tribes living on the east coast of New Zealand's North Island, claim descent from members of the *Arawa*, the legendary voyaging canoe that brought the Maori to New Zealand. A notable collection of ceramic tiles given to the division by E. Stanley Wires, ranges from early Moorish, Spanish, and Dutch tiles to American types of recent manufacthure. They are the result of Mr. Wires's lifetime interest in the history of tile manufacturing. Through the efforts of Mr. Wires, the tile collection was further enhanced by a pair of ceramic tile panels with animal designs in relief, sculptured by the late Frederick G. R. Roth and presented by his widow.

Other donations to the ethnological collections include a total of 170 examples of Rockwood and other late nineteenth century and early twentieth century pottery assembled by the late Dr. Edwin Kirk and presented by his widow, Mrs. Page Kirk; 17 examples of stoneware and pottery made by country potters in Maryland, Pennsylvania, and West Virginia, given by Clyde N. Fahrney; and numerous glass and ceramic specimens together with documented papers and account books presented by Miss Madeleine Wilkinson.

The division of archeology received a collection of 187 polished jadeite and other stone objects from La Venta, Tabasco, Mexico, as a permanent loan from the Museo Nacional, Mexico. These include beads, celts, figurines, ear-spool parts, and other objects representing the prehistoric Olmec culture of southeastern Mexico. A group of conch-shell segments elaborately carved with anthropomorphic and ceremonial art motifs in the style of the late prehistoric Southern Cult, from the Spiro Mound, near Spiro, Okla., was received as an indefinite loan from the Lightner Museum of Hobbies, St. Augustine, Fla. A large collection of pre-Spanish Peruvian artifacts consisting of carved wood, metal, textiles, stone, and pottery, collected about 1910 in Peru by Alexander J. Norris, was presented as a gift by his daughter, Mrs. Joseph C. Green, and her husband. A large collection of archeological material excavated from prehistoric sites on Hokkaido Island, Japan, was generously donated by Lt. Col. Howard MacCord, who has added many unusual objects to the collections.

A series of pathological human bones from Calhoun and Jersey Counties, Ill., was donated to the division of physical anthropology by Dr. P. F. Titterington. Many of the examples of pathology are unusual and extremely interesting from the standpoint of the history of disease. All the material relates to a late prehistoric period. A collection of 85 skulls received from the Wistar Institute of Philadelphia

includes material no longer obtainable and fills some gaps in the national collections. Outstanding in this series is a group of early Eskimo skeletons collected by the W. B. Van Valin-John Wanamaker Expedition, University of Pennsylvania Museum, 1917–19. These Eskimo skeletons were found at Point Barrow, Alaska, and represent the bearers of the well-known "Old Bering Sea Ivory Culture."

Zoology.—One of the most valuable and largest single accessions, comprising 600 specimens collected by Robert E. Elbel in Siam, was received in the division of mammals. Included was an especially good series of squirrels and carnivores from localities not previously represented in the collections. Several noteworthy African mammal collections included 250 specimens from Libya collected by Dr. H. W. Setzer; 61 specimens from the Belgian Congo obtained by Dr. Waldo L. Schmitt in the course of the Smithsonian-Bredin Expedition; and smaller collections made in the Gold Coast by Donald Lamm and in Kenya by John P. Fowler. From Ponapé in the Caroline Islands, a team headed by Dr. J. T. Marshall, Jr., investigating the ecology of the local rat populations under the auspices of the Pacific Science Board, sent in a collection of 103 mammals. Another welcome addition consists of a skeleton of a large sperm whale and the types of three baleen whales presented by the Academy of Natural Sciences of Philadelphia. Worthy of notice also are the approximately 300 small mammals collected by Dr. C. O. Handley, Jr., and John L. Paradiso at selected sites in the Middle Atlantic States. Among the individual accessions of outstanding interest is a Ross seal brought back by the U. S. Navy's Antarctic expedition. Other interesting additions include a rare big-eared bat (*Idionycteris phyllotis*) from Arizona, a rock wallaby from the introduced colony on the island of Oahu in the Hawaiian group, the type of a new shrew from North Carolina obtained by Dr. Albert Schwartz, and the type of a new bog lemming from Kentucky sent in by Dr. R. W. Barbour.

The more important of the year's ornithological accessions consist of 145 bird skins from the Gold Coast and 137 bird skins from Burma, both lots collected by Donald W. Lamm. Two deposits were received by the Institution: 890 skins, 12 skeletons, 2 alcoholic specimens, 5 sets of eggs, and a nest from Panama collected by Dr. A. Wetmore; 261 skins and 32 skeletons of birds collected in Northern Rhodesia by E. L. Haydock. A transfer from the U. S. Fish and Wildlife Service increased the Museum's North American collection by 1,400 bird skins.

Through Dr. Hobart M. Smith, the division of reptiles and amphibians received from the University of Illinois the gift of 25 paratypes of of Mexican reptiles and amphibians. Other noteworthy gifts include 104 reptiles and amphibians from Germany and Cuba donated by Jerry

D. Hardy, and 478 reptiles and amphibians from Virginia collected by William L. Witt.

In recent years the division of fishes has received a number of very valuable private collections. This year the largest accession, 2,550 specimens, the remainder of the collection of the late Dr. William C. Kendall, was transferred from the University of Maine. Through Dr. J. M. Carpenter, of the University of Kentucky, the division also received 914 South American fishes, forming the collection of the late Dr. William Ray Allen. Other types of fishes were received from the California Academy of Sciences; Dr. William A. Gosline, of the University of Hawaii; the Chicago Natural History Museum; the University of Hawaii; and Herbert R. Axelrod, editor of the "Tropical Fish Hobbyist." Among 53 Pacific fishes transferred to the Museum by the Atomic Energy Commission was a giant sea bass (*Promicrops lanceolatus*), the first record for the Marshall Islands. A gift from the University of California yielded 634 fishes from the eastern Pacific. From the Smithsonian-Bredin Expedition to the Belgian Congo, 550 fishes collected by Dr. Waldo L. Schmitt were added to the collections. Worthy of mention also is the fine series of 1,246 Alabama fresh-water fishes received in exchange from Dr. J. S. Dendy, of the Alabama Polytechnic Institute.

By transfer from branches of the U. S. Department of Agriculture the division of insects received three valuable collections: The largest single accession in the past decade or more, consisting of over 230,000 termites transferred from the Forest Service upon the recommendation of Dr. T. E. Snyder, one of the world's leading authorities on these destructive insects; over 13,000 miscellaneous specimens from the Cereal and Forage Insects Laboratory, Lafayette, Ind.; and nearly 70,000 specimens from the Entomology Research Branch. Among the year's notable gifts were the 4,400 specimens consisting of 4,127 examples (including immature stages) of the family Psychidae (Lepidoptera) and 273 hymenopterous parasites reared from them, donated by Dr. Frank Morton Jones; the personal collection of Dr. F. W. Poos, comprising 3,433 miscellaneous North American insects; an important lot of 1,553 midges (*Culicoides*) from Hawaii, given the Museum by Dr. W. W. Wirth; 3,577 reared flies of the family Drosophilidae from the Department of Zoology, University of Texas; and the second most important collection to come from Thailand, 3,331 insects collected by Robert E. Elbel with the aid of a grant from the Casey Fund.

Outstanding among the collections received in the division of marine invertebrates were 1,709 fresh-water crustaceans and other invertebrates obtained by the Smithsonian-Bredin Expedition to the Belgian Congo and 267 Australian decapod crustaceans purchased through the Richard Rathbun Fund from S. Kellner of Sydney.

Other valuable gifts included the personal collection of Associate Curator Charles E. Cutress, consisting of 1,056 coelenterates and other invertebrates from the Hawaiian and Marshall Islands, New Zealand, Oregon, and Florida; 2,326 miscellaneous marine invertebrates from the University of California, through Dr. Theodore H. Bullock; 75 porcellanid crabs from the Institut Français d'Afrique Noire, Dakar, through Dr. Théodore Monod; 300 isopods of the genus *Limnoria* from Dr. Robert J. Menzies, Lamont Geological Observatory, Palisades, N. Y., and 96 specimens of the nearly extinct shrimp *Barbouria cubensis* (von Martens) from Dr. Miguel L. Jaume, Museo y Biblioteca de Zoología de la Habana, Cuba. As an exchange, 37 copepods from the Indian Ocean were received from the Zoological Survey of India, Calcutta. Two comprehensive collections received as transfers—one from the U. S. Fish and Wildlife Service, comprising 1,269 crustaceans and other invertebrates from survey vessel collections in the Gulf of Mexico and off the southeastern United States, the other from the U. S. Navy Hydrographic Office—brought to the national collections plankton samples and other invertebrates amounting to more than 10,000 specimens from the Antarctic.

The division of mollusks was fortunate in receiving considerable material from regions poorly represented in its collections. An exchange from the Bernice P. Bishop Museum yielded 531 specimens from the Bonin Islands; 600 marine mollusks from Kuwait at the head of the Persian Gulf were sent in by Harrison M. Symmes; and 447 land and marine mollusks from Libya were collected for the Museum by Dr. Henry W. Setzer. Fine series of North American shells were received: 4,150 specimens from Arkansas including some paratypes from Henry E. Wheeler; 262 miscellaneous mollusks, including 4 holotypes of the new species of the genus *Conus*, donated by Dr. Jeanne S. Schwengel. For the helminthological collections Dr. Edwin J. Robinson, Jr., contributed the types of two new species of trematodes, and Prof. Helen I. Ward sent in the holotype of a new acanthocephalan. A specimen of the rare deepwater coral *Pocillopora modumanensis* Vaughan was donated to the coral section by the Bernice P. Bishop Museum.

Botany.—Notable gifts to the National Herbarium were 1,298 specimens of Brazilian plants, many from remote areas, contributed by the Instituto Agronomico do Norte, Belém, Brazil; and 823 grasses given by the Welsh Plant Breeding Station, University College of Wales, as voucher material of cytogenetic studies of *Lolium* and *Festuca*. A fine collection consisting of 420 slides and 56 photomicrographs of fossil diatoms from the Summulong Shale of the Philippine Islands was presented by Col. William D. Fleming. This accession was assembled by the late James Smith, of Pasadena, Calif., and will

be kept intact as a unit to be known as the James Smith Memorial Collection. C. V. Morton obtained 1,066 specimens of plants on his collecting trip to the Sawtooth Wilderness Area, Idaho.

Significant material from the Guayana Highland area, Venezuela, included 1,341 specimens sent by the New York Botanical Garden in exchange or with a request for identifications; and 330 specimens received from the Chicago Natural History Museum as a gift for names.

A valuable collection of 1,000 Brazilian plants collected by Amaro. Macedo was purchased by the Museum. More than 900 plants of Fiji and New Caledonia collected by H. S. McKee were acquired in part by purchase, in part for identification, and in part in exchange from the Botanical Gardens, Department of Agriculture, Sydney, Australia.

Among the numerous exchanges were 1,285 plants of New Guinea and Australia received from the Commonwealth Scientific and Industrial Research Organization, Canberra, Australia; and 1,769 specimens from the Academy of Natural Sciences of Philadelphia, including a number of historic importance from the United States and Latin American countries.

Two transfers were received from the Department of the Interior: 578 plants of Alaska collected by Victor H. Cahalane from the National Park Service; and 1,197 plants of Micronesia collected by F. R. Fosberg from the Geological Survey.

Geology.—Specimens of great scientific and historical value, made by the General Electric Co. and described by them as the first synthetic diamonds, make up one of the most unusual and interesting items added to the mineral collection in recent years. Among other fine and rare minerals received as gifts are: From Prof. A. Schoep a specimen of his new species likasite, a complex copper nitrate from the Belgian Congo; from Prof. F. Heide crystals of his new iron-boracite (ericaite) from the South Harz District, Germany; and several large masses of jadeite from a newly discovered locality in Guatemala, collected for the Museum by James Dupont.

Among the 564 specimens added to the Roebling collection were some of outstanding exhibition quality, including an 18-inch pink tourmaline crystal from Mozambique, a flawless peridot crystal from Burma weighing 455 carats, and a magnificent group of unusually large autunite crystals from the Daybreak mine near Spokane, Wash. From the led-zinc mines of Trepca, Yugoslavia, came a series of select crystallized specimens of pyrrhotite, sphalerite, and arsenopyrite. A magnificent specimen of the rare paradamite from the Ouelja mine, near Mapimi, Mexico, recently described as a new species by Dr. George Switzer, was obtained as an exchange.

Among the important specimens credited to the Canfield collection is a large specimen of brilliant green crystals of the copper silicate dioptase from French Equatorial Africa, and a large opal mass with brilliant fire from Virgin Valley, Nev.

Several unusual gems from Burma acquired by purchase from the Chamberlain fund for the Isaac Lea collection include a violet-colored spinal (30 carats), yellow danburite (18 carats), and yellow diopside (5 carats).

Eleven meteorites new to the collection, purchased through the Roebling fund, are: Cashion, Okla., Achilles, Kans., Bununu, Nigeria, Giroux, Can., Clover Springs, Ariz., Lombard, Mont., Briggsdale, Colo., Livingston, Mont., Ovid, Colo., Taiban, N. Mex., and Rifle, Colo.

Important gifts received in the division of invertebrate paleontology and paleobotany include types and figured specimens of Upper Cambrian brachiopods received from Dr. W. C. Bell, University of Texas; 4,500 specimens of Tertiary mollusks from Los Angeles County, Calif., presented by Mrs. Effie Clark; and 2,000 specimens of Lower Devonian fossils from Orange County, N. Y., given by Robert Finks of Brooklyn College. Important gifts of Foraminifera are: 94 type specimens from Venezuela donated by W. H. Blow; 28 type slides of Paleocene species from New Jersey given by Dr. J. Hofker; and 315 type slides from the Jurassic, Cretaceous, Paleocene, and Eocene of Egype presented by Dr. Rushdi Said.

The invertebrate fossil collections were further enhanced through field trips made possible from Walcott funds. Dr. A. R. Loeblich, Jr., and Dr. N. F. Sohl of the U. S. Geological Survey collected 32 microsamples from the early Tertiary of New Jersey. Dr. G. A. Cooper and R. J. Main brought back 12 foraminiferal samples and 2,000 specimens of Cretaceous mollusks from Texas. Purchases made with Walcott funds added to the collections 896 Tertiary Foraminifera and Ostracoda from Czechoslovakia through Dr. V. Pokorny, and 2,000 type Foraminifera from the Upper Cretaceous of Spain from Dr. J. R. Bataller.

More than 200 specimens of fossil fishes and reptiles from the Upper Cretaceous chalk of Kansas were collected for the division of vertebrate paleontology by Dr. D. H. Dunkle and G. D. Guadagni. Other notable accessions include a skeleton of the largest of the Permian pelycosaurs, *Cotylorhynchus*, received from the University of Oklahoma; 26 specimens of Mesozoic and Tertiary fishes of Europe and the Near East from the Carnegie Museum; and specimens of the Devonian arthrodire *Dinichthys*, and the shark *Cladoselache*, from the Cleveland Museum of Natural History. Particularly valuable to the study collections were: The subholostean fish *Ptycholepus* and the holostean

Semionotus, from the Upper Triassic in nearby Virginia, presented by Shelton Applegate of the University of Virginia; the lower jaws and skeletal portions of the rare Miocene porpoise *Phocageneus*, found by Rowland A. Fowler at Fairhaven Cliffs in Maryland; and a skull of the porpoise *Rhabdosteus*, collected also from Fairhaven Cliffs by Dr. Remington Kellogg, F. L. Pearce, and G. D. Guadagni. The first representation of an interesting fish, a suite of *Leptolepis nevadensis*, collected by Dr. Thomas B. Nolan from the Lower Cretaceous of Nevada, was transferred from the U. S. Geological Survey. The exceedingly rare Middle Eocene bowfin *Paramiatus gurleyi*, from the famous fossil fish quarries in the Green River formation near Fossil, Wyo., was purchased by Walcott funds.

Engineering and Industries.—A large collection of hydraulic machines from the pioneer turbine inventors Uriah Boyden, James B. Francis, and A. M. Sevain are welcome additions in the section of heavy machinery. These were presented by the Proprietors of Locks and Canals on Merrimac River, Lowell, Mass. Other important power machines received are an Otto and Langen gas engine, gift of the firm of Klöckner-Humboldt-Deutz, Germany; the first De Laval steam turbine exhibited in the United States, lent by the De Laval Steam Turbine Co.; the first steam engine built by M. W. Baldwin (1829) and a Corliss steam engine, gifts of the Franklin Institute; and a model of the world's first hydroelectric central station at Appleton, Wis., lent by the Wisconsin-Michigan Power Co. Further notable additions are: The steam velocipede built by Sylvester H. Roper about 1869 and the steam tricycle built by George A. Long about 1880, lent by John H. Bacon; the astronomic transit constructed by Repsold about 1860, from the U. S. Naval Observatory. From the Smithsonian Astrophysical Observatory examples were received of some of the important instruments developed by that bureau, such as Abbot's pyrheliometer and the vacuum bolometer.

Among the outstanding examples of the graphic arts are a lithograph, "Three Figures," by Georges Rouault, and a stencil print, "Compotier," by Pablo Picasso, presented by Mrs. Robert S. Schwab. Thirteen original pictorial photographs by Edward Weston were purchased through the Eickemeyer Fund.

Received in the division of medicine and public health are examples of recent advances in the field of medicine consisting of vials of poliomyelitis vaccine produced for the 1954 field trials by Wyeth Laboratories, Eli Lilly & Co., and Pitman-Moore Co., and hearing-aid apparatus made by the Sonotone Corp., Otarion, Inc., and Telex, Inc.

In the fields of woods and textiles, notable specimens received are a double length of an early nineteenth century damask tablecloth, made

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on a draw loom, gift of Mrs. Katherine Estey Cross, deceased, through her daughter, Mrs. John A. Bartlett, and a group of woods from Florida, Texas, and Mexico, received from Orville A. Oaks.

History.—Since the Museum has in its exhibition and study groups the only collection of White House china of any size, a concentrated effort has been made to expand this collection. Specimens of the state service designed for use in the newly decorated White House dining-room at the end of the Truman administration and continued in use as the state china during the Eisenhower administration were received as gifts from Lenox, Inc. Received as a gift from the Polk Memorial Association, Nashville, Tenn., is a dessert plate from the state china used in the White House during the Polk administration. The largest single donor of White House china was Col. Theodore Barnes, who presented a plate and a dessert cup from the official White House china of the Lincoln administration and two dessert plates from the state service of the Hayes administration.

Mrs. Dwight D. Eisenhower presented miscellaneous costume materials, including the pin she wore as an ornament on her wedding dress which is exhibited in the Museum. A magnificent garnet-red velvet dress worn by Rose Elizabeth Cleveland, sister of President Grover Cleveland and First Lady of the White House from his inauguration in 1885 until his marriage in 1886, was presented by Miss Constance H. Wood, niece of Miss Cleveland.

The division of military history received as a bequest of Albert G. McChesney a fine officer's sword of the period of the War of 1812 with a finely engraved scabbard and blued and gilded steel blade.

The most important additions to the philatelic collections are original sketches for stamp designs by the late President Franklin D. Roosevelt and autographed or initialed by him. These items were among 30,817 specimens lent by former Postmaster General James A. Farley. The Fish and Wildlife Service, Department of the Interior, transferred a complete set of 22 die proofs of the Migratory Bird Hunting (Duck) stamps believed to be the only complete set of die proofs outside the Bureau of Engraving and Printing. A worldwide collection of 71,726 varieties was received from Mrs. Theodore S. Palmer, in accordance with the will of her late husband, Dr. Theodore S. Palmer.

Outstanding accessions received in the division of numismatics are: 2 ten-thaler pieces of Brunswick-Luneburg struck in 1660; 2 gold coins of Albania and Egypt, presented by Paul A. Straub; and a series of 232 coins lent by the American Numismatic Association as an addition to their collection of twentieth-century foreign coins.

EXPLORATION AND FIELDWORK

To acquaint the exhibits staff engaged in preparing the displays which will be shown in the Cultural History Hall (No. 26) with the relationship of styles of furniture to types of architecture and the use of materials in the craftsmanship of the Colonial period, C. Malcolm Watkins, associate curator of ethnology, John E. Anglim, chief exhibits specialist, and Rolland O. Hower, exhibits specialist, in September 1955 visited a number of museums and historic houses in Massachusetts. Mr. Watkins devoted the last three days in December 1955 and the first four days in January 1956 to a search for documentary data on the history of the seventeenth-century "Bookhouse" installed in the Cultural History Hall (No. 26). He also selected and packed the Wires collection of tiles at Wellesley Hills for transportation to the U. S. National Museum. Before returning to Washington, Mr. Watkins examined the furniture, including Pennsylvania Dutch material, and paintings which Mrs. Arthur M. Greenwood is prepared to present for installation in the Cultural History Hall.

Dr. Clifford Evans, associate curator of archeology, studied the archeological collections of the University of Florida at Gainesville and collaborated with Dr. John M. Goggin on the analysis of specimens from Trinidad which have an important bearing on Dr. Evans's British Guiana excavations.

During November 1955 Dr. T. Dale Stewart, curator of physical anthropology, studied portions of the Todd Skeletal Collection at Western Reserve University, Cleveland.

Dr. Marshall T. Newman, associate curator of physical anthropology, conferred at Boston during November 1955 with members of the staffs of the Blood Grouping Laboratory of the Children's Hospital, the Climatic Research Laboratory, and the Nutritional Biochemical Laboratories of the Massachusetts Institute of Technology relative to suitable procedures to be followed in conducting physical and other studies on the Indians at Hacienda Vicos and elsewhere in the Callejon de Huaylas, Peru. On March 16, 1956, Dr. Newman departed for Lima, Peru, to inaugurate a research project financed by a grant from the National Science Foundation.

Following several preliminary survey visits in March 1956, Frank M. Setzler, head curator of anthropology, began excavations on April 2 at the site of Marlborough, Va., which was established as a port and county seat for Stafford County by acts of the Virginia Assembly dated 1691 and 1705 and which was abandoned sometime in the eighteenth century. Marlborough was located at Marlboro Point on the southern tip of Potomac Neck, a peninsula formed by Accokeek Creek on the west, Potomac Creek on the south, Potomac River on the east, and Aquia Creek on the north; the site is about 13 miles east of

Fredericksburg. The investigation is being carried on in collaboration with Prof. Oscar H. Darter, department of history, Mary Washington College, and C. Malcolm Watkins, associate curator of ethnology, U. S. National Museum, under a grant from the American Philosophical Society. The excavations have revealed the foundation of a house of large size which seems definitely to have been the one occupied by John Mercer during the first half of the eighteenth century. This determination is based mainly on documentary records together with cultural objects found, such as wine bottles bearing seals with Mercer's initials and the date 1737. A number of smaller house sites, probably dependencies of the main house, have been found, and in moving the earth a large amount of cultural material of the period was discovered. The excavations also revealed a series of walls, extending for hundreds of feet, which appear to represent lot lines and may indicate the layout of the original town shown on two existing surveys dated 1691 and 1731.

At the University of Michigan during the first week of February 1956, Dr. Egbert H. Walker, associate curator of phanerogams, conferred with Dr. W. H. Wagner relative to certain species of ferns found on Okinawa and the southern Ryukyu Islands, which will be included in his flora of that region. Subsequently he worked with Dr. F. G. Meyer and Dr. J. Ohwi at the Missouri Botanical Garden, St. Louis, in the editing of a manuscript translation of a Flora of Japan.

Edward C. Kendall, associate curator of crafts and industries, systematically studied the historical agricultural implements displayed in the Centennial of Farm Mechanization at Michigan State University, East Lansing, in August 1955. Consultations were held with representatives of agricultural implement manufacturers for the purpose of procuring historically important implements to illustrate chronological stages in the mechanization of farming.

Dr. Robert P. Multhauf, acting head curator of engineering and industries, consulted with Orville R. Hagans, horologist of "Clock Manor," Denver, regarding the repair of clocks in the national collections. At San Francisco during August 1955 he studied the exhibits in the Maritime Museum and conferred with the director, Karl Kortum, regarding the contemplated extensive display of land transportation. Continuing his search for an old Pelton turbine for the Power Hall, Dr. Multhauf conferred with Richard Goyne, owner of the Miners Foundry, Nevada City, Calif., where these turbines were reportedly first manufactured. A wooden-wheel type which may represent one of the oldest Pelton turbines still in existence was located. During the last week of October 1955 Dr. Multhauf visited several sites in New England in an effort to locate old water turbines for display in the reconstructed Power Hall. Nine old sites where water

turbines were formerly operated were visited. The collection of measuring instruments at Old Sturbridge Village was studied. Brief visits were made also to the Patent Museum at Plymouth, N. H., the Shelburne Museum at Shelburne, Vt., in which are displayed large carriage and tool collections, and the small museum maintained by the Proprietors of the Locks and Canals of Merrimack River, Lowell, Mass.

Data and ideas that contributed materially to the planning of the new health hall were obtained by George Griffenhagen, curator of medicine and public health, during a European trip August 11 to September 23, 1955. Pharmaceutical and other medical collections were reviewed in London, particularly the medical museums in the Wellcome Building, the British Museum, and the Victoria and Albert Museum. The recently installed apothecary shop restoration at Leeds and the pharmaceutical antiquities in the Castle Museum and the Yorkshire Museum were examined. At Paris, Dr. Maurice Bouvet, president of the World Union of Societies of Pharmaceutical History, devoted a day to the showing of materials in his personal collection and in the Faculty of Pharmacy. At Basel Mr. Griffenhagen was shown the Castiglione collection of pharmaceutical majolica belonging to Hoffmann La Roche, and subsequently he viewed the pharmaceutical antiquities in the Schweizer Pharmazie Historische Museum and the Historisches Museum. At Waldenbuch, Germany, the Dörr Pharmaceutical Museum collection was the primary point of interest. After visiting the Deutsches Museum at Munich, Mr. Griffenhagen proceeded to Garmisch-Partenkirchen to examine an original Roentgen X-ray tube as well as the private collection of pharmaceutical antiques of Franz Winkler. Particular attention was paid to the pharmaceutical antiques and apothecary shop restorations in the Germanisches National Museum at Nuremberg and the Deutsches Apotheke Museum at Bamberg. Officials of the German Health Museum, Cologne, were consulted in regard to arrangements for the procurement of a transparent woman for the Hall of Health. The Rijksmuseum and the Medical-Pharmaceutical Museum in Amsterdam and the Rijksmuseum voor de Geschiedenis der Natuurwetenschappen in Leiden were visited. Following his return to London, Mr. Griffenhagen reviewed the special exhibits displayed at the meeting of the Federation Internationale Pharmaceutique.

Precise specifications for exhibits required in the planning for the Hall of Health were requested from Dr. Bruno Gebhard, director, Cleveland Health Museum, by George Griffenhagen and Benjamin Lawless, exhibits specialist, during October 1955. Old prints which will be reproduced in medical history panels were studied in the Rare Book Division of the Armed Forces Medical Library. Mr. Griffen-

hagen continued on to Chicago for consultations with the staff of the American Medical Association and with Dr. Max Thorek, founder of the Museum and Hall of Fame of the International College of Surgeons. Madison, Wis., was included in this trip for consultations with Dr. George Urdang and Alex Berman of the American Institute of the History of Pharmacy in regard to several projects related to the planning of exhibits.

For the purpose of advancing the planning for the Hall of Health, Messrs. Griffenhagen and Lawless, during the period February 5–10, 1956, traveled to Boston to study the health exhibits in the Science Museum, the Ether Dome and the Museum of the Massachusetts General Hospital, and the Museum of the Massachusetts College of Pharmacy. At New York visits were made to the New York Historical Society for materials to be incorporated in the Food and Drug Administration exhibit, to the Hall of Man in the American Museum of Natural History, to the Hispanic Society of America Museum for data relating to Spanish majolica, to the Wood Library-Museum of Anesthesiology to examine anesthesia equipment and to inspect the medical-instrument collection of Dr. Bruno Kisch. Data relating to Italian majolica were sought at the Metropolitan Museum. The secretary of the American College of Cardiology, Dr. Philip Reichert, gave permission for the loan of examples of stethoscope and manometer for display in the Gallery of Medical History. Data relating to health exhibits were obtained from the Lankenau Hospital Health Museum, Philadelphia. The giant heart exhibit at the Franklin Institute was studied, and visits were made also to the Pennsylvania Hospital and the Philadelphia College of Physicians to inspect the historical collections.

At New York, during October 1955, Frank A. Taylor, Assistant Director, and Dr. Multhauf studied the Atomic Energy Commission exhibit which had been shown at Geneva. In addition to a series of plexiglass models of atomic-energy powerplants and devices for the handling and chemical analysis of radioactive materials, exhibits relating to the uses of atomic energy in medicine, agriculture, and other fundamental activities occupied about half of the floor space.

Dr. Multhauf and Mr. Kendall during November 1955 proceeded to the Pennsylvania State University and to the Priestley Museum at Northumberland, Pa., to locate and examine laboratory equipment used by Joseph Priestley and to arrange for the return to the National Museum of Priestley materials that had been lent to that museum.

Planning of the projected exhibits for the Museum of History and Technology was advanced by the comparative studies made by Dr. Multhauf, during the three weeks' tour of European museums, March 18 to May 6, 1956. He was advised that the Museo Nationale della

Scienza e della Tecnica, Milan, Deutsches Museum, Munich, Technische Museum, Vienna, and Science Museum, London, are undertaking enlargement of existing facilities and that similar plans had been made for the Conservatoire National des Arts et Métiers, Paris. This activity conveys some indication of the present lively interest in the history of technology in Europe. The museums in Munich and Milan are housed in buildings heavily damaged by war, but since repaired. The exhibits techniques at Munich were very effective and represent a marked improvement over the prewar museum. Many novel techniques were noted which can be adopted advantageously. The following museums feature physical science and the history of science: Palais de la Découverte, Paris; Museo di Storia della Scienza, Florence; Liebig Museum, Giessen; Scientific Collections, Landesmuseum, Kassel; Museum of History of Science, Leiden; Teyler's Museum, Haarlem; Whipple Museum, Cambridge; History of Science Museum, Oxford; and Berzelius Museum, Stockholm. The Palais de la Découverte is a unique example of a museum that aims to instruct in the principles of science from the simplest to its most abstruse aspects through pushbutton and demonstration exhibits. The abovelisted museums possess unusual materials representing the science of the seventeenth and eighteenth centuries. Of the three marine museums visited, the Scheepvaarts Museum, Amsterdam, exihibits many unique navigational instruments, books, and maps. The Musée de Marine, Paris, has been renovated recently, but seems to have sacrificed maritime history to the exigencies of exhibits technique. In the Greenwich Naval Museum, England, the history of the British Navy is effectively and logically shown in spacious rooms.

Print storage methods and exhibition furniture were inspected by Jacob Kainen, curator of graphic arts, in California institutions during March 1956. On the same trip his research on the life and work of John Baptist Jackson was advanced by examination of chiaroscuro color prints in the Achenbach Foundation for Graphic Arts in San Francisco. The collection of eighteenth-century color prints in the M. H. de Young Memorial Museum and late nineteenth- and twentieth-century color prints in the San Francisco Museum of Art, as well as reference works in the library of the Art Room of the San Francisco Public Library, were consulted. Jackson prints and other pertinent material were inspected in the Los Angeles County Museum, as well as the collections of fine and decorative arts. Early books printed in color were examined in the Huntington Library and Art Gallery in San Marino.

Dr. George S. Switzer, associate curator of mineralogy and petrology, inspected the John B. Jago mineral collection in San Francisco, Calif., during July 1955 and conferred with the owner regarding his

plans for its future disposition. In November 1955 he made a selection of minerals at Easthampton, Mass., for the Roebling collection and also conferred with the staff of the department of mineralogy of Harvard University.

In the interest of enhancing the usefulness of the national collection of meteorites, E. P. Henderson, associate curator of mineralogy and petrology, and F. E. Holden, physical science aide, were engaged from September 6 to October 8, 1955, in inspecting the collections of the Institute of Meteorites at the University of New Mexico, the museum at Meteor Crater, Ariz., the Meteorite Museum at Sedona, Ariz., the Museum at Fort Hayes, Kans., and Texas Christian University at Fort Worth, Tex. Private collections owned by A. R. Allen, Trinidad, Colo., H. O. Stockwell, Hutchinson, Kans., and Oscar Monnig, Fort Worth, Tex., were also studied. Data and photographs of meteorites for research and reference purposes not otherwise available were obtained by these visits. Five meteorites were presented for the national collections by H. O. Stockwell, two unrepresented iron meteorites by Oscar Monnig, and one large iron meteorite by H. H. Nininger.

Prospecting in the field for suitable fish and amphibian fossils for inclusion in the planned Hall of Lower Vertebrates was conducted by Dr. David H. Dunkle, associate curator of vertebrate paleontology, and G. D. Guadagni, preparator, during the summer of 1955. While en route to Kansas, arrangements were made at the Carnegie Museum, Pittsburgh, for the transfer on an exchange basis of specimens of European Mesozoic holostean fishes and of late Cretaceous and Eocene teleosts. In northwestern Ohio a worthwhile collection of disassociated fish bones was obtained at the level of contact between the middle Devonian Praut limestone and the base of the black upper Devonian Ohio shales formation. Through the cooperation of George F. Sternberg, curator of the Museum at Fort Hays State College, arrangements had been made for a camping site on the R. W. Haverfield ranch in southwestern Gove County. From the upper Cretaceous Niobrara chalk formation in badlands locally known as Hell's Bar and later in other exposures on one of the Ben Christie ranches such typical fishes as *Cimolichthys*, *Portheus*, *Syllaemus*, *Enchodus*, *Protosphyraena*, *Gillicus*, and *Kansanius* were excavated. One of the most unusual recoveries were entire schools of the small acanthopterygian fish *Kansanius*, found preserved on the insides of giant shells of the clam *Inoceramus*.

In continuation of the search for exhibition specimens, Dr. Dunkle, accompanied by Franklin L. Pearce, in charge of the divisional preparatory staff, proceeded on October 27, 1955, to Norman, Okla., where advice was received from Dr. Carl Branson, of the Oklahoma Geological Survey and School of Geology, and Dr. Stephen Borhegyi,

director of the Oklahoma University Museum, regarding the location of exposures of the Permian Hennessey formation that had previously yielded skeletons of the large pelycosaur *Cotylorhynchus*. Although five specimens of this unique reptile were located, only one incomplete young individual merited the work involved in excavation. As a result arrangements were made with the University Museum to obtain a skeleton on an exchange basis. Dr. Dunkle's party then traveled to Richard's Spur, Okla., where 11 bags of Permian bone-bearing matrix were removed from solution fissures in Ordovician limestone. Arriving in Austin, Tex., on November 10, 1955, they were given an opportunity by Dr. John A. Wilson to examine the vertebrate fossil collections at the University of Texas. Preliminary conversations were held regarding some basis for exchange of materials. On November 15 and 16, 1955, a brief reconnaissance of the upper Cretaceous beds of the Big Bend area, Texas, was made under the guidance of David Jones, assistant superintendent of the Big Bend National Park, with a view to evaluating the possibilities for procurement of dinosaurs which will ultimately be needed for display. An exchange of upper Devonian marine fossils between this Institution and the Cleveland Museum of Natural History was completed April 16–20, 1956, by Dr. Dunkle. Skeletal materials representing a very large shark, *Cladoselache*, and the arthrodire *Dinichthys* were selected and delivered to the Museum.

Inasmuch as the Museum lacked a suitable representation of upper Devonian fishes, Dr. Dunkle conducted fieldwork in the fresh-water sediments exposed along the shores of Escuminac Bay at Maguasha, Province of Quebec, Canada. These sediments yield well-preserved specimens of lungfishes, fringed-finned fishes, antiarch, and, less commonly, acanthodians, arthrodires, and palaeoniscoids, all of which are important in any synoptic display in the exhibition hall. Prior to commencing fieldwork, cooperative help had been obtained from the National Museum of Canada, Ottawa, and the Royal Ontario Museum, Toronto. While en route to Canada, Dr. Dunkle visited the Dartmouth College Museum to make preliminary arrangements for an exchange of upper Silurian ostracoderms. In Canada, consultations were held with Dr. I. W. Jones, director, Quebec Geological Survey, and with Abbe Laverdirere, chairman, Department of Geology, Laval University, Quebec City. On the return trip early Mississippian palaeoniscoid fishes were sought at Albert Mines, as well as at the well-known Devonian occurrences at Cambellton, both localities in New Brunswick. This trip extended from May 21 to June 30, 1956.

The Walcott bequest financed the trip to a locality near Burnet, Tex., where Dr. David Nicol, associate curator of invertebrate paleontology, and Robert J. Main, Jr., aide in that division, obtained fossil

mollusks from exposures of the Glenrose formation. At Lipan, Tex., samples of the Pennsylvanian Dickerson shale were collected. This trip extended from July 28 to August 13, 1955.

Income from the same bequest provided funds for the paleontological fieldwork of Dr. G. A. Cooper, curator of invertebrate paleontology and paleobotany. At Fort Worth, Tex., he took charge of the Smithsonian truck and accompanied by Mr. Main proceeded to Ardmore, Okla., where they spent three days collecting Pennsylvanian invertebrate fossils. From Ardmore they traveled to Muskogee and Pryor for material from beds of Mississippian age. At Neosho, Mo., they collected Mississippian productid brachiopods, Pennsylvanian fossils at Bartlesville, Okla., and subsequently Permian fossils in Cowley County, Kans. Other materials were collected in Kansas and Nebraska, and a large collection of Mississippian fossils was made near Harrison, Ark. This field party returned to Washington September 17, 1955. A profitable discussion of problems involved in his Permian studies on the Glass Mountain fauna was held with Dr. Carl Dunbar, Peabody Museum, Yale University, by Dr. Cooper in February 1956. An arrangement was made to secure by exchange some examples of Greenland Permian invertebrates.

Dr. A. R. Loeblich, Jr., associate curator of invertebrate paleontology, devoted four days, April 10–13, 1956, to the collection of Paleocene and Cretaceous Foraminifera in New Jersey in strata that are of disputed age. The material obtained was not previously represented in the national collections.

Mrs. Margaret Brown Klapthor, associate curator of civil history, was invited to lecture at the historic-housekeeping course sponsored by the National Trust and the New York State Historical Association at Cooperstown, N. Y., the last week in September 1955. During October 1955, while attending the meeting of the National Trust at Nashville, Tenn., Mrs. Klapthor acquired for the national collections a dessert plate of the Polk White House china, Mrs. Polk's lace fan, and a pair of spectacles owned by President Polk.

During late August and early September 1955, Mendel L. Peterson, acting head curator of history, inspected all existing specimens of early artillery now preserved at Albany, N. Y., the Saratoga battlefield, Fort William Henry, The Citadel on the ramparts, Fort Ticonderoga, and the Plains of Abraham battlefield in Quebec, Canada, for the purpose of advancing the completion of his report on the marking and decoration of these military objects. Transportation furnished by Life Magazine enabled Mr. Peterson to proceed to Bermuda to investigate a collection of objects of probable early seventeenth-century origin recovered from a sunken ship presumably of French registry which had been wrecked there. The ordinary imple-

ments of shipboard use were French, while the gold bar, cakes of gold, gold buttons, and silver coins were Spanish.

From June 21 to November 24, 1955, Frederick M. Bayer, associate curator of marine invertebrates, participated in a biological survey of the coral reef and other marine habitats found in the Palau Islands Archipelago, sponsored jointly by the Office of Naval Research, the Pacific Science Board of the National Academy of Sciences, the George Vanderbilt Foundation of Stanford University, and the Trust Territory of the Pacific Islands, and directed by Dr. R. R. Harry of Stanford University. An ecological resurvey was made of Iwayama Bay, Koror Island, to supplement the survey made 20 years previously by members of the Japanese Palao Tropical Biological Station. Circumscribed problems of more specific interest, such as epizootic associates of gorgonian corals, parasitic mollusks, crustaceans associated with coelenterates, sea anemones and their biological associates, and the relationship of hole-dwelling gobies with burrowing shrimps, were selected for thorough investigation. The team cooperated in obtaining information on the injurious, poisonous, and noxious animals of the reef complex. In September Dr. Harry and Mr. Bayer visited Japan to consult with former members in regard to the research of the Palau station and to trace the location of biological collections obtained there before War II. They returned to Koror on October 7 and terminated fieldwork there on November 15.

Dr. Harald A. Rehder, curator of mollusks, was given a detail September 19–29, 1955, to pack up and arrange for transportation of a collection of mollusks at the New York State Museum that had been transferred to the Museum on an exchange basis.

Dr. David H. Johnson, acting curator of mammals, and John L. Paradiso, aide, were engaged from September 12 to 15, 1955, in moving and loading whale skeletons at the Academy of Natural Sciences of Philadelphia for transfer to the Museum.

Under an Office of Naval Research contract, Dr. Henry W. Setzer, associate curator of mammals, left Washington on September 16, 1955, for Tripoli, Libya, to conduct the field study requested by Naval Medical Research Unit No. 3. Fieldwork was carried on from 18 different camps ranging from Tripoli to Derna and to Sebha Oasis in the interior. Ectoparasites and mammals were collected.

As part of a long-term project on the zoogeography of the southern Appalachian Highlands, Dr. Charles O. Handley, Jr., associate curator of mammals, devoted the period from September 12 to 26, 1955, to collecting mammals near Mountain Lake, Giles County, Va. Taxonomic problems involving southern African and neotropical mammals necessitated an examination of pertinent comparative specimens by Dr. Handley at the Chicago Natural History Museum, January

16–20, 1956. During April 1956 Dr. Handley, with Mr. Paradiso as assistant, made a collection of small mammals in the generally neglected salt-marsh areas of the Middle Atlantic States. Particular effort was made to secure material at Back Bay in southeastern Virginia, Assateague Island off Delmarva Peninsula, and Oceanville in southern New Jersey.

A grant from the American Philosophical Society enabled Dr. J. F. Gates Clarke, curator of insects, to obtain larvae and rear moths of the family Oecophoridae and to determine the host specificity of these moths and their relationship to plants of the family Umbelliferae. Specimens were collected and host observations were made at 71 stations mainly in Wyoming, Utah, Idaho, Oregon, and Washington, as well as at scattered localities in Montana, North Dakota, Wisconsin, Minnesota, and Michigan.

Dr. Ernest A. Lachner, associate curator of fishes, was awarded a fellowship by the John Simon Guggenheim Foundation for the purpose of advancing his research studies on tropical marine and North American fresh-water fishes. Examination of type specimens and other pertinent material will be made at various European museums. Dr. Lachner left Washington for London on March 8, 1956.

Mr. and Mrs. Bruce Bredin, of Greenville, Del., presented funds to the Smithsonian Institution to finance a collecting expedition. These funds were used to finance a Caribbean field study. The Smithsonian party comprised Dr. Waldo L. Schmitt, leader, Dr. A. C. Smith, Dr. J. F. Gates Clarke, and Dr. Fenner A. Chace, Jr. The expedition left Trinidad on March 13, 1956, for visits to Grenada, several of the Grenadines, and Martinique. Other stops included anchorages at Dominica, Guadeloupe, Barbuda, Redonda, Nevis, St. Christopher, Virgin Gorda, and Tortola, and terminated at St. Croix. A number of interesting observations of shore fauna, including shrimp commensal with anemones, and windrows of red-crab megalops on the beach were made. Several thousand crustaceans were collected by Drs. Schmitt and Chace, as well as crinoids, starfish, sea-urchins, sea-hares, and cephalopods. On arrival at Trinidad Dr. Smith, curator of phanerogams, proceeded directly to the field station of the New York Zoological Society at Simla, Arima Valley, where he spent five days collecting plants on the crest and slopes of the northern range and preparing the material. Botanical collections were made on 11 islands, and more than 4,000 specimens were prepared for herbarium study. Dr. Clarke, curator of insects, traveled from Washington to Dominica by airplane and collected insects there in the interval between March 8 and 28 and then joined the party on the schooner at Roseau. Some 20,000 insects were obtained. V. E. B. Nicholson, captain of the *Freelance*, the schooner used by the expedition, was ex-

tremely helpful to members of this party and materially assisted in the collection of marine animals. Drs. Clarke and Smith departed for Washington from St. Croix, Virgin Islands, by air on April 19 and 20, respectively. Drs. Schmitt and Chace sailed from St. Croix on the Alcoa *Runner* on April 23.

Between September 2 and 26, 1955, W. L. Brown, chief zoological exhibits preparator, visited Glacier and Yellowstone National Parks to procure photographs and other background data for authentic habitat settings for the grizzly-bear and elk groups. Alpine fir, limber pine, various grasses, flowers, soils, and rocks were secured for the bear group. At Gardiner, Mont., sage bushes and grasses were selected and shipped for inclusion in the elk unit.

On December 2, Dr. Alexander Wetmore, research associate and former Secretary of the Smithsonian Institution, reached Panamá for a further season of fieldwork concerned with the distribution of the birdlife of the Isthmus. Work during the first month was devoted to studies on the Río Chagres, from a base at the Juan Mina field station of the Gorgas Memorial Laboratory for Tropical Medicine, and other investigations in and near the Canal Zone, including a few days on Taboga and nearby islands. At the beginning of January, through the interest of Dr. Alejandro Méndez P., director of the Museo Nacional of Panamá, and of His Excellency Alejandro Remón C., Minister of Government and Justice, Col. Bolívar Vallarino, Comandante Jefe of the Guardia Nacional, kindly gave the necessary permission and instructions for a month's stay on Coiba Island. This, the largest island on the Pacific coast of Central America, has been the location of the penal colony of the Republic of Panamá since 1919. With the friendly cooperation of Col. J. W. Oberdorf, commanding officer, Albrook Air Base, transportation to Coiba and return on completion of the work were arranged in an Air Force crashboat. On arrival at the Colonia Penal on January 6, Dr. Wetmore and his two assistants were assigned quarters by Capt. J. A. Souza, in command, and were given all needed assistance in their work, which continued until February 6. The island is covered with high gallery forest, with mangrove swamps at the mouths of the numerous rivers. Clearings for pasture and cultivation have been cut back of the convict work camps, which are located along the Bahía de Damas and on the eastern side north to Punta Aguja. The interior of the island, which rises to an elevation of 1,400 feet, remains in its primitive condition, without trails except in limited areas. Birds are common and of good variety, though many of the familiar forest species of the mainland do not occur in spite of conditions favorable to them. The heavy rainfall is reflected in darker coloration in various of the smaller kinds, several of which are new to science, some being remarkably distinct from

their mainland representatives. Following return to the mainland, work continued until the end of February, with San Félix in eastern Chiriquí as a base. Collections made here over a considerable area between the seacoast and the inland mountains offer many valuable data in plotting distribution. Most of the original forest has been cut to provide pastureland, so the information secured is of special importance since soon all forest areas will be gone. After some further observations at Barro Colorado Island and on the savannas near Pacora, work for the season terminated on March 10.

EXHIBITION

Modernization of selected exhibition halls was continued in 1956 by a Congressional allotment of $411,500. Construction by outside contractors began in the Power Hall in July 1955. Contracts were awarded for the second American Indian Hall in April 1956 and the Health Hall in May 1956; construction was commenced in these halls in May and June 1956, respectively. During March 1956, the new Bird Hall and the east side of the North American Mammal Hall were completed and opened for public inspection.

The new Bird Hall, after months of planning by Curator Herbert Friedmann, was officially opened to the public on March 22, 1956, at an evening reception sponsored jointly by the Smithsonian Institution and the Audubon Society of the District of Columbia. John E. Graf, Assistant Secretary of the Smithsonian Institution, reviewed the program for modernization of exhibits, and Irston R. Barnes, president of the District of Columbia Audubon Society, commented on the interest shown by ornithologists in the methods employed for presentation of topical exhibits. Guy Emerson, honorary president of the National Association of Audubon Societies, complimented the Institution and Dr. Friedmann on the successful completion of this hall and cut the ribbon, thereby officially opening the hall.

In the hall of North American Mammals, habitat groups for the puma, wolf, pronghorn antelope, and white-tailed deer were opened to the public. Four previously completed groups were again shown to visitors after being shut off by construction work for more than a year.

During the current fiscal year, 37 new exhibit units, miniature dioramas, and life-size lay figures are being developed in the second Indian hall. These units will portray the manner of living of Indian tribes that formerly occupied the forested eastern third of the United States; the nomadic hunting tribes of the Great Plains; the salmon-fishing and totempole-building Indians of the Northwest Pacific coast; and the Arctic Eskimo of Greenland and Alaska. The over-all plans for this hall and the case layouts were prepared by Associate Curator John C. Ewers in collaboration with Exhibits Specialist John E.

Anglim and his staff. The installation of the exhibits portraying colonial life in eastern North America is proceeding satisfactorily in Hall 26. Six period rooms have been installed. Of these the Reuben Bliss parlor (1754) is the oldest. Among others are a late Georgian colonial parlor from Sussex, Va., an early nineteenth-century schoolroom, and a farmhouse bedroom of about 1800.

Plans were completed in the division of mineralogy and petrology for the layout of the Mineral Hall. Exhibits to illustrate the origin, properties, and mode of occurrence of minerals will be prepared, in addition to displays of the major minerals of the world. Outstanding examples of uncut crystals of the more important gem minerals, as well as series of cut and polished gems, will be utilized to make an informative presentation of this phase of mineralogy.

The hall for display of fossil plants and invertebrates will provide the visitor with some concepton of what fossils are, how they are preserved, and their role as geological time indicators. Reconstructed assemblages of fossil animals and plants from some of the geologic periods will be utilized to portray the ecological associations that made possible their mode of life.

Selection and preparation of specimens of lower vertebrates for display in Hall 3 are being actively continued in the laboratory of vertebrate paleontology. Associate Curator Dr. David H. Dunkle was successful in his search for upper Cretaceous marine fishes in the Niobrara chalk of western Kansas, and for upper Devonian fishes in the fresh-water sediments of the Province of Quebec, Canada. Other lower vertebrates were acquired on an exchange basis to complete the developmental series in the systematic exhibits.

A display case containing manmade diamonds sorted in compartments in accordance with size was presented on May 3, 1956, by Dr. C. G. Suits, vice president of General Electric Co., to Dr. Leonard Carmichael, Secretary of the Smithsonian Institution, for inclusion in the gem exhibit in the Natural History Building. At the presentation ceremony Dr. Suits introduced the technical team responsible for the development of the process that made manufacture feasible.

An exhibit illustrating the history of iron and steel production in the United States was opened on January 11, 1956, in the Arts and Industries Building by Secretary Carmichael and John C. Long, of the Bethlehem Steel Co. This exhibit traces in 10 units the development of the industry from the discovery of iron ore to the high-alloy steels of today. Outstanding features of the exhibit are a group of early artifacts from the excavations at Jamestown, Va.; a section of the massive Hudson River chain swung into place near West Point, N. Y., on April 16, 1778, to prevent the British from sailing to the upper river; and rare examples of American iron and steel work from the nineteenth century.

Modernization of the Power Hall was delayed several months by a shortage of steel, but it is now nearing completion. Models of types of power machinery no longer available for acquisition have been constructed and a number of machines hitherto unrepresented in the national collections have been acquired.

Four of the older makes of automobiles have been refurbished during the past fiscal year. The 1903 Cadillac, the 1903 Oldsmobile, and the 1913 Ford were reconditioned through the courtesy of the Cadillac, Oldsmobile, and Ford companies. The 1901 Autocar was reconditioned by the Autocar Division of the White Motor Co. The return of these cars to the exhibition floor markedly improved this portion of the section of land transportation.

The gallery exhibit of the section of scientific instruments now consists of 12 units devoted to various fields, beginning with weights and measures and ending with astrophysics. Each case is designed to tell the story of the mechanical development of some instrument. The section devoted to typewriters, phonographs, and calculating machines was greatly improved by repainting and lettering, as was the section of manufactures by the installation of special lighting fixtures. Loom products of the early nineteenth century weaver Peter Stauffer, the small hand sewing machine, and the safety factor of after-dark pedestrian garments were featured in new display units in the section of textiles.

Of the 35 new exhibit units illustrating photomechanical printing, in the chapel of the Smithsonian Building, 26 were completed during the past year. Selected examples of photogravure, rotogravure, relief halftone and the halftone screen, collotype, photolithography, and offset lithography are included in the display. The special monthly exhibits by contemporary printmakers and photographers were continued in addition to short-term displays of materials drawn from the collections.

Individual exhibit units for the Hall of Health have for the most part beeen designeed, the contents have been selected, and descriptive text for many of the labels has been written. Construction work on this hall has commenced. A series of 30 oil paintings depicting the history of pharmacy lent by Parke, Davis & Co. was formally opened for public view on September 30, 1955, at a ceremony attended by Secretary Carmichael, George A. Bender, Robert A. Thom, the artist, and Dr. Robert P. Fischelis, secretary of the American Pharmaceutical Association.

Eleven new exhibits were installed in the gallery of Medical History during the year. An informative display unit labeled "Vitamins for Health, Growth and Life," prepared for the exhibit series of the division of medicine and public health by Merck & Co., was

accepted from Dr. W. H. McLean by Secretary Carmichael on February 1, 1956. The 10 principal vitamins are shown inside revolving transparent globes. Outstanding historical facts on vitamin development are illustrated. Display panels entitled "Dr. Wiley's Crusade," "Fifty Years of Progress in Food and Drug Protection," and "How Food and Drug Administration Protects You Today" were formally presented for public view on May 4, 1956, at a ceremony attended by Bradshaw Mintner, the Assistant Secretary of the Department of Health, Education, and Welfare, Dr. George P. Larrick, Commissioner of the Food and Drug Administration, Mrs. Harvey W. Wiley, Mrs. Grace Drexler Nichols, executive director of the General Federation of Women's Clubs which supported Dr. Wiley's crusade, and Secretary Carmichael. These three panels commemorate the fiftieth anniversary of the enactment of the Federal Food and Drug legislation.

Substantial progress was made during the year on the installation of the uniform and insignia display on the West Hall gallery. Glass screens were placed over the fluorescent lights to protect the materials from fading, printed labels were prepared for many of the specimens, and various items of personal adornment were installed.

The United States section of the National Postage Stamp Collection was completely remounted and placed in the floor frames for public viewing during the past fiscal year. Special displays of postal materials were made available to the Fifth International Philatelic Exhibition, held in the new Coliseum in New York, April 28–May 6, 1956, and at the American Stamp Dealer's Association shows in New York, Chicago, and Los Angeles.

VISITORS

During the fiscal year 1956 there were 3,520,106 visitors to the Museum buildings, an average daily attendance of 10,028. This is an increase of 207,236 over the total in the previous fiscal year. Included in this total are 385,187 school children, who arrived in 10,457 separate groups. Among the visitors this year were special groups such as the 4–H Club and the Safety Patrol. The month of April 1956 drew the largest crowd with 572,368 visitors. May 1956 was the second largest with 517,447 and June 1956 was third with 421,107. Attendance records for the buildings show the following numbers of visitors: Smithsonian Building, 716,048; Arts and Industries Building, 1,796,480; and Natural History Building, 1,007,578.

BUILDINGS AND EQUIPMENT

A contract between the Government and the architectural firm of McKim, Mead & White for the design of the Museum of History and

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Technology building was signed on March 16, 1956. A program of the requirements for the building based on many years of study by the Smithsonian staff was presented to the architects, and the work of designing a building that will effectively serve the Museum and the public is progressing well. Schedules of work anticipate that working drawings will be sufficiently advanced to permit bids to be asked for the construction of the building in the spring of 1957. Legislation appropriating $33,712,000 for the construction of the building passed both the House and the Senate in the second session of the 84th Congress. This legislation (Public Law 573) was signed by the President on June 13, 1956. The total amount appropriated for this building is $36,000,000.

The Secretary designated Frank A. Taylor, Assistant Director of the United States National Museum, staff liaison with the architects. The Planning Office was established to develop plans and requirements for the building and its exhibits. John C. Ewers, associate curator in the division of ethnology, was promoted to planning officer, and J. H. Morrissey, architect of the Public Buildings Service, was assigned to the Smithsonian by the General Services Administration to assist in the planning.

CHANGES IN ORGANIZATION AND STAFF

Frank A. Taylor, previously head curator of the department of engineering and industries, was promoted to Assistant Director of the Museum on August 7, 1955.

Charles E. Cutress, Jr., a coelenterate specialist, was appointed associate curator in the division of marine invertebrates, effective January 3, 1956.

The department of history lost through death on February 20, 1956, the valuable services of Stuart M. Mosher, associate curator of numismatics.

John C. Ewers, associate curator of the division of ethnology, was transferred to the office of the assistant director to serve as planning officer for the Museum of History and Technology, effective February 26, 1956.

G. Carroll Lindsay was appointed assistant curator, division of ethnology, effective February 20, 1956.

During January and February 1956, a reorganization of the exhibits staff was effected with the promotion of John E. Anglim to chief exhibits specialist, R. O. Hower and Benjamin Lawless to exhibits specialists, and William L. Brown to chief zoological exhibits specialist.

Dr. William F. Foshag, head curator of the department of geology since August 1948, and a member of the staff of that department from June 1919, died May 21, 1956, of a heart attack at his home in West-

moreland Hills, Md. During the 37 years since graduation from the University of California with a degree in chemistry, Dr. Foshag advanced knowledge of the minerals of Mexico particularly and of the world. Borax minerals claimed his interest for several years. While assigned for work in Mexico during World War II, he witnessed the early stages in the origin of the Parícutin Volcano and followed its growth until activity subsided.

Four members of the honorary scientific staff were lost through death during the fiscal year. Dr. Theodore S. Palmer, a member of the staff of the Bureau of Biological Survey, U. S. Department of Agriculture, for 44 years and an associate in zoology of the National Museum since August 1, 1933, died at his home in Washington, D. C., on July 23, 1955, at the age of 87. Dr. Frank L. Hess, custodian of rare metals and rare earths in the division of mineralogy and petrology since December 11, 1917, died August 29, 1955, in Washington, D. C., at the age of 83. Prior to 1925 Dr. Hess had been employed by the U. S. Geological Survey, and from that time until his retirement in 1944, by the Bureau of Mines. William B. Marshall, assistant curator in the division of mollusks until his retirement in 1934 and associate in zoology since May 1, 1934, died in Washington, D. C., on December 18, 1955, at the age of 91. Gerrit S. Miller, Jr., curator of the division of mammals for 42 years and research associate of the Smithsonian Institution since January 1, 1941, died in Washington on February 24, 1956, at the age of 84.

Respectfully submitted.

Remington Kellogg, *Director.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

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, 1956, conducted in accordance with the Act of Congress of April 10, 1928, as amended August 22, 1949, which directs the Bureau "to continue 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."

SYSTEMATIC RESEARCHES

Dr. M. W. Stirling, Director of the Bureau, remained in Washington during the major portion of the fiscal year. In addition to regular administrative duties, he continued studies on the archeological collections made in Panama during 1952 and 1953. In May and June he made two brief inspection trips to Russell Cave in Jackson County, Alabama, where Carl Miller conducted archeological excavations under the auspices of the Bureau and financed by the National Geographic Society. The services of Mr. Miller were lent to the Bureau by the River Basin Surveys for six weeks, the duration of this work. The excavations, which reached a depth of 14 feet in the cave floor, gave evidence of a fairly continuous occupation which extended from approximately A. D. 1650 to the early Archaic. Samples from the 14-foot level yielded a carbon-14 date of 8160 B. P. (before the present) ± 300.

The beginning of the fiscal year found Dr. Frank H. H. Roberts, Jr., Associate Director of the Bureau and Director of the River Basin Surveys, on an inspection trip in the Missouri Basin. He visited survey and excavation parties working in the Oahe Reservoir basin in North Dakota and South Dakota and the Fort Randall Reservoir area, also in South Dakota. After his return to Washington he devoted practically full time to the management of the River Basin Surveys program and in reviewing and revising a number of manuscript reports on the results of investigations in various areas. In October Dr. Roberts went to Clarksville, Mo., to attend the annual fall meeting of the Missouri Archeological Society. He spoke at one of the sessions on the subject "The Inter-Agency Archeological Salvage

Program." From Clarksville he proceeded to the field headquarters at Lincoln, Nebr., where he reviewed the results obtained by the field parties, working in the Missouri Basin during the summer and early fall months. Following his return to Washington he participated in the annual meeting of the Committee for the Recovery of Archeological Remains. During the winter and early spring months Dr. Roberts worked on the manuscript of an article summarizing the activities and the results of the archeological salvage program for the 10 years that it has been operating. In May he went to the Lincoln office to assist in the preparation of plans for the summer's fieldwork in the Missouri Basin. He was in the Washington office at the end of the fiscal year.

During the first two months of the fiscal year Dr. Henry B. Collins, anthropologist, with three assistants conducted archeological fieldwork on Southampton and Walrus Islands in Hudson Bay. The work was sponsored by the Smithsonian Institution and the National Museum of Canada and was supported in part by a grant from the American Philosophical Society. The party, consisting of Dr. Collins, Dr. J. N. Emerson, University of Toronto, William E. Taylor, Jr., National Museum of Canada, and James V. Wright, anthropology student at the University of Toronto, left Montreal by R. C. A. F. aircraft on June 8, 1955, and arrived at Coral Harbour, Southampton Island, the following day. On June 13 they went by Eskimo dog team over the sea ice to Native Point, an abandoned Eskimo village site 40 miles down the coast, where they camped for the summer. Native Point (Tunermiut) was the principal settlement of the Sadlermiut, the aboriginal Eskimo tribe of Southampton Island, the last of whom died there in an epidemic in the winter of 1902–3. The site consists of the ruins of 75 semisubterranean stone and sod houses in addition to a dozen old "quarmats" or autumn houses built by the Aivilik Eskimos who have camped there in recent years. Hundreds of stone graves, cairns, and meat caches lie along the beach near the site and on the old shorelines in every direction for miles around. Excavation of house ruins, middens, and graves at the main Sadlermiut site and two smaller sites nearby supplemented the work of the previous year and provided an adequate picture of the material culture and way of life of the Sadlermiut Eskimos. The Sadlermiut are commonly thought to have been descended from the Thule Eskimos who migrated from Alaska to Canada and Greenland some seven or eight hundred years ago. However, from the work on Southampton and Walrus Islands it seems more likely that the Sadlermiut had merely been influenced in some ways by the Thule culture and that they were actually the descendants of the prehistoric Dorset Eskimos, who were the other, and principal, object of study by the expedition.

The main Dorset site at which excavations were made lies a mile to the east of the Sadlermiut site. It is situated on the gently sloping surface of a 70-foot high headland which had once fronted the sea but which now lies half a mile back from the present beach. The site consists of shallow midden deposits, covered by a low, sparse growth of vegetation, extending for an area of well over 20 acres, one of the largest Dorset sites known. The site was designated T 1, from Tunermiut, the Eskimo name for Native Point. A second, later Dorset site was found near the Sadlermiut site and called T 2. A third Dorset site, T 3, slightly later than T 1, was found on the old beach line immediately below it, at an elevation of 40 feet above sea level. Samples of charred bone excavated at the T 1 site in 1954 were submitted to the University of Pennsylvania Carbon-14 Laboratory and found to be 2060±230 years old. The thousands of stone, ivory, and bone artifacts found at T 1 and T 3, though conforming in general to the basic Dorset culture pattern, were in many respects specifically different from those found at other Dorset sites in Canada and Greenland. Flint implements, which were far more abundant than any other artifacts, were small and delicately chipped, like Dorset implements generally, but most of them differed in form from previously known Dorset types, and some of them were unlike anything known from America. The majority of the blades would be described as microlithic, and some of them in shape and technique were similar to microlithic types from pre-Eskimo sites in Alaska and Mesolithic sites in the Old World. The cultural material from T 1 and T 3 seems to represent an older, simpler stage leading up to the classic Dorset culture; it should probably be referred to as formative or proto-Dorset. All faunal remains from the excavations were preserved. The thousands of bird bones and occasional fish bones and mollusks were brought back to the Smithsonian for identification. The mammal bones were counted and as many as possible identified in the field. As a result of the bone count some striking differences were observed in the food economy of the Sadlermiut and Dorset Eskimos.

Five days in July were devoted to excavations at an abandoned village site on Walrus Island. The houses, which had been made of massive blocks of granite, proved to be Dorset rather than Sadlermiut as expected, and provided the first adequate information on the house types of the Dorset Eskimos. The artifacts from the houses were typical or classic Dorset, different from and later than those from the proto-Dorset site T 1 at Native Point. Plants, fossils, and insects, including ectoparasites on birds and lemmings, were also collected during the summer.

Two preliminary reports on the Southampton and Walrus Island work were prepared by Dr. Collins, one for the Annual Report of the

National Museum of Canada and the other for Anthropological Papers of the University of Alaska. "Archaeological Research in the American Arctic," a general article describing the current status of Arctic archeology, was published in Arctic Research, Special Publication No. 2 of the Arctic Institute of North America. Dr. Collins continued to serve as a member of the Board of Governors of the Arctic Institute of North America and of its committee on research. As chairman of the Directing Committee of Arctic Bibliography, he continued to supervise the preparation of this work, a comprehensive annotated bibilography which lists and summarizes the contents of publications in all fields of science relating to the Arctic and sub-Arctic regions of the world. Volume 6 of the Bibliography, 1,208 pages, was issued by the Government Printing Office in April 1956, and material for volume 7, of approximately the same size, was turned over to the printer in June. Funds for the preparation of an eighth volume were obtained from the Departments of the Army, Navy, and Air Force, and the Defense Research Board of Canada. As a member of the Permanent Council and the Organizing Committee of the International Congress of Anthropological and Ethnological Sciences, Dr. Collins participated in the work of planning for the fifth session of the Congress to be held in Philadelphia, September 1–9, 1956. At the close of the fiscal year Dr. Collins was in Europe, making a survey of Mesolithic materials in museums for their possible bearing on the Eskimo problem.

At the beginning of the fiscal year Dr. Philip Drucker was in Mexico finishing up his fieldwork at La Venta, studying the material collected there and comparing it with the collections in the Museo Nacional at Mexico City. It was through Dr. Drucker's intercession that the U. S. National Museum received a collection of 187 polished jadeite and other stone objects from La Venta as a loan from the Museo Nacional of Mexico. Upon his return to Washington in September he completed the writing of his share of the final report on the La Venta excavations, and also completed and submitted for publication his manuscript on the Native Brotherhood Societies of Alaska and British Columbia. On December 9, 1955, Dr. Drucker resigned from the Bureau.

RIVER BASIN SURVEYS

(Prepared by FRANK H. H. ROBERTS, JR., Director, from data submitted by staff members)

Throughout the year River Basin Surveys continued its program for salvage archeology in areas to be flooded or otherwise destroyed by the construction of large dams. As in previous years, the work was carried on 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

State and local institutions. An increase in funds for the fiscal year made possible more extensive investigations than in the preceding year. During 1955–56 the program of the River Basin Surveys was financed by a transfer of $92,360 from the National Park Service and a grant of $12,000 from the Idaho Power Co. The funds from the National Park Service were for use in the Missouri Basin. A carryover of $3,663 from the previous year made the total available for operations in the Missouri Basin $96,023. The grant from the Idaho Power Co. was to provide for the excavation of sites along the Snake River in Oregon-Idaho which will be flooded by the construction of that company's Brownlee and Hells Canyon dams. The latter funds were the first for work outside the Missouri Basin made available to the River Basin Surveys in several years.

Investigations in the field during the year consisted of surveys and excavations. Most of the efforts were concentrated in the digging of sites. Because of a slight delay in receiving the new Federal funds, it was the middle of July before parties were sent out from the field headquarters at Lincoln, Nebr. On July 15 a survey party began investigations in the Tiber Reservoir. On July 18 a second party started digging at a fortified village site near the mouth of the Cheyenne River in the Oahe Reservoir area, and on July 20 a third party started operations in the vicinity of the Oahe Dam near Pierre, S. Dak. In May a historic-sites party began excavations at the location of an early trading post in the area of the outlet channel below the Oahe Dam. Early in June a second party returned to the Cheyenne site and resumed excavations at that locality. Later a third party proceeded to a village site near Whitlocks Crossing in the Oahe Reservoir basin and started investigations where no previous work had been done. On June 2 a survey party began operations in the Big Bend Reservoir area near Fort Thompson, S. Dak., and on June 12 an excavating party began digging a site in the Lovewell Reservoir area in northern Kansas. Late in June a party proceeded to Robinette, Oreg., where it established camp and initiated excavations in one of the Snake River sites. All these parties were continuing their investigations at the close of the fiscal year. During the year no paleontological studies were made in any of the areas by the River Basin Surveys. However, some fossil collecting was done by State institutions.

As of June 30, 1956, reservoir areas where archeological surveys and excavations had been made since the Salvage Program got under way in 1946 totaled 244 in 27 States; also four canal areas and one lock project had been investigated. The survey parties have located and reported 4,365 archeological sites, and of that number 862 have been recommended for limited testing or excavation. The term "excavation" in this connection implies digging approximately 10 percent of

a site. Preliminary appraisal reports have been issued for all the reservoirs surveyed, and in cases where additional reconnaissance has resulted in the finding of other sites supplemental reports have been prepared. During the last fiscal year four such reports were written and were distributed in a single mimeographed pamphlet. Throughout the years since the initiation of the program 181 reports have been distributed. The discrepancy between that figure and the total number of reservoirs visited is due to the fact that in several instances the information obtained from a whole series of proposed reservoir projects occurring in a basin or subbasin has been included in a single report.

By the end of the fiscal year 329 sites in 46 reservoir basins scattered over 17 different States had either been tested or partially dug. Only a single site was excavated in some of the reservoir areas, while in others a whole series was studied. Thus far at least one example of each type of site recorded in the preliminary surveys has been examined. The results of certain phases of the excavations have appeared in various scientific journals and in the bulletins of the Bureau of American Ethnology and the Miscellaneous Collections of the Smithsonian Institution. During the year River Basin Surveys Paper No. 8, which is to be Bulletin 166 of the Bureau of American Ethnology, was sent to the printer, and at the close of the year galley proofs of the publication were being read by the author. Two detailed technical reports on the results of earlier work were completed during the year and are ready for publication.

The reservoir projects that have been surveyed for archeological remains as of June 30, 1956, were distributed as follows: Alabama, 1; California, 20; Colorado, 24; Georgia, 5; Idaho, 11; Illinois, 2; Kansas, 10; Kentucky, 2; Louisiana, 2; Minnesota, 1; Mississippi, 1; Montana, 15; Nebraska, 28; New Mexico, 1; North Dakota, 13; Ohio, 2; Oklahoma, 7; Oregon, 27; Pennsylvania, 2; South Dakota, 10; Tennessee, 4; Texas, 19; Virginia, 2; Washington, 11; West Virginia, 2; and Wyoming, 22.

Excavations have been made or were under way in reservoir basins in: California, 5; Colorado, 1; Georgia, 4; Kansas, 4; Montana, 1; Nebraska, 1; New Mexico, 1; North Dakota, 4; Oklahoma, 2; Oregon, 4; South Carolina, 1; South Dakota, 4; Texas, 7; Virginia, 1; Washington, 4; West Virginia, 1; and Wyoming, 2. The foregoing figures include only the work of the River Basin Surveys or that in which there was direct cooperation with local institutions. Projects that were carried on by local institutions under agreements with the National Park Service are not included because complete information about them is not available.

During the year the River Basin Surveys continued to receive helpful cooperation from the National Park Service, the Bureau of Reclamation, the Corps of Engineers, the Geological Survey, and various State and local institutions. Transportation and guides were furnished in a number of instances, and mechanical equipment made available by the construction agency speeded the work at a number of locations. Temporary headquarters as well as living accommodations were made available at several projects. Detailed maps of the reservoirs under investigation were supplied by the agency concerned and helpful information was provided whenever it was needed. The National Park Service continued to function as the liaison between the various agencies both in Washington and in the field and through its regional offices obtained information about the locations for dams and reservoirs as well as data concerning construction priorities. The National Park Service was also chiefly responsible for the preparation of estimates and justifications and in procuring funds for carrying on the program. Had it not been for the enthusiastic assistance of the personnel in all the cooperating agencies, it would not have been possible for the River Basin Surveys to have accomplished so much for the year.

General direction and supervision of the program were continued by the main office in Washington. The field headquarters and laboratory at Lincoln, Nebr., was in direct charge of the work in the Missouri Basin. All the materials collected in the Missouri Basin were processed at the Lincoln laboratory and subsequently two large lots of specimens were transferred to the U. S. National Museum. Through the cooperation of the Washington State Museum at Seattle, the Snake River party was provided with a base of operations. The general direction of the activities in that area, however, was from the Washington office.

Washington office.—The main headquarters of the River Basin Surveys at the Bureau of American Ethnology continued throughout the year under the direction of Dr. Frank H. H. Roberts, Jr. Carl F. Miller, archeologist, was based on that office and assisted the director in general administrative duties from time to time. William M. Bass was added to the staff on June 18 as a temporary physical anthropologist.

Mr. Miller reported to the Lincoln office shortly after the beginning of the fiscal year and worked in the Missouri Basin until late in September, when he returned to the Washington office. His activities during the summer are covered in the Missouri Basin portion of this report. After his return to Washington he prepared a series of brief reports on the results of his fieldwork and then turned his attention to his unfinished report on his previous investigations at the John H.

Kerr (Buggs Island) Reservoir in Virginia. In April Mr. Miller was transferred to the regular staff of the Bureau of American Ethnology for the purpose of carrying on investigations in a cave in Jackson County, Ala., where the deposits contained a long sequence of Indian cultural history. He returned from Alabama in June and resumed his duties as a member of the River Basin Surveys staff. He proceeded to Lincoln, Nebr., and on June 21 left for South Dakota where he began excavations at a site in the Oahe Reservoir area. During the months in the Washington office Mr. Miller spoke before a number of Boy Scout troops and acted as scientific consultant to a number of high-school students who were participating in a science contest in Alexandria, Va. During the year Mr. Miller's manuscript "Revaluation of the Eastern Siouan Problem, with Particular Emphasis on the Virginia Branches—the Occaneechi, the Saponi, and the Tutelo," which was a byproduct of his study of the data pertaining to the John H. Kerr Reservoir, was sent to the printer and will appear as Anthropological Paper No. 52 in Bulletin 164 of the Bureau of American Ethnology.

After joining the River Basin Surveys Mr. Bass began a study of the human skeletal material that had been collected in the Missouri Basin and transferred to the U. S. National Museum. His work was well under way at the end of the year.

Columbia Basin.—After a lapse of several years the River Basin Surveys resumed investigations in the Columbia Basin late in the fiscal year. On June 11 Dr. Warren W. Caldwell joined the staff as archeologist. He left Seattle, Wash., on June 22 and proceeded with a party to Robinette, Oreg., where camp was established and excavations were started in a cave not far from the town of Robinette. The latter is built on a series of Indian sites, and tests were to be made also at various places in the town. The party was actively engaged in its investigations at the close of the year.

A report, "Excavations in the McNary Reservoir Basin near Umatilla, Oregon," by Dr. Douglas Osborne, was sent to the printer toward the end of the fiscal year. It will appear as River Basin Surveys Paper No. 8, Bulletin 166 of the Bureau of American Ethnology. The report covers investigations made during a previous year when the River Basin Surveys was operating a full-scale program along the Columbia River.

Missouri Basin.—The Missouri Basin project continued to operate throughout fiscal 1956 from the field headquarters and laboratory at 1517 "O" Street, Lincoln, Nebr. Except for periods of one week in August and two weeks in September, when he was detailed to the Department of Justice to assist in an Indian Lands Claim case, G. Hubert Smith served as archeologist-in-charge from July 1 to Janu-

ary 10. On the latter date Dr. Robert L. Stephenson, chief, returned from academic leave and resumed direction of the project. Activities during the year included all four phases of the Salvage Program: (1) survey; (2) excavation; (3) analysis; and (4) reporting. Phases 2 and 3 received the greatest attention however.

At the beginning of the fiscal year the Missouri Basin project had a permanent staff of eight, six assigned to the Lincoln office and two to the Washington office. Since the chief was in leave status there actually were only seven on active duty. Dr. Waldo R. Wedel, archeologist, and George Metcalf, field assistant, were detailed to the Missouri Basin project from the U. S. National Museum during July and August. In July, August, September, and October there were 20 temporary student and local nonstudent employees working in the field. Their services were gradually terminated as excavations were brought to a close, and by November 5 only the permanent staff remained. During the winter and early spring months a clerk-stenographer, a photographer, and a part-time records custodian were employed. These permanent additions to the staff continued on duty throughout the remainder of the year. In addition, a temporary part-time draftsman and a temporary part-time photographer assisted in the laboratory on various occasions. Wedel and Metcalf were again detailed to the Missouri Basin project on June 5 and were working for it at the close of the fiscal year. One temporary field assistant entered on duty May 28 and another on June 11. Both were with field parties at the end of the year. A temporary physical anthropologist was appointed on June 18 and was assigned to the Washington office to prepare reports on the skeletal materials from various Missouri Basin sites. The archeologist assigned to the Washington office returned to the Missouri Basin on June 20 and was on duty there at the end of the fiscal year. Also, 29 temporary student and local nonstudent laborers were employed in the field. Thus at the close of the year there were 11 permanent employees, 2 employees detailed to the Surveys, 2 temporary field assistants, 1 temporary physical anthropologist, and 29 temporary laborers on the staff of the Missouri Basin project.

During the year eight River Basin Surveys field parties operated in the Missouri Basin, three in the period July–October and five in the period May–June. One party in the July–October period and one in the May–June period were occupied in survey and site-testing activities. One party in the May–June period was engaged in the excavation of a historic site. The other five were excavating in prehistoric and protohistoric Indian village sites. Other fieldwork in the Missouri Basin during the year included six field parties from State institutions working under agreements with the National Park Service

and in cooperation with the Smithsonian Institution. Three of these parties were in the field in the July–October period and three in the May–June period.

In the Tiber Reservoir area a small field party directed by Carl F. Miller conducted excavations along the Marias River in north-central Montana from July 19 to August 16. Various sites located by previous Smithsonian Institution parties in the area were revisited and excavations were conducted at site 24TL26. This site proved to be of Woodland affiliation with some possible earlier and later sporadic occupation. Other sites visited by previous parties and recommended for further study have been destroyed by periodic flooding in the area, and on the completion of the 1955 season no further work was recommended for the reservoir.

In the Pactola Reservoir basin, the Carl F. Miller party conducted investigations on Rapid Creek in Pennington County, S. Dak., August 19–24. A brief survey had been made there in 1948 by a Smithsonian Institution field party, but heavy vegetation prevented adequate investigation at that time. Miller's party failed to find any archeological materials and no further work was recommended for the area.

In the Merritt Reservoir basin, the Carl F. Miller party conducted investigations on the Snake River and Boardman's Creek in Cherry County, Nebr., from August 26 to September 2. Sites recorded by a previous Smithsonian Institution party were revisited, sampled, and analyzed. Two of these had largely been covered by windblown sand, one was test excavated, and two yielded Woodland and later materials. Several blowouts were examined where chipped-stone artifacts were recovered. No further work was recommended for this area until such time as construction activities might bring to light new material.

In the Glendo Reservoir area, on the North Platte River in Platte County, Wyo., the Carl F. Miller party continued its field season from September 5 to 13. Investigations there consisted of a reexamination of sites located by an earlier Smithsonian Institution field party and recording of two new sites. One site, 48PL15, remains as the principal locality for further examination in the Glendo Reservoir area, and work will be started there early in the new fiscal year.

In the Oahe Reservoir area, the Carl F. Miller party concluded its field season at the Buffalo Pasture site (38ST6) in Stanley County, S. Dak., a short distance above the dam construction area. With the aid of a bulldozer a trench 11 feet wide, 367 feet long, and about 3½ feet deep was cut across a portion of the site in order to expose the stratigraphy from the present surface to sterile deposits below any cultural remains. There had been extensive digging at the Buffalo Pasture site during a previous season when the remains of several

earth lodges were uncovered and the encircling moat and remnants of the palisade were studied, but it was not until the big trench was cut that the site was determined to represent a single occupation. The trench bisected the depressions of four circular lodges and exposed some 20 refuse-filled cache pits which were cleaned out by hand. An excellent series of specimens, including a large pottery vessel, was recovered while the operations were under way.

The second field party in the Oahe Reservoir area in the 1955 field season was a Smithsonian Institution group directed by Richard P. Wheeler. This party conducted excavations from July 20 to November 5 at the Leavitt site (39ST215) and at the Breeden site (39ST16), formerly known as the Mathison site. The Leavitt site proved in part to represent an early historic Indian occupation related directly to the occupation at the Philip Ranch site, excavated in 1951 and reported in Bulletin 158 of the Bureau of American Ethnology, and in part to an older late prehistoric period. The site produced materials that assist greatly in the interpretation of both phases in the Oahe area. Especially important was the recovery of 15 human burials. One of them was particularly interesting because the skeleton was that of a large male with a lead musket ball embedded in the dorsal surface of the right pelvic bone. The individual had been shot in the back, possibly while running away from an assailant. There was nothing to indicate immediate death, but the man had not lived long because the bone surrounding the ball had not started to heal. Iron and brass bracelets, as well as glass beads, were found in several of the graves. At the Breeden site there was evidence for at least three occupations. The earliest was older than the first one at the Leavitt site and produced four deeply buried rectangular house remains indicative of the Monroe Focus which is thought to date at approximately A. D. 1200–1300. The later occupations have not been sufficiently identified to correlate definitely with other known cultures but they did have circular house structures. One has been attributed tentatively to the La Roche Focus, which is estimated by some to be A. D. 1600–1700, and the other to the historic Teton Dakota of about 1825 to 1875.

The third Smithsonian Institution party in the Oahe area in the 1955 season was directed by Dr. Waldo R. Wedel, assisted by George Metcalf. Working from July 18 to August 31, that party continued investigations at the Cheyenne River site (39ST1) which were begun by Dr. Wedel in 1951 for the River Basin Surveys. The site, a multicomponent one, is located near the juncture of the Cheyenne River with the Missouri. Excavation of a large rectangular pit house, begun in 1951 and identified with the earliest of three occupations, was completed in 1955, and a 70-foot section of the stockade line forming part of the defensive works for the last (third) occupation was un-

covered. Much of the fill removed from the rectangular house pit consisted of sherds, bone, and other refuse material attributable to an intermediate late prehistoric occupation for which no houses have yet been opened on the site. The 1955 work apparently confirms earlier inferences that the site represents three separate occupations, the earliest probably postdating circa A. D. 1300, the latest antedating 1800 and in all likelihood attributable to the Arikara. At the close of the season Dr. Wedel recommended further investigations during the 1956 season in order to ascertain the nature of the dwellings left by the second occupation which it has been suggested may belong to the Bennett Focus. The site also promises important data bearing on the interpretation of village plans, the cultural sequences, and the way of life of the prehistoric Indians of that area.

The fourth party in the Oahe area in the 1955 season was sponsored by the University of South Dakota and the South Dakota Archeological Commission working under a cooperative agreement with the National Park Service. Dr. Wesley R. Hurt, of the University of South Dakota, was the director, and the party continued excavation of the Swan Creek site (39WW7) which was begun the previous year, ending a 7-week season on August 1. Human burials, a moat, a palisade, and houses were excavated, greatly increasing the information on these features for the region. This party also conducted limited test excavations at sites 39WW300, 39WW301, 39WW302, and 39-WW303.

In the North Dakota portion of the Oahe Reservoir area the State Historical Society of North Dakota, working under a cooperative agreement with the National Park Service, comprised the fifth field party in that reservoir. The party, directed by Alan R. Woolworth, conducted excavations at the Paul Brave (or Fort Yates) site (32S14) from early July until late August. Three earth lodges of rectangular pattern were excavated. Limited testing was also accomplished in sites 32SI2 and 32SI3. Surface collections were made at a series of other sites in the vicinity, and aerial survey provided photographic records of 10 other sites in the North Dakota portion of the reservoir.

The 1956 field season in the Oahe Reservoir area began early, and by the end of the fiscal year six parties were in the field. G. Hubert Smith led a Smithsonian Institution party to the vicinity of the dam-construction area on May 21 and was still in the field at the end of the fiscal year. Smith's party spent some time examining old historic land records in the General Land Office at the State Capitol in Pierre, as well as records in the South Dakota Historical Society, in an effort to determine the location of various frontier trading posts. They then covered the area carefully on foot and finally found what appear to be the remains of Fort Pierre II which was in use around 1859–63. It

also seems probable now that Fort Pierre II and Fort Galpin (1857–59) are identical in location. Excavations in this locality in June revealed the outline of the stockade, the location of several structures, and produced interesting artifactual materials. The fort was much larger than most trading posts as the enclosure was approximately 200 feet square. It was destroyed by fire. Other historic sites scheduled for investigation by this party include Forts La Framboise and Primeau (both dating in the 1860's) and, if time permits, the sites of Fort Sully and Fort Bennett.

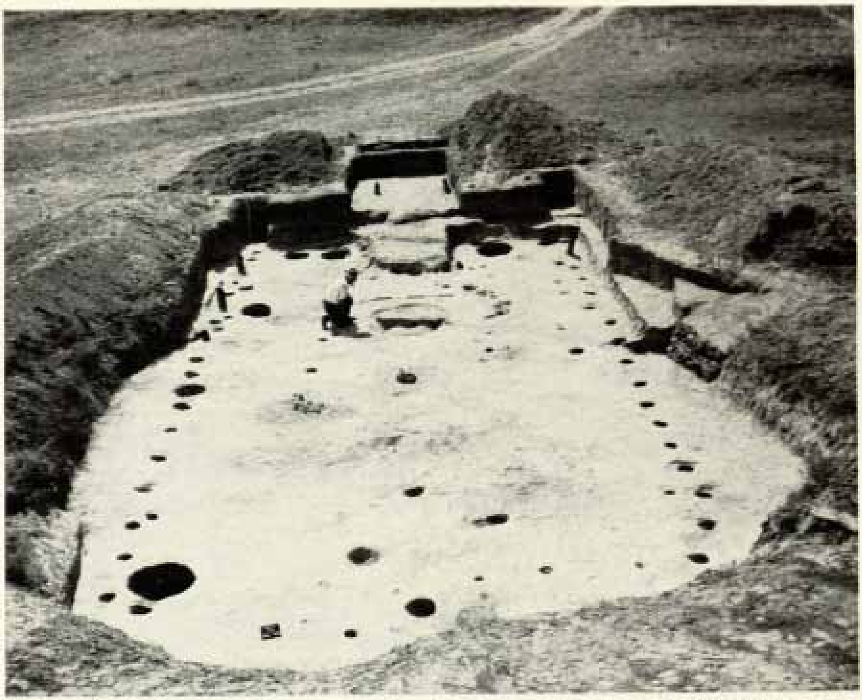
On June 5 Dr. Waldo R. Wedel returned to the Missouri River Basin and took a Smithsonian Institution field party to the Cheyenne River site (39ST1) where the final season of excavation was started. By the end of the fiscal year the party had opened several test areas, cache pits, and house features, recovering a good sample of artifacts. Upon completion of work at this site the Wedel party plans to finish excavations which were begun by another River Basin Surveys party in 1952 at the Black Widow site (39ST3).

A Smithsonian Institution party directed by Carl F. Miller began digging at the Hosterman site (39PO7) near Whitlock's Crossing, S. Dak., the last week in June. Having only started by the end of the fiscal year this party had nothing to report.

A University of South Dakota–South Dakota Archeological Commission party, working under a cooperative agreement with the National Park Service and directed by Roscoe Wilmeth of the University of South Dakota, began excavations in mid-June at the Swan Creek site (39WW7). This party also planned to make test excavations at two nearby sites (39WW302 and 39WW303) after completing the work at the Swan Creek site which was begun two seasons ago. They were in the field at the end of the fiscal year.

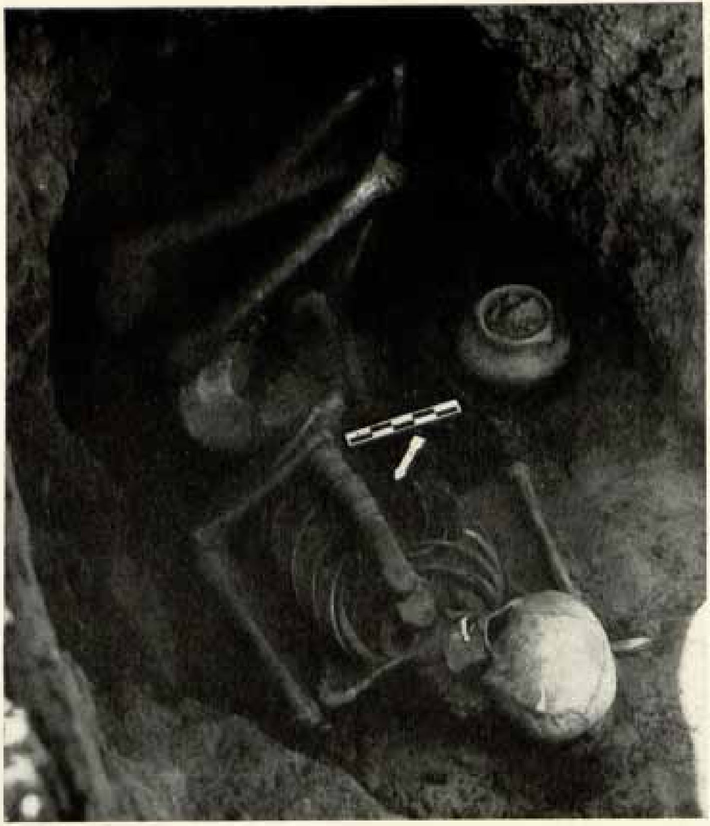
A University of Wisconsin field party, working under a cooperative agreement with the National Park Service and directed by Dr. David A. Baerreis of that University, began work early in June at the Eklo site (39WW3) near Mobridge, S. Dak. The party expected to conduct test excavations at two other nearby sites (39CA6 and 39CA9) after finishing the season's work at the Eklo site. They were in the field at the end of the fiscal year.

In the North Dakota section of the Oahe Reservoir a State Historical Society of North Dakota field party directed by Alan R. Woolworth, working under a cooperative agreement with the National Park Service, began investigations in mid-June. They excavated at the Demery site (39CO1) in Carson County, S. Dak., and at the Fireheart site (32SI2) in Sioux County, N. Dak. They also were to test an additional site (32SI208) in the vicinity. All three sites are near the North Dakota–South Dakota border. The party was in the field at the end of the fiscal year.

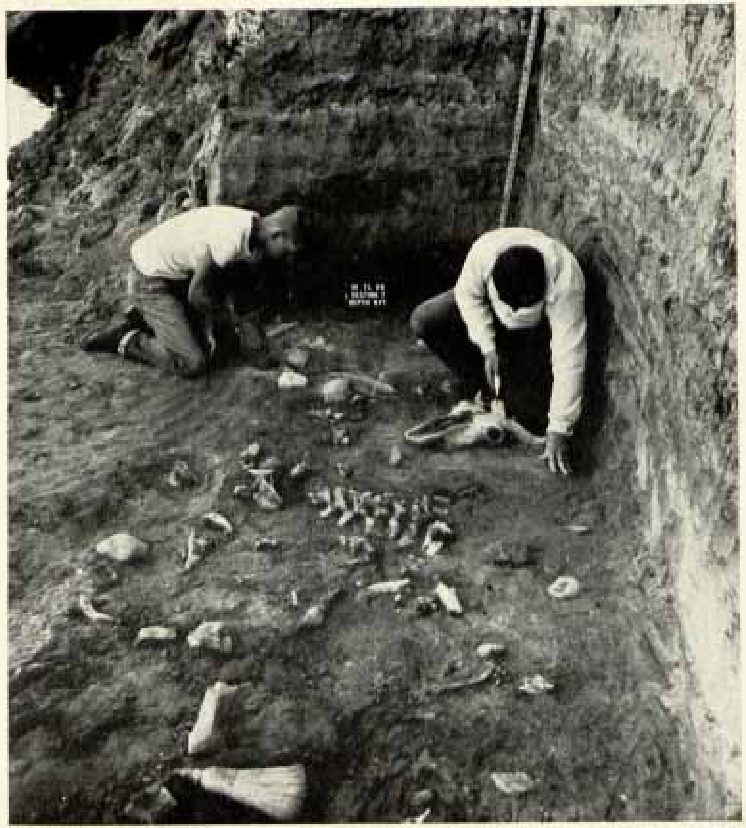


1. River Basin Surveys: Floor pattern of rectangular earth lodge at the Cheyenne Village site. Rows of holes indicate position of walls. Larger holes were cache pits. Entrance platform at far end. Workman is kneeling by fire pit

2. River Basin Surveys: Long curved line of post holes shows location of palisade at the Cheyenne Village. Men working on small cache pits and other post holes inside the stockade. Field camp in background.



1. River Basin Surveys: Indian burial at the Leavitt site near the Oahe Dam. Arrow indicates north and scale stick is 1 foot long. Pottery vessel was a mortuary offering.



2. River Basin Surveys: Uncovering remains of a bison kill at a camp site in the Tiber Reservoir area. Occupation level was 8 feet below the present surface.

With the added results of the current year's work, it is now possible to identify at least nine archeological complexes in the Oahe portion of the Missouri Basin, covering the years about A. D. 850 to 1859. Some indications have been found of occupations belonging to an earlier period, but they are not sufficiently known as yet to be included in the definitely identified list.

In the Fort Randall Reservoir two field parties operated in the 1955 field season. The Nebraska State Historical Society, under a cooperative agreement with the National Park Service, had a party directed by Marvin F. Kivett excavating at the Crow Creek site (39BF11). Work was started on this site in the 1954 season and the second season's digging there was completed late in August of 1955. This complex site contains the remains of two and possibly three occupations ranging in time over 300 or more years. The season's work provided new data on village plans, house types, fortifications, and relationships of this area to other areas in South Dakota and Nebraska.

The second party in this area was that of the University of Kansas led by Dr. Carlyle S. Smith of that institution and working under a cooperative agreement with the National Park Service. They excavated site 39BF204 over a 7-week period ending the last of July. They also conducted some test excavations in site 39BF201, which appeared to be culturally identical to the former site. Both relate directly to the Spain site (39LM301) and the Talking Crow site (39BF3), which were excavated in previous years by parties under Dr. Smith.

In the Big Bend Reservoir area a Smithsonian Institution party directed by Harold A. Huscher began an intensive survey and site-testing operation in this newly activated reservoir on the Missouri River in South Dakota on June 2. The party planned to search the entire reservoir area for archeological potentialities. It was scheduled to visit all known sites, locate all possible new sites, and make exploratory tests in all of them in order to determine what additional excavation must be done before inundation. By the end of the fiscal year it had visited and tested 20 sites and had located several others from previous records.

In the Lovewell Reservoir area a Smithsonian Institution party directed by Robert W. Neuman began the excavation, on June 12, of three sites on White Rock Creek in Jewell County, Kans. They started at site 14JW1 and worked there until the end of the fiscal year. The other two sites are 14JW2 and 14JW201. These sites should help materially in establishing the significance and cultural

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content of the White Rock Focus and its relation to the western extension of the Oneota Aspect.

A total of 15 parties were in the field during fiscal 1956, 7 in the 1955 season, and 8 in the 1956 season, investigating archeological remains in 8 reservoirs. They conducted excavations at 24 sites, tested over 40 sites, and examined the surfaces of nearly 100 sites. Each field party consisted of a crew chief and from 6 to 10 crewmen. Bulldozers and other heavy equipment, supplied through the courtesy of the Lytle-Green Construction Company and the Corps of Engineers, were used at some sites in order to expedite investigations. At all reservoir projects the complete cooperation of the Corps of Engineers and the Bureau of Reclamation personnel was always willingly given.

On May 14 three members of this staff joined Dr. Dwight R. Crandell of the U. S. Geological Survey, Denver office, on an archeological-geological field trip to the areas of the Oahe, Big Bend, and Fort Randall Reservoirs in South Dakota. The party was in the field for seven days, examining Pleistocene and early Recent geological deposits and fossil soils. The principal purpose of the trip was to instruct members of the River Basin Surveys staff how to recognize possible localities where archeological deposits of Early Man material or other pre-pottery cultural remains might be found. The results of the trip, while negative from the standpoint of actually finding such sites, provided this office with a great deal of information as to where and how to search for such material in the future and what might be expected in specific localities. The three members of this staff who accompanied Dr. Crandell were Richard P. Wheeler, G. Hubert Smith, and Lee G. Madison. Dr. Crandell's participation in the project was arranged through the cooperation of Dr. Wilmot H. Bradley, Chief, Geologic Division of the Geological Survey.

While fieldwork during the fiscal year was devoted to phases 1 and 2 (survey and excavation) of the salvage program, laboratory and office activities were devoted to phases 3 and 4 (analysis and reporting). During the time the archeologists were not in the field they were engaged in analyses of their materials and in laboratory and library research. They also prepared manuscripts of technical scientific reports and wrote articles and papers of a more popular nature. The laboratory and office staff devoted its time to processing specimen materials for study, photographing specimens and preparing specimen records, and typing and filing records and manuscript materials. The accomplishments of the laboratory and office staff are listed in the following tables.

TABLE 1.—*Artifact materials processed*

Reservoir	Number of sites	Catalog numbers assigned	Number of specimens processed
Glendo	16	431	585
Merritt	1	7	220
Oahe	14	5, 183	36, 376
Tiber	3	172	374
Non-Reservoir	2	58	70
Unassigned	4	179	527
Total	40	6, 030	38, 152

As of June 30, 1956, the Missouri Basin project had cataloged 570,238 specimens from 1,517 numbered sites and 47 collections not assigned site numbers.

Two shipments of archeological materials were sent to the United States National Museum for permanent transfer. One was by Missouri Basin project vehicle and consisted largely of fragile items such as human skeletal remains, pottery vessels and vessel sections, bone, shell, and wooden artifacts. The second was by truck freight and consisted of stone specimens and other more durable materials.

TABLE 2.—*Record materials processed*

Reflex copies of records	1, 286
Photographic negatives made	615
Photographic prints made	2, 784
Photographic prints mounted and filed	1, 004
Plate layouts made for manuscripts	42
Transparencies mounted in glass	81
Drawings, tracings, and maps	14
Pottery vessels restored	3
Pottery vessel sections restored	32

On May 3, 4, and 5 the annual meetings of the Society for American Archaeology were held in Lincoln, Nebr. As a programmed part of the meetings, Thursday evening, May 3, was devoted to an "open house" at the Missouri Basin project laboratory at 1517 "O" Street. The office and laboratory were prepared with suitable displays of photographic and specimen materials in order to best exhibit the work of the Missouri Basin project. The "open house" was scheduled for 8:00 to 10:00 p. m. but lasted until well past midnight. Approximately 120 people visited the office and laboratory at that time.

Most of the activities of the Lincoln office during the first three weeks in March were devoted to a general remodeling of the office space at 1517 "O" Street. The entire first floor was cleaned and painted. The floors were sanded and coated with floor preservative.

The west half of the first floor was partitioned into seven office cubicles. A map room was made and the filing and secretarial facilities were improved. All the work was done by members of the staff.

Dr. Robert L. Stephenson, chief of the Missouri Basin project, returned to Lincoln on January 10 after 16 months academic leave and resumed his duties at the headquarters and laboratory. During the remainder of the fiscal year most of his activities were directed toward the preparation of plans for the summer's field program. In addition, he started work on a summary report of the Missouri Basin Salvage Program for the calendar years 1952–1955. He presented a paper, "Topography of a Late Archeological Site," at the 66th Annual Meeting of the Nebraska Academy of Sciences held in Lincoln on April 20–21. An abstract of the paper was published in the Proceedings of the Nebraska Academy of Sciences. He also took an active part in the annual meeting of the Society for American Archaeology held in Lincoln May 3–5 and presented a paper entitled "Pottery from the Accokeek Site, Maryland." At the close of the fiscal year he was preparing to take a field party to the Sully site (39SL4) in the Oahe area north of Pierre, S. Dak.

Harold A. Huscher, field assistant, who worked several previous seasons for the River Basin Surveys, rejoined the staff on May 28, and on June 2 left Lincoln in charge of a survey party which proceeded to Pierre, S. Dak., and began a reconnaissance of the proposed Big Bend Reservoir area on the Missouri River. The work of the Huscher party was continuing on June 30.

Robert W. Neuman, temporary field assistant, joined the staff on June 11. He left Lincoln on June 12 as the leader of a party which proceeded to the Lovewell Reservoir on White Rock Creek, Jewell County, Kans. By the end of the fiscal year he had excavated for two weeks in site 14JW1 and one week in site 14JW201. The work of Mr. Neuman and his party was handicapped by severe rains but was continuing at the close of the year.

G. Hubert Smith, archeologist, as previously stated was in charge of the Lincoln office during most of the period from July 1 to January 10. His work for the Department of Justice pertained to preparing an ethnohistorical report on the Omaha tribe and appearing as a witness at a hearing held in Washington late in September when his report was introduced as evidence. During the fall and winter months Mr. Smith completed the manuscript of a detailed archeological report on excavations at the site of Fort Berthold II (32ML2) in the Garrison Reservoir area in North Dakota. In addition Mr. Smith worked on a manuscript pertaining to excavations at Fort Berthold I and the adjacent Like-a-Fishhook Village. The latter paper is being prepared in collaboration with Alan R. Woolworth of the North Dakota Historical Society and James H. Howard who was formerly associated

with that organization and is now at the Kansas City Museum. Mr. Smith participated in the annual Plains Archeological Conference, the meetings of the Nebraska Academy of Sciences and of the Society for American Archaeology which were held at Lincoln. At the Anthropological Section of the Academy of Sciences, he presented a paper on the ethnographic contributions of Paul Wilhelm, Duke of Wuerttemberg, who first visited the Upper Missouri region in 1820. Early in May Mr. Smith went to Pierre, S. Dak., and spent a week with the geological party that was studying deposits in the Oahe Reservoir area. Following that activity he remained at Pierre and began his regular summer's program, as mentioned in previous pages. Mr. Smith's party was continuing its excavations just below the Oahe Dam at the end of the year.

Upon completing the 1955 season's work Dr. Waldo R. Wedel returned to Lincoln, and before his departure for Washington from the Missouri Basin project headquarters, proceeded to Turin, Iowa, to examine a reported find of human skeletons. He was accompanied by Lawrence L. Tomsyck of the Lincoln office, and when they arrived at the location of the burials they joined representatives from a number of institutions in studying the finds. Absence of diagnostic artifacts with the skeletons precluded any valid estimate of age or cultural affiliations, but nothing was noted that would confirm assertions which had been freely made that the bones were those of Paleo-Indians and had a Pleistocene dating. Upon his return to Washington Dr. Wedel resumed his regular duties at the U. S. National Museum. He was again detailed to the River Basin Surveys for the 1956 season and reported at the Lincoln headquarters on June 4. His subsequent activities were described in the preceding discussion of field parties in the Oahe area.

Richard P. Wheeler, archeologist, was in charge of a field party working in the Oahe Reservoir area from July 25 through October 29. During the remainder of the fiscal year he devoted his time to analyzing the materials obtained in the field and in working on a number of technical reports and short articles. One article, "Recent Archeological Salvage Operations in the Missouri Basin," was published in the Missouri River Basin Progress Report, October–December, 1955, and another, "'Quill Flatteners' or Pottery Modeling Tools," was published in the Plains Anthropologist, April 1956. Wheeler presented a paper on his work in the Oahe Dam area at the Plains Conference in November and participated in a number of discussions during the conference. He was elected chairman of the 14th Plains Conference which will be held in Lincoln in November 1956. At the end of the fiscal year Mr. Wheeler was at the Lincoln headquarters working on reports.

Cooperating institutions.—Several State and local institutions continued to cooperate in the Inter-Agency Salvage Program throughout the year, although the shortage of funds for working agreements in projects outside the Missouri Basin considerably reduced the activities. Several State groups carried on independently but their investigations were correlated with the general program. The New York State Museum at Albany kept close check on projects in that State. The Department of Anthropology at the University of Michigan studied the possible effect of proposed enlargements of the South Canal on St. Marys River on archeological manifestations in that district. The University of Minnesota made preliminary investigations relative to sites that may be involved in the flood-control program for the Mankato area. The Florida State Museum checked several proposed canal routes in the northern part of Florida. The Ohio State Historical and Archeological Society continued salvage work in several localities, and the Historical Society of Indiana included examination of proposed reservoir areas in its general program for surveys in that State. The University of California Archeological Survey did some further work on projects for which it previously had agreements with the National Park Service, and the Archeological Survey Association of Southern California continued its volunteer efforts in the vicinity of San Diego. In the Columbia Basin the University of Oregon did additional digging at sites on the Oregon side of the Columbia River at the Dalles Reservoir, while the University of Washington continued its investigations on the Washington side.

The only work done under an agreement with the National Park Service, except for that previously described for the Missouri Basin, was that of the University of Missouri in the Table Rock Reservoir on the White River in southern Missouri. A special appropriation for that project for the fiscal year made possible an extensive series of investigations under the direction of Dr. Carl H. Chapman. Sites in the Table Rock area are exceptionally numerous and represent a variety of cultures. Considerable progress was made by Dr. Chapman and his parties during the year.

ARCHIVES

The Bureau Archives continued during the year under the custody of Mrs. Margaret C. Blaker. From June 4 to 6 Mrs. Blaker attended the Special Libraries Association Convention in Pittsburgh, Pa., where copyright problems and the preservation, microfilming, cataloging, and arranging of photographic and manuscript collections were discussed.

MANUSCRIPT COLLECTIONS

The manuscript collections continue to be utilized by students. Visitors consulted about 264 manuscripts, and reproductions of 70

manuscripts were mailed out. In addition, 89 mail inquiries concerning manuscripts were received and more than 200 manuscripts were consulted by the archivist in preparing replies.

While examining these manuscripts, 93 of them were analyzed and more fully described in anticipation of publishing a manuscript catalog. Several descriptive lists of manuscripts relating to specific subjects or tribes were prepared for distribution.

Additions to the collections included a manuscript translation of the Book of Genesis into Choctaw by Rev. Cyrus Byington, dated 1862. This translation was received from Miss Marcia Walton of New York City. Accompanying the gift were a number of photographs and news clippings relating to the Reverend Byington's work; some of these are for permanent deposit, while others have been lent for copying only.

Just at the year's end, Dr. Philip Drucker's field notebooks and unpublished manuscripts for the period 1937–55 were accessioned and sorted. They cover ethnological and archeological work in Alaska, the Northwest coast, California, Meso-America, and Micronesia. They occupy about 20 manuscript boxes.

PHOTOGRAPHIC COLLECTIONS

A sustained interest in pictorial data relating to the American Indian has been shown by authors, publishers, students, and others who have continued to draw heavily on the Bureau's photographic collections. There were 294 inquiries and purchase orders for photographs, and 978 prints were distributed. In response to public inquiry, the archivist prepared numerous lists that described photographs available for specific subjects or tribes.

Public interest has also been demonstrated by the contribution of additional Indian photographs to the Bureau's collections.

Frank B. Shuler of Hamilton, Ohio, lent a group of 29 photographs of Kiowa, Comanche, Caddo, Wichita, and Sioux Indians. These photographs were made about 1900. Copy negatives of 17 of these were made for Bureau files.

Through the courtesy of Mr. and Mrs. Hugh N. Davis, Jr., of Miami, Fla., the Bureau received 295 photographic prints of Seminole, Cheyenne, and Alaskan Indians photographed during the years 1905–52 by Deaconess Harriet M. Bedell, a missionary now residing in Everglades City, Fla. Mr. and Mrs. Davis contributed their services in making enlarged 8-x-10″ prints from snapshot negatives lent to them by Deaconess Bedell; the cost of the materials used was borne by the Bureau.

Later in the year a collection of 450 snapshot negatives of Seminole Indians, made principally by Stanley Hanson in the period 1927–31, was lent to the Bureau by Robert Mitchell of Orlando, Fla., through

Gene Stirling of Venice, Fla. Copy negatives of some 280 of these were made. Enlargements of the remainder are being printed, the work being about half completed at year's end.

ILLUSTRATIONS

Illustrative work for the Bureau of American Ethnology and the River Basin Surveys consumed the major portion of the illustrator's time for the year. This included a great variety of work on charts, graphs, maps, diagrams, photograph retouching, and other illustrations for the Bureau and River Basin Surveys publications.

There were also charts, graphs, mechanical renderings, and illustrations on a variety of other subjects prepared for other Smithsonian departments.

EDITORIAL WORK AND PUBLICATIONS

There were issued 1 Annual Report and 1 Bulletin, as follows:

Seventy-second Annual Report of the Bureau of American Ethnology, 1954–1955. ii + 24 pp. 1956.

Bulletin 163. The Diné: Origin myths of the Navaho Indians, by Aileen O'Bryan. viii + 188 pp., 1 pl., 23 figs. 1956.

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

Bulletin 161. Seminole music, by Frances Densmore.

Bulletin 162. Guaymí grammar, by Ephraim S. Alphonse.

Bulletin 164. Anthropological Papers Nos. 49–56.

- No. 49. The Ormond Beach Mound, east central Florida, by Jesse D. Jennings, Gordon R. Willey, and Marshall T. Newman.
- No. 50. Hair pipes in Plains Indian adornment, a study in Indian and White ingenuity, by John C. Ewers.
- No. 51. Observations on some nineteenth-century pottery vessels from the Upper Missouri, by Waldo R. Wedel.
- No. 52. Revaluation of the Eastern Siouan problem, with particular emphasis on the Virginia branches—the Occaneechi, the Saponi, and the Tutelo, by Carl F. Miller.
- No. 53. Archeological reconnaissance of Tabasco and Campeche, by Matthew W. Stirling.
- No. 54. Valladolid Maya enumeration, by John P. Harrington.
- No. 55. Letters to Jack Wilson, the Paiute Prophet, written between 1908 and 1911, edited by Grace M. Dangberg.
- No. 56. Factionalism at Taos Pueblo, New Mexico, by William N. Fenton.

Bulletin 165. Music of Acoma, Isleta, Cochiti, and Zuñi Pueblos, by Frances Densmore.

Bulletin 166. River Basin Surveys Papers, No. 8. Excavations in the McNary Reservoir Basin near Umatilla, Oregon, by Douglas Osborne.

Bulletin 167. Archeological investigations at the mouth of the Amazon, by Betty J. Meggers and Clifford Evans.

Miscellaneous publications. List of publications of the Bureau of American Ethnology, with index to authors and titles. Revised to June 30, 1956.

Publications distributed totaled 17,018 as compared with 24,533 for the fiscal year 1955.

COLLECTIONS

Acc. No.

208851. 4 specimens of birch bark bearing pictographs incised and etched by the Passamaquoddy Indians of Maine and the Abnaki of New Brunswick.

209009. 35 vials and 39 envelopes of insects from Southampton and Walrus Islands, 300 plants, mollusks, fossils, lemmings, and 38 mammals, collected by Henry B. Collins.

FROM RIVER BASIN SURVEYS

207595. Archeological material consisting of pottery, stone, bone, glass, and metal objects collected by reconnaissance parties of the Missouri Basin Project in and about 16 reservoir areas in Nebraska, and human skeletal material from 4 sites.

207596. Archeological specimens from North Dakota.

208180. 149 fresh-water mollusks from Nebraska and Wyoming, collected by Carl F. Miller.

209283. Archeological specimens consisting of pottery, stone, bone, glass, and metal objects collected by parties of the Missouri Basin Project, in and about two sites in area of Fort Randall Reservoir, Charles Mix County, S. Dak., and human skeletal material from 39CH7.

209694. Archeological material consisting of rim and body sherds from Clay County, Kans.

209962. Archeological material consisting of pottery, stone, bone, and shell objects collected by reconnaissance parties of the Missouri Basin Project, from two mound sites in South Dakota, 1947–48, human skeletal material.

209963. Shell beads collected by reconnaissance parties of the Missouri Basin Project from site in Stanley County, S. Dak., human skeletal material.

210409. Archeological and human skeletal material from site in Fort Randall Reservoir, S. Dak.

MISCELLANEOUS

Dr. John R. Swanton, Dr. Frances Densmore, Dr. Antonio J. Waring, Jr., and Ralph S. Solecki continued as collaborators of the Bureau of American Ethnology. Dr. John P. Harrington is continuing his researches with the Bureau as research associate. Dr. William C. Sturtevant, ethnologist, joined the staff of the Bureau on March 29, 1956.

Information was furnished during the past year by staff members in reply to numerous inquiries concerning the American Indians—past and present—of both continents. Many new descriptive lists and information leaflets were prepared in answer to requests for information on the Bureau's photographic and manuscript collections and other subjects. There continued to be a constant demand for information, published material, and photographs from teachers, particularly of

primary and secondary grades, from Scout organizations, and from the general public. Material for use in writing term papers was in frequent demand by high-school students who show an increasing interest in this popular subject. On several occasions publishers consulted various staff members regarding ethnological and archeological problems, and the archivist regarding unpublished manuscripts and the photograph collections. Specimens sent to the Bureau were identified and data on them furnished for their owners.

Respectfully submitted.

M. W. Stirling, *Director*.

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

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, 1956:

The Astrophysical Observatory includes two research divisions: the Division of Astrophysical Research, for the study of solar and other sources of energy impinging on the earth, and the Division of Radiation and Organisms, for investigations dealing with radiation as it bears directly or indirectly upon biological problems. Three shops—for metalwork, woodwork, and optical electronic work—are maintained in Washington to prepare special equipment for both divisions, and a field station for solar observation is located at Table Mountain, Calif.

DIVISION OF ASTROPHYSICAL RESEARCH

At the beginning of the fiscal year, the scientific headquarters of the Division of Astrophysical Research were moved from Washington to Cambridge, Mass. In this new location, a close liaison with Harvard University is expected to add to the research effectiveness in astrophysics for the Smithsonian Institution. With this transfer and the development of a working association with Harvard College Observatory, a reevaluation of the basic scientific policies and goals of the Astrophysical Observatory was undertaken. Because of the present-day rapid progress in the physical sciences, the understanding of the fundamental astrophysical processes of the sun, earth, planets, and interplanetary medium has grown at an ever-increasing rate. In addition, our mushrooming technology has become more and more sensitive to phenomena of the solar system which were once considered as of only academic interest. The Astrophysical Observatory's long tradition of active research in solar and terrestrial phenomena and their interrelationships has laid a firm foundation upon which will be based new research objectives including, besides solar radiation, other phenomena of the solar system which also affect the earth and its atmosphere. Energy sources other than the sun have a profound effect on our atmosphere, on geophysical phenomena, and on practical technological aspects of radio communication, the guidance of missiles, and other practical considerations. Among the sources of energy are corpuscular radiation from the sun, meteors,

cosmic rays, interplanetary gas, and radiation from without the solar system.

This broadened research program of the Astrophysical Observatory now embraces not only research in solar activity and its effects upon the earth, but also meteoritic studies and studies of the higher atmosphere. New methods of research, as they develop, will be included in the program. For example, radioactivity and nuclear processes will be utilized in the study of meteorites. Theoretical research and magnetohydrodynamics will increase our understanding of how solar variations and activity occur and how the energy from these activities affect the earth's magnetic field, produce air night glow, the aurora borealis, and other phenomena of a geophysical character.

The new Satellite Program of the International Geophysical Year, sponsored by the National Academy of Sciences and the National Science Foundation, and in which the Astrophysical Observatory has a very important part, promises a new and startling tool of remarkable power in the study of solar-system and geophysical phenomena. Such technological tools as may be developed will be incorporated in the working potential of the Astrophysical Observatory. A restudy of plans and methods was an important first step.

Work on solar radiation.—As reported last year, the quality of the skies at the Montezuma station in Chile deteriorated to an intolerable degree because of smoke introduced by smelting operations at nearby copper mines. Consequently, the station was closed September 22, 1955. The scientific and new transportation equipment was moved to Table Mountain in southern California. By the middle of winter the three observers at that station, F. A. Greeley, A. G. Froiland, and Stanley Aldrich, extended the observational program to include simultaneous observations of the sun from two similar arrays of radiation-measuring equipment. In this fashion it will now be possible to check the influence of instrumental variations upon the measurements of solar radiation and atmospheric opacity.

However, the Table Mountain skies are also beginning to show progressive deterioration from the smog from the Los Angeles urban area. So far this has not been too disadvantageous, but probably the transparency loss will eventually necessitate the acquisition of a new observing station for solar radiation. Serious searches for a site with clear skies have been conducted in recent years, but the time is approaching when a conclusive investigation must be made of the usable high-altitude locations that offer the necessary atmospheric qualifications for precise solar measurements. It is possible that the use of satellite vehicles for carrying instruments to measure solar radiation will eventually obviate the need for ground stations by elim-

inating the errors arising from atmospheric opacity. On the other hand, the measurements of atmospheric opacity in the observing program of the Astrophysical Observatory have become of increasing interest to meteorologists and geophysicists in recent years. Records from Table Mountain show clearly the increased opacity of the atmosphere arising from the Alaskan volcano in 1953. However, they show no effect of increased opacity arising from the explosions of nuclear or thermal nuclear bombs.

Meteoritic studies.—Meteoritic studies have been a part of the Smithsonian Institution's scientific research program for the past 80 years. The Institution's meteorite collection, which has been developed through these decades of exploration and study, is one of the most outstanding in the world. In cooperation with meteorite specialists in the department of geology of the United States National Museum, E. P. Henderson and the late Dr. W. F. Foshag, a freshly oriented plan of meteoritic research has been explored. This new program has been placed under the supervision of Dr. John S. Rinehart for the purpose of ascertaining the answers to numerous questions concerning astrophysical dynamics. As a result, the following aspects of the problem are now in course of consideration: Past and current research pertaining to the nature and distribution of meteorite debris and micrometeorites; the nature of meteorite craters; exterior and terminal ballistics and other phenomena that relate to meteoritic impact against the earth; and the extraterrestrial life of meteorites. All these studies are directed toward answering astrophysical rather than specific geologic questions.

Under the sponsorship of the United States Air Force, the Astrophysical Observatory has initiated a program whose objective is to develop a better understanding of the processes that cause ablation as meteorites hurtle through the atmosphere. Effort thus far has been confined (1) to renewed search of museum collections for specimens that exhibit ablation, and (2) to a metallurgical examination of meteorites that show heat alteration effects caused by their passage through the atmosphere.

In June 1956, Dr. J. S. Rinehart, Nicholas Matalas, R. O'Neil, and R. Olson journeyed to the meteorite crater near Winslow, Ariz., in order to investigate, by systematic sampling, miniscule spherules, globules, and pieces of meteoritic matter in the soil around the crater. The search will extend over an area of more than 100 square miles. Magnetic means are being used to extract meteoritic material from soil samples. Initial effort is being directed toward the development of sampling techniques and the identification of material. The results of the first survey will be used as the basis for further and more extensive exploration of the Arizona crater and other terrestrial me-

teorite craters. A long-term objective of the program is to arrive at a better estimate of the rate of accretion of meteoritic material by the earth.

Design and construction of a fluorescent X-ray micronanalyzer have likewise been initiated and are now well under way. When completed this instrument can be used to determine within a microscopic (5-micron) area the concentration and distribution of the various chemical elements within a meteorite, without destruction of the sample. The method will be applied first to the determination of nickel-iron percentages in meteorites that have Widmanstaetten figures. A knowledge of the distribution of nickel will be of considerable cosmological significance as related to the origin of meteorites.

Satellite Tracking Program.—The United States National Committee of the International Geophysical Year under the National Academy of Sciences and through the National Science Foundation has assigned to the Smithsonian Institution the responsibility, and also a grant of funds, for initiating and executing an optical research program involving the tracking of the planned artificial earth's satellite. Dr. J. Allen Hynek has joined the project as associate director in charge of the Optical Observing Program and will join the permanent Smithsonian staff in July 1956.

The Satellite Tracking Program consists of two distinct parts: the visual search and tracking program, of low-order accuracy, and the photographic tracking program, of extremely high precision. The two have a common denominator in the needs for a communication system and a central computing bureau to provide ephemerides and for the later analysis of scientific results attained from the tracking of the satellites.

The precision optical program will be carried out by means of special Schmidt cameras of aperture 20 inches, mirrors of aperture 30 inches, and focal length of 20 inches, for which a newly developed optical system is being designed by Dr. James G. Baker. A unique drive system for these cameras is being designed by Joseph Nunn and associates to make possible the photography of a 15-inch sphere at a distance of a thousand miles and a 3-foot sphere at the moon's distance during hours of deep twilight or darkness when the satellite is illuminated by the sun. A tracking accuracy of some 2 seconds of arc normal to the path of the satellite on the sky and some 6 to 10 seconds along the direction of motion with a time precision of one-thousandth of a second is anticipated in the operation of these cameras.

A number of observing stations, possibly 12, each of which will include one of these cameras and a precise crystal-clock system, will be established at intervals around the globe. Observations of artificial earth satellites from such a system of stations, combined with an

accurate computing system, should make possible the calculation of the position of the satellite at any moment and the relative position of the stations in respect to each other and to the center of the earth with a precision of some 30 feet. Not only is such precision tracking essential to the general scientific value of the Artificial Satellite Program, but it will lead specifically to precise determination of the atmospheric density and pressure as a function of height to an altitude of some 300 to 500 miles above the earth's surface. It will provide a precise interconnection among the geodetic networks of the continents and islands, the inclination of these networks with respect to the true geoid, the shape of the earth, certain gravimetric data concerning the distribution of mass in the earth, and other geophysical information of great significance.

The visual tracking program will have two aspects: (1) Acquisition of a satellite in case the electronic tracking equipment contained in the satellite should fail, as well as possible tracking near the end of a satellite's lifetime as it plummets through the lower atmosphere; and (2) a broad contribution to general interest in scientific research by young potential scientists as well as the general public. The visual observations will be carried out by a large number of nonprofessional observers under the general direction of Dr. Armand N. Spitz. It is expected that between one and two thousand observers, usually amateur astronomers, will be activated in this program, but many times that number will follow the program in considerable detail and gain scientific understanding and interest because of it.

The organization of the visual observation part of the program is well under way, and the first of a series of bulletins has been prepared and issued to more than 20,000 potential observers.

The participation of the Smithsonian Astrophysical Observatory in the Artificial Satellite Program follows two traditions that we cherish in the Smithsonian Institution. We are participating as pioneers in the progress of science, comparable to Dr. Langley's original research in the flight of heavier-than-air craft. We are also promoting international interest in the Satellite Tracking Program which is in keeping with the worldwide pattern of contributions to knowledge by the Smithsonian Institution.

DIVISION OF RADIATION AND ORGANISMS

(Prepared by R. B. Withrow, Chief of the Division)

The major activities of this division have been concerned with fundamental physiological and biochemical research on the role of light in regulating growth in higher plants. Seed germination, seedling growth, flowering, and the development of what is commonly referred to as a "normal plant" are controlled by light. Pigments

within the organism absorb the light and convert it into chemical bond energy and thus initiate a chain of events that produce the observed growth effects. In most instances, relatively little light is necessary. This is in contrast to the photosynthesis of sugars where very high intensities are required for optimal results. There is a similar group of light-controlled reactions in animals which regulate many phases of reproductive behavior. Plans have been prepared for extending the findings and technics developed in the laboratories to this phase of animal physiology.

The regulatory plant photochemical reactions may be divided into two general groups: (1) Those controlled chiefly by red and far-red light; and (2) those controlled principally by blue light. The respective pigment systems channel the energy into different biochemical pathways and therefore induce entirely different physiological responses.

Photomorphogenesis.—Included in the photochemical reactions initiated by red light are formative growth processes in seedlings, such as the ability to form normal leaves and the disappearance of the stem hook that often is present on germination. Any one of these responses, among many others, can be used as quantitative bioassays of the photoreactions. In these laboratories we have developed a technic based on the rate of angular opening of the excised stem hook or arch that appears in seedlings of beans and other dicotyledonous plants that have been grown in complete darkness. If the hook portion of the stem is cut from the seedling and exposed to red light, and then returned to darkness, the hook will open in the following 20 hours to an angle that is proportional to the logarithm of the incident red-light energy. Last year it was determined that the most effective region of the spectrum for producing this response was in the red at 660 mμ. If, after an exposure to red light, the hook is treated with far-red energy from 700 to 750 mμ, much of the effectiveness of the initial red treatment is inhibited or "reversed." Dr. W. Klein, Dr. R. B. Withrow, and V. Elstad have completed the action spectrum of this far-red reversal phenomenom and have found that the maximum reversal occurs at 710 and 730 mμ, with a weak maximum at 640 mμ. The reversal action has been determined at 27 points in the spectrum from 365 to 800 mμ in the following incident energy series: 25, 10, 7.5, and 5.0 millijoules (mj). The percentage reversal is directly proportional to the far-red incident energy, up to values of 10 mj which produces about 85 percent reversal. This linear response is in contrast to logarithmic function of the red-light induction reaction.

Phototropism.—Another expression of photoregulatory processes in plants is bending toward a light source, or phototropism. Previously, Dr. E. S. Johnston of this laboratory had found the action

spectrum of this response in oat plants to have two maxima in the blue. However, because of poor resolution of the reaction in this region, subsequent disagreement has arisen and it has not yet been clearly established what pigment absorbs the incident energy and initiates the response. There are several blue-absorbing pigments, including the carotenoids and flavins, with absorption characteristics that might qualify them as candidates for the role of the photoactivated pigment. For example, beta-carotene has absorption maxima in the blue at 435 and 470 mμ and riboflavin at 445 and 475 mμ. Both pigments are commonly found in plants.

However, the flavins and the carotenoids have very clear-cut spectral differences in the near ultraviolet. Riboflavin has a strong absorption maximum at 370 mμ, but the carotenoids do not absorb in this region. Therefore, the effectiveness of various ultraviolet wavelengths in promoting phototropic curvature might be used as an indicator as to which of these two pigment types is involved. When the pigment system responsible is identified, it will be possible to resolve the initial steps of the chemical reactions leading to curvature.

In order to establish the effectiveness spectrum, a large-grating monochromator, for irradiation in the near ultraviolet and visible, has been built in the Observatory shops. Calibration of the equipment has been completed and Walter Shropshire has standardized bioassay technics, using curvatures of the oat and barley coleoptiles to measure the effectiveness spectrum. Although positive phototropic curvatures have been obtained in the near ultraviolet in preliminary studies, a complete monochromatic analysis of the action spectrum in the entire visible and near ultraviolet appears necessary before the photoactivated pigment system can be clearly identified.

Photochemical synthesis of plant pigments.—Dr. J. Wolff and L. Price have found that the complete chlorophyll molecule is not formed immediately on irradiation of leaves of plants grown in the dark, as heretofore postulated. Instead, protochlorophyll, the green pigment present in very low concentrations in leaves of dark-grown seedlings, is rapidly converted by light to chlorophyllide *a*. This pigment is subsequently linked to the long chain alcohol, phytol, by the action of the enzyme chlorophyllase in a strictly nonphotochemical thermal reaction. Chlorophyllide *a* and chlorophyll *a* have identical absorption spectra in the visible, but differ in chemical properties. Protochlorophyll has a different absorption spectrum from chlorophyllide *a*, yet the two pigments have similar chemical properties. These facts indicate that what has been commonly termed "protochlorophyll" is actually protochlorophyllide.

Modification of X-ray damage by visible radiant energy.—The damaging effects of X-rays and other forms of ionizing radiation to liv-

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ing cells are due chiefly to the breaking of the chromosomes and interference with normal cell division. Young rapidly dividing cells are most susceptible to X-ray damage and evidence three types of aberrations—chromatid break, isochromatid break, and chromatid exchange. In the past year, Dr. C. C. Moh and Dr. R. B. Withrow continued the study of the effect of infrared, far-red, and red radiant energy on the modification of chromosomal damage induced by X-rays, using root tips of the horse bean, *Vicia faba*, as the chief experimental material.

It has been found that infrared, from 820 to 1350 mμ, causes no significant increase in X-ray damage to the chromosomes. However, far-red at 710 to 820 mμ did significantly increase the frequency of chromosomal aberrations induced by X-rays. The three types of chromosomal aberrations were not effected equally, however. Chromatid exchanges increased 100 percent; chromatid breaks, 34 percent; isochromatid breaks were increased very little, if at all. These results were substantiated with the pollen of the *Tradescantia* flower where the chromosomes of the microspores showed similar results.

When wavelengths from 680 to 820 mμ (involving red and far-red radiant energy) were used, the ability of far-red to increase the X-ray damage was not secured. Thus, apparently, when red and far-red are combined in proper proportions, the two regions nullify each other. This could explain the negative results obtained by several workers who irradiated the biological material with filters that did not sharply absorb all the red.

Red radiant energy (wavelengths from 630 to 680 mμ), when used alone prior to X-irradiation, increased the yield of chromatid exchanges significantly, but chromatid and isochromatid breaks were consistently decreased by 10 to 20 percent. This action of red radiant energy on X-ray-induced chromosomal breaks is not yet clear. It is suggested that the red radiant energy might accelerate the rejoining process after the breakage occurs.

PUBLICATIONS

During the current year the following publication concerned with the work of the Division of Astrophysical Research was issued by the Smithsonian Institution:

Leading operations of the Smithsonian Astrophysical Observatory, 1895 to 1955, by C. G. Abbot. Smithsonian Misc. Coll., vol. 131, No. 1, Sept. 22, 1955. (Publ. 4222.)

The following publications by Dr. F. L. Whipple appeared in various other scientific journals:

On meteors. Proc. Astron. Soc. Pacific., vol. 67, pp. 367–386, 1955.

Photographic a-Capricornid meteors (with F. W. Wright and L. G. Jacchia). Astron. Journ., vol. 61, p. 61, 1956.

A research program based on the optical tracking of artificial earth satellites (with J. A. Hynek). Proc. Inst. Radio Eng., vol. 44, pp. 760-764, 1956.

On meteors and rainfall (with G. S. Hawkins). Journ. Meteorol., vol. 13, No. 3, pp. 236-240, June 1956.

A new series, Smithsonian Contributions to Astrophysics, has been initiated to provide a proper outlet for the research contributions of the Smithsonian Astrophysical Observatory and to provide an additional avenue of publication for a limited number of contributions by other investigators with interests in common with those of our observatory. These contributions will contain research papers specifically in astrophysics, with particular attention to problems of the sun, the earth, and the solar system.

The first number of the Smithsonian Contributions to Astrophysics, in galley proof at the end of June, is entitled "New Horizons in Astronomy." It is a collection of scientific papers by leaders in the various fields of astronomy who present their concepts of the research problems that should prove most important to the advancement of astronomy during the next decade or two. These papers are published with partial support by the National Science Foundation. An *ad hoc* committee of the National Science Foundation, on the "Needs of Astronomy," has devoted its attention to methods of increasing the potential of astronomy. One of the methods is the publication of the "New Horizons" series of papers. There is hope that the Smithsonian Contributions to Astrophysics will serve to further our understanding and appreciation of this part of the universe in which we are privileged to live.

OTHER ACTIVITIES

During the course of the year, the Director attended and contributed to the following international congresses: The International Federation of Astronautics at Copenhagen, Denmark, in August 1955; a symposium on radio astronomy at the Jodrell Bank Experimental Station, University of Manchester, England, in August 1955; and the Congress of the International Astronomical Union held at Dublin, Ireland, in early September 1955. He was appointed President of the Subcommission on Meteoritics of the IAU commission No. 22.

In national science and defense, the Director contributed by serving in the following capacities: Chairman of an *ad hoc* committee on "Needs of Astronomy" on the Panel on Astronomy of the National Science Foundation; chairman of a working group to set up a standard atmosphere for national and international use; as chairman of the Panel on Rocketry of the International Geophysical Year, U. S. Council of the National Academy of Sciences; member of the Technical Panel on the Earth Satellite Program of the International Geophysical Year; member of the working group on the Tracking

of Artificial Earth Satellites under the above panel; associate editor of the Astronomical Journal; and member of the Panel of the Atmosphere of the Scientific Advisory Board to the Air Force.

Respectfully submitted.

F. L. Whipple, *Director*.

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

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, 1956.

SMITHSONIAN ART COMMISSION

The 33d annual meeting of the Smithsonian Art Commission was held in the Regents Room of the Smithsonian Building on Tuesday, December 5, 1955. Members present were: Paul Manship, chairman; Robert Woods Bliss, vice chairman; John E. Graf, acting secretary; John Nicholas Brown, Gilmore D. Clarke, David E. Finley, Lloyd Goodrich, Walker Hancock, Charles H. Sawyer, Stow Wengenroth, Archibald G. Wenley, Lawrence Grant White, Andrew Wyeth, and Mahonri Young. Thomas M. Beggs, Director, and Paul V. Gardner, curator of ceramics, National Collection of Fine Arts, were also present.

Dr. Finley, chairman, reported that the executive committee had met on November 18, 1955. Those present were: Mr. Clarke, Mr. Wenley, Mr. Manship, Dr. Carmichael, ex officio, and Mr. Beggs. Various means of acquiring works by living artists were discussed. Existing membership of the Commission was considered, and it was suggested that at its annual meeting the present imbalance between its three categories of membership (artists, experts, and men from civic life) be corrected by strengthening representation of public interest. Acting as a nominating committee, at the request of Mr. Manship, the executive committee suggested a list of officers and members for new terms. Following this report, the Commission voted to recommend to the Smithsonian Board of Regents the reelection of Lloyd Goodrich, Walker Hancock, Lawrence Grant White, and Bartlett H. Hayes, Jr., for the usual 4-year period.

The following officers were elected for the ensuing year: Paul Manship, chairman; Robert Woods Bliss, vice chairman; and Leonard Carmichael, 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 Leonard Carmichael, as secretary of the Commission, are ex-officio members of the executive committee.

Mr. Beggs pointed out that gifts of valuable art objects will not be received until exhibition space of the National Collection of Fine Arts is noticeably increased. He stated that since the National Gallery of Art now collects and superbly exhibits the art of the past, the proper function of the National Collection of Fine Arts should be the acquisition of meritorious examples of painting, sculpture, and design by living artists. The Ranger Fund of the National Academy of Design establishes a precedent for placing such works of art in other institutions until re-called for use in the National Collection of Fine Arts. Until a new Smithsonian Gallery of Art is built, therefore, accessions by gift, as well as by purchase, might be lent if donations were made with that understanding. The advantage of purchase prize competitions was discussed, and possible circulation of selected items from these by the Smithsonian Traveling Exhibition Service was mentioned. The urgent need for space in a new building to house all these services was cited.

Mr. Goodrich recalled that at the last annual meeting discussion concerning the Smithsonian Gallery of Art had not been completely resolved and presented a resolution which was unanimously accepted as follows:

Whereas the Congress of the United States approved a Joint Resolution on May 17, 1938, titled Public Resolution No. 95, 75th Congress, providing that a suitable tract of public land in the District of Columbia between Fourth and Fourteenth Streets and Constitution and Independence Avenues should be assigned as a site for the Smithsonian Gallery of Art, that appropriate designs for a building for the Gallery should be secured, the sum of $40,000 being appropriated for this purpose, and that the Regents of the Smithsonian Institution should be authorized to solicit and receive funds from private sources to meet the cost of construction of such a building, to purchase works of art, conduct exhibitions, and carry on other related activities; and *whereas* a competition for designs for such a building was held by the Smithsonian Gallery of Art Commission; therefore be it

Resolved, that the Smithsonian Art Commission strongly favors the early construction of such a building; that the Commission believes that if this is to be accomplished, funds must be appropriated by the Congress in addition to donations from private sources; and that the Commission requests that the Secretary of the Smithsonian Institution transmit this resolution to the Regents of the Institution and to other interested persons.

Mr. Brown proposed the following motion which was carried unanimously:

It is moved that the executive committee be requested to take under advisement the program for the new building and, in consultation with the Secretary of the Smithsonian Institution, define the purposes and the scope of the much desired new building.

The Commission recommended acceptance of the following objects:

Oil, Brooding Silence, by John F. Carlson, N. A. (1875–1945). Henry Ward Ranger Bequest.

Three miniatures, A Gentlewoman, Lady with Blue Hair Ribbon, and Lady with Pearls in Hair, by Hattie E. Burdette (?–1955). Gift of George F. Linkins.

A German antique cabinet and a collection of 31 pieces of glass, mostly German and Bohemian from the sixteenth to the nineteenth centuries. Bequest of Henry Osthoff.

Two award-winning pieces from the Fifth International Exhibition of Ceramic Art, 1955; sgraffito bowl, by Roger D. Corsaw, winner of the Frank A. Jelleff award; and a green bowl, by Cynthia Wilder Mott, winner of the Popular Ceramics Magazine award. Gift of the Kiln Club.

Three bronze busts, offered by the sculptors to the Smithsonian Institution—Dr. Charles Greeley Abbot, by Alicia Neathery; Dr. Albert Schweitzer, by Leo Cherne; and Daniel Carter Beard, by Nickolai V. Dimitrieff—were recommended for addition to the Smithsonian collection, the latter two for transfer to the division of medicine and public health and the division of civil history, respectively.

THE CATHERINE WALDEN MYER FUND

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

101. Richard Yates (1732–1808), attributed to John Ramage (1748–1802).

102. Mrs. Richard Yates (nee Catherine Brass) (1735–?), attributed to John Ramage.

103. Lawrence Reid Yates (brother of Richard) (?–1796), by Walter Robertson, after Gilbert Stuart.

104. Mrs. Elizabeth Pollock Hartigan, attributed to Walter Robertson.

Nos. 101 through 104 were acquired from Capt. Edward E. Lull, U. S. N. R., Norfolk, Va.

105. Mrs. Benjamin Silliman (Harriet Trumbull) (?–1850), attributed to Henry Colton Shumway (1807–1884); from Spencer R. McCulloch, Kirkwood, Mo.

WITHDRAWAL BY OWNERS

Twenty-two bronzes, 20 by Frederic Remington, lent in 1947, Paleolithic Woman, by Sally James Farnham, lent in 1947, and Destiny of the Red Man, by Adolph A. Weinman, lent in 1950, were withdrawn by the R. W. Norton Art Foundation, Shreveport, La., and taken to the Remington Art Memorial, Ogdensburg, N. Y., on December 8, 1955.

Five family portraits, Lady Standing by Tombstone (Henrietta Gordon), signed Martin, and Lucy Walters and the Duke of Monmouth, said to be by Sir Peter Lely, lent by the Bruce Corporation (Ltd.) of Kildary, Scotland, and Wilmington, Del., through Sir Charles Ross in 1926; Hon. Grizel Ross, said to be by William Hogarth, lent by Lady Ross in 1949, and Charles II, and Earl of Lauderdale, by undetermined artists, lent by her in 1951, were withdrawn by Lady Ross for shipment to Balnagown Castle, Ross-shire, Scotland, on February 28, 1956.

Four hundred and sixty-seven Chinese jade ornaments, 111 Chinese snuff bottles, 45 Chinese mirrors, 1 plate, and 3 bowls, lent by Dr. Edwin Kirk in 1943 and 1944, were withdrawn by Mrs. Kirk on March 29, 1956.

ART WORKS LENT

The following art works, oil paintings on canvas unless otherwise noted, were lent for varying periods:

To the United States District Court for the District of Columbia, Washington, D. C.:

July 5, 1955 — Friendly Neighbors, by Alfred Howland.
Head of a Woman, by Jean Gustave Jacquet.
Head of a Woman, by Eisman Semonowski.
Queen Henrietta Maria, Wife of Charles I, in the manner of Anthony Van Dyck.

May 24, 1956 — Francis James Child, by Leila Usher. (Plaster bas-relief.)
American Eagle, by undetermined sculptor. (Plaster cast.)
Madonna with Halo of Stars, by undetermined artist.
November, by Dwight W. Tryon.

To David Reasoner, as executor of the estate of Abbott H. Thayer, and Charles M. Plunket, Washington, D. C.:

August 3, 1955 — Two Hooded Warblers, by Abbott H. Thayer.
11 cardboard folders containing sketches made by Abbott H. Thayer during his study of Protective Coloration in the Animal Kingdom.

To the Naval Historical Foundation, Washington, D. C.:

August 11, 1955 — Portrait of Stephen Decatur, by Gilbert Stuart. (Returned May 1, 1956.)

To the Department of Defense, Washington, D. C.:

August 23, 1955 — The Rapids, by W. Elmer Schofield.
Tohickon, by Daniel Garber.

To the Museum of the City of New York, New York, N. Y., for a special exhibition "Four Centuries of Italian Influence in New York":

September 15, 1955 — The Street Shrine, by Jerome Myers. (Returned January 20, 1956.)

To The Pennsylvania State University, University Park, Pa., for its Centennial Exhibition:

September 27, 1955 — Cliffs of the Upper Colorado River, Wyoming Territory, by Thomas Moran. (Returned November 16, 1955.)

To the Department of Health, Education, and Welfare, Washington, D. C.:

October 4, 1955 — The Grand Canal, Venice, by Gabrini.
Figure Group, by O. Lear.
Dr. George Washington Carver, by Betsy Graves Reyneau.
Rockwell Studio, by Macowin Tuttle.

To the Department of Justice, Washington, D. C.:

November 21, 1955 — Mrs. Tarbell as a Girl, by Edmund C. Tarbell. (Permission granted by owner, Mrs. Josephine Tarbell Ferrell.)

November 22, 1955 — Gen. Albert J. Myer, by G. P. A. Healy. (Returned January 24, 1956.)

January 24, 1956 — Maj. Gen. George B. McClellan, by Julian Scott.
Hon. Charles Evans Hughes, by Harry L. Raul. (Plaster bas-relief, bronzed.)

To the International Business Machines Corporation, New York, N. Y., for casting in bronze:

November 28, 1955 — Joseph Henry, by Herbert Adams. (Plaster bust.) (Returned February 15, 1956.)

To the Smithsonian Traveling Exhibition Service, Washington, D. C., to be included in an exhibition "Pennsylvania Painters":

December 6, 1955 — Cliffs of the Upper Colorado River, Wyoming Territory, by Thomas Moran.

December 20, 1955 — Mary Abigail Willing Coale, by Thomas Sully.

To the Virginia Museum of Fine Arts, Richmond, Va., to be included in a special exhibition "Portraits of Virginia-born Presidents":

January 17, 1956 — President John Tyler, by G. P. A. Healy. (Returned February 15, 1956.)

To the Federal Power Commission, Washington, D. C.:

February 23, 1956 — John Burroughs, by Walter Beck.
September, by William A. Coffin.
After a Storm, Amagansett, by Arthur T. Hill.

To the Alexandria Association, Alexandria, Va., for an exhibition "Our Town, 1749–1865":

April 10, 1956 — Miniature, John Gadsby, by Benjamin Trott.
Miniature, Member of the Washington Family, attributed to James Peale.
Miniature, John Parke Custis, by Charles Willson Peale.
Miniature, Martha "Patty" Custis, by Charles Willson Peale. (Permission to lend the Custis miniatures was granted by the owners.) (Returned May 29, 1956.)

To the Department of State, Washington, D. C.:

May 11, 1956 — Triptych, by Kano Tsunenobu.
Scroll, Tiger and Cub, by Mr. Whang Jang Har.

June 20, 1956 — Hindu Merchants, by Edwin Lord Weeks.

To the Interstate Commerce Commission, Washington, D. C.:

June 20, 1956 — Male Wood Duck in a Forest Pool, by Abbott H. Thayer.

June 26, 1956 — Male Wood Duck, by Abbott H. Thayer.

LOANS RETURNED

Oil, Abraham Lincoln, by George H. Story, lent March 15, 1955, to the Department of Justice, was returned November 22, 1955.

Oil, Andrew Jackson, by Ralph E. Earl, lent September 20, 1949, to the Department of State, was returned November 30, 1955.

Oil, Gen. Dwight D. Eisenhower, by Capt. Sir Oswald Birley, lent June 29, 1955, to the Bureau of the Budget, was returned November 30, 1955.

Two oils, Charles G. Abbot, by Samantha L. Huntley, and Charles D. Walcott, by Hattie Burdette, lent April 17, 1953, to the National Academy of Sciences, were returned November 30, 1955.

Oil, Samuel P. Langley, by Robert G. Hardie, lent May 1, 1950, to the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics, Langley Field, Va., was returned December 2, 1955.

Oil, Man in White (Dr. Henry S. Drinker), by Cecilia Beaux, lent December 7, 1954, to the Pennsylvania Academy of Fine Arts, Philadelphia, Pa., was returned December 15, 1955.

Oil, Early Spring, by Alexander T. Van Laer, lent November 10, 1953, to the Department of State, was returned January 16, 1956.

Oil, Summer, by Charles H. Davis, lent September 17, 1954, to The White House, was returned April 4, 1956.

Oil, Stephen Decatur, by Gilbert Stuart, lent August 11, 1955, to the Naval Historical Foundation, was returned May 1, 1956.

SMITHSONIAN LENDING COLLECTION

Oil, Grand Canyon, by Carl Oscar Borg (1879–1947), a gift of Mrs. Martin O. Elmberg, was accepted December 6, 1955.

Two hundred and seventeen unframed oils, by Frank W. Stokes (1858–1955), to be known as the Arthur Curtis James and Robert Curtis Ogden Memorial Collection, were added. One hundred and thirty-five were received July 19, 1954; 76 on April 5, 1955; and 6 on May 18, 1955.

The following paintings were lent for varying periods:

To the United States District Court for the District of Columbia, Washington, D. C.:

July 5, 1955	Hippolyte Dreyfus, by Alice Pike Barney.
	La Concord, by Edwin Scott.
	Place de la Concord, No. 2, by Edwin Scott.
	Porte St. Martin, No. 1, by Edwin Scott.
	Rue de Village, by Edwin Scott.
	Rue des Pyramides, by Edwin Scott.
	Rue San Jacques, by Edwin Scott.
	Self Portrait, by Edwin Scott.
May 24, 1956	Marine, by Edwin Scott.
	The Seine at Paris, by Edwin Scott.

To the Department of Labor, Washington, D. C.:

July 6, 1955 A. P. B. in Painting Robe, by Alice Pike Barney.
Porte St. Denis, by Edwin Scott.
Somnolence, by Edwin Scott.
Study of Seated Woman, by Alice Pike Barney.
Mme. I. D. C., by Alice Pike Barney.
E. P. (Evalina Palmer), by Alice Pike Barney.
Italian Woman and Child, by Alice Pike Barney.
Italian Woman at Foot of Steps, by Edwin Scott.
La Madeleine, No. 1, by Edwin Scott.
Notre Dame in Winter, by Edwin Scott.
Old Dwelling, Paris, by Edwin Scott.
St. Germain des Pres, No. 1, by Edwin Scott.
(The last nine were returned July 27, 1955.)

To the Bio-Sciences Information Exchange, Washington, D. C.:

July 26, 1955 Minnete and Minet, by Alice Pike Barney.
The Visitor (Mrs. Richard P. McCullough), by Alice Pike Barney.
Endymion, by Alice Pike Barney.
The Dimple, by Alice Pike Barney.
Little Girl, by Alice Pike Barney.
Hail Fellow, Well Met, by Alice Pike Barney.

November 2, 1955 An Oriental, by Alice Pike Barney.
Fantasy, by Alice Pike Barney
Gladys, by Alice Pike Barney.
Hippolyte Thom, by Alice Pike Barney.
Laura in Hat, Profile, by Alice Pike Barney.
Natalie in Greens, by Alice Pike Barney.
Peggy, by Alice Pike Barney.
Romance, by Alice Pike Barney.

To the Department of Health, Education, and Welfare, Washington, D. C.:

October 4, 1955 Musketeer on Guard, by A. Arrunategin.
St. Germain des Pres, No. 1, by Edwin Scott.
The Bali Temple Festival, by Maurice Sterne.

To the Department of Justice, Washington, D. C.:

November 21, 1955 Mountain and Valley, by James Henry Moser.
Notre Dame in Winter, by Edwin Scott.
La Madeleine, No. 1, by Edwin Scott.
Church of St. Germain des Pres, by Edwin Scott.
Church and Lake, by Henry Bacon.

To the Federal Power Commission, Washington, D. C.:

February 23, 1956 An Evening Effect, Greenland, by Frank W. Stokes.

To the Interstate Commerce Commission, Washington, D. C.:

June 20, 1956 The Placid Potomac, by William H. Holmes
Greenland, by Frank W. Stokes.

ALICE PIKE BARNEY MEMORIAL FUND

Additions to the principal during the year amounting to $1,824.37 have increased the total invested sums in this fund to $36,428.22.

THE HENRY WARD RANGER FUND

No. 176, On Strike, by Robert A. Hitch (1920–), purchased by the National Academy of Design March 24, 1954, was assigned by the Academy to the Hudson River Museum at Yonkers, Yonkers, N. Y., on December 3, 1955.

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, four paintings were re-called for action of the Smithsonian Art Commission at its meeting December 6, 1955.

No. 28, Brooding Silence, by John F. Carlson, N. A., listed earlier in this report, was accepted by the Smithsonian Art Commission to become a permanent accession.

No. 36, Midsummer, by William S. Robinson, N. A. (1861–1945), assigned in 1956 to the George Washington University, Washington, D. C.

No. 100, Rhododendron, by H. Dudley Murphy, N. A. (1867–1945), assigned in 1932 to the University of Tulsa, Tulsa, Okla.

No. 107, The Blue Jar, by Cullen Yates, N. A. (1866–1945), assigned in 1954 to the Norfolk Museum of Arts and Sciences, Norfolk, Va.

The last three paintings were returned to the institutions to which they had been assigned by the National Academy of Design, as indicated.

SMITHSONIAN TRAVELING EXHIBITION SERVICE

Seventy-two exhibitions were circulated during the past season, 71 in the United States and 1 abroad, as follows:

UNITED STATES

Paintings and Drawings

Title	*Source*
American Indian Painting	Philbrook Art Center, Tulsa, Okla.
American Natural Painters	Galerie St. Etienne and private collections.
A Century and A Half of Painting in Argentina.	Government of Argentina; Argentine Embassy; private collections.
As I See Myself	Junior Arts and Activities; Galerie St. Etienne.
Austrian Drawings and Prints	Albertina, Vienna; Austrian Embassy.
Paintings by Austrian Children	Superintendent of Schools in Vienna; Austrian Embassy.
California Painting	Municipal Art Center, Long Beach, Calif.
Paintings by George Catlin	Smithsonian Institution, Department of Anthropology.

Children's Paintings from Forty-five Countries IV. Children's Paintings from Forty-five Countries V. Children's Paintings from Forty-five Countries VI.	Embassy of Denmark; Friendship Among Children and Youth Organization.
Children's Paintings from Japan	United Nations Educational, Scientific and Cultural Organization.
Ethiopian Paintings	George Washington University; Dr. Bruce Howe; Embassy of Ethiopia.
Watercolors and Drawings by Gavarni.	Walters Art Gallery, Baltimore; Rosenwald Collection, National Gallery of Art.
German Drawings	German Government; German Museums and private collections; German Embassy.
Goya Drawings and Prints	Prado and Galdiano Museums, Madrid; Spanish Embassy; Rosenwald Collection, National Gallery of Art.
Italy Rediscovered	Munson-Williams-Proctor Institute, Utica; dealers; museums; artists.
19th Century American Paintings from the Karolik Collection.	Maxim Karolik; Museum of Fine Arts, Boston.
Kokoschka's "Magic Flute"	Minneapolis Institute of Arts; artist.
Pennsylvania Painters	Pennsylvania State University, State College; museums; private collections.
Plant Portraits	University of Colorado Museum, Boulder.
Work by Rudy Pozzatti (graphic work also).	Print Club of Cleveland; Cleveland Museum of Art; dealers; private collections.
Watercolors and Prints by Redouté	Luxembourg State Museum; private collections; Legation of Luxembourg.
Sargent Watercolors	Museum of Fine Arts, Boston.
Seal Islands	Cleveland Museum of Natural History.
Contemporary Swedish Paintings	National Museum, Stockholm; Swedish Embassy.
Swedish Children's Paintings	National Museum, Stockholm; Swedish Embassy.
Painters of Venezuela	Ministry of Education at Caracas; Pan American Union.
Watercolor Today	Toledo Museum of Art; dealers; artists.

Graphic Arts

American Color Prints	Library of Congress.
Recent British Lithographs	British Council; British Embassy.
Children's Picture Books II	Washington Post Children's Book Fair.
International Children's Books	Washington Post Children's Book Fair; Embassies.
Contemporary Japanese Prints	Art Institute of Chicago; Japanese Association of Creative Printmakers.

Japanese Woodcuts	United Nations Educational, Scientific and Cultural Organization.
Southern California Serigraphs	Los Angeles Museum of Art; artists.
Woodcuts by Antonio Frasconi	The Print Club of Cleveland; The Cleveland Museum of Art; Weyhe Gallery; artist.

Architecture

Contemporary Finnish Architecture	Finnish-American Society; Association of Finnish Architects; Finnish Embassy.
New Libraries	American Institute of Architects.
The Re-Union of Architecture and Engineering.	American Institute of Architects.
Building in the Netherlands	Bond of Netherlands Architects and Bouwcentrum; Netherlands Embassy.
San Francisco Bay Region Architecture.	California Redwood Association; Northern California Chapter American Institute of Architects.

Design

American Craftsmen II	University of Illinois, Urbana; artists.
American Jewelry & Related Objects I.	Huntington Galleries, Huntington, W. Va.; artists, Hickok Company.
Brazilian Landscape Architecture—New Designs by Roberto Burle Marx.	Brazilian Embassy; artist.
Contemporary European Tapestry	Contemporary Arts Association, Houston, Tex.; artists; private collections; museums.
Dutch Arts and Crafts	Department of Education, Arts and Sciences in The Hague; Netherlands Embassy.
European Glass Design	Georg Jensen, Inc.; designers.
Fifty Years of Danish Silver	Georg Jensen, Inc.; Danish Embassy.
Finnish Crafts	Waertsila-Arabia and other Finnish Manufacturers; Finnish-American Society, Helsinki; Finnish Embassy; artists, Tapio Wirkkala and Rut Bryk.
Italian Arts and Crafts	Compagnia Nazionale Artigiana, Rome; Bonniers; Altamira; Italian Embassy.
New England Crafts	Worcester Art Museum; Junior League of Worcester, Inc.; The Craft Center, Worcester, Mass.
Tapestries by Hannah Ryggen	Norwegian Government; Embassy of Norway; Norwegian Museums; private collections.

Ceramics

Norwegian Ceramics	Norwegian Embassy.

Oriental Art

Chinese Gold and Silver from the Kempe Collection.	Dr. Carl Kempe; Embassy of Sweden.
Chinese Ivories from the Collection of Sir Victor Sassoon.	Sir Victor Sassoon.

Folk Art

Americana	Index of American Design, National Gallery of Art.
Eskimo Art I Eskimo Art III	Eskimo Art, Inc.; Canadian Handicrafts Guild.
Norwegian Decorative Painting	Norwegian Artists Guild; Embassy of Norway.
Popular Art in the United States	Index of American Design, National Gallery of Art.
Scrimshaw Exhibition	Col. Leslie Buswell.

Photography

Ansel Adams Photographs 1933–1953	Artist; George Eastman House, Rochester.
Architectural Photography	American Institute of Architects; Architectural Photographers Association; George Eastman House.
Birds in Color, by Eliot Porter	Artist; American Museum of Natural History.
Birds of Argentina, by Salvador Magno.	Artist; Williams Foundation; American Museum of Natural History.
This is the American Earth	Ansel Adams; Nancy Newhall; National Park Service; California Academy of Sciences; Sierra Club.
Venetian Villas	Soprintendenza ai Monumenti Medievali e Moderni, Venice; Dr. Michelangelo Muraro; Italian Embassy.
Japan, by Werner Bischof	Magnum Photos, Inc.

Ethnology

Art and Magic of Arnhem Land	Smithsonian Institution, Department of Anthropology.
Carl Bodmer Paints the Indian Frontier.	Karl Viktor, Prinz zu Wied; German Embassy.

ABROAD, BY THE UNITED STATES INFORMATION AGENCY

Plastics in America

These displays were scheduled as an integral part of the programs of 182 museums and galleries, located in 39 States, the District of Columbia, Hawaii, Canada, and Cuba.

Twenty-seven exhibitions are in preparation, 26 for circulation in the United States and 1 abroad, as follows:

FOR CIRCULATION IN THE UNITED STATES

American Printmakers.
A Half Century of Architectural Education.
Contemporary American Glass.
American Jewelry and Related Objects II (second edition).
Argentine Children as Illustrators.
Recent Work by Harry Bertoia.
Contemporary Brazilian Prints.
Canadian Abstract Paintings.
Prints by Chodowiecki.
Contemporary Danish Architecture.
Dutch Art, 1946–1956.
Early Prints and Drawings of California.
German Architecture Today.
German Art Books.
Contemporary German Prints.
Japan II by (second edition), Werner Bischof.
Japanese Woodcuts II (second edition).
Landscape Architecture Today.
A. J. Miller Watercolors.
Perceptions.
Prints by Henri-Georges Adam and John Paul Jones.
Sixty Swedish Books.
Swedish Rock Carvings.
Venetian Villas II (second edition).
The World of Edward Weston.
Fritz Winter and Hans Uhlmann.

FOR CIRCULATION ABROAD BY THE UNITED STATES INFORMATION AGENCY

John Marin.

INFORMATION SERVICE AND STAFF ACTIVITIES

In addition to the many requests for information received by mail and telephone, inquiries made in person at the office numbered 2,257. Examination was made of 598 works of art submitted for identification.

An article, "The Golden Brush of Kristian Krekovic," by Thomas M. Beggs, was published in the December 1955 issue of the American Artist and reprinted (revised and translated) in Cultura Peruana, January 1956.

Special catalogs were published for the following six exhibitions: Italian Arts and Crafts; German Drawings; Hannah Ryggen; Contemporary Finnish Architecture; Venetian Villas; and Finnish Crafts—Tapio Wirkkala and Rut Bryk. The last five contained acknowledgments written by Mrs. Annemarie H. Pope, chief of the Smithsonian Traveling Exhibition Service.

In recognition of the significant contribution Mrs. Pope had made to the re-establishment of cultural relations between the United States and Germany, she was decorated with the Order of Merit of the Federal Republic of Germany by German Ambassador Heinz L. Krekeler on April 28, 1956.

Mr. Beggs discussed the problem of a college museum for classical antiquities at Howard University on December 13, 1955. He was also a speaker at the biennial art banquet of the National League of American Pen Women on April 8, 1956, at the Sheraton-Park Hotel. He served as a judge for four exhibitions in the Washington area.

Paul Vickers Gardner, curator of ceramics, attended the Wedgwood International Seminar in Philadelphia on April 12 and 13, 1956, and was moderator of a panel "The Editors Discuss Design," at the convention of the American Ceramic Society held in New York City April 23 through 25, 1956.

Rowland Lyon, exhibits preparator, served on the juries of five local exhibitions and one at La Plata, Md. He exhibited sculpture, prints, and designs at the Silver Spring Art Gallery, Woodward and Lothrop, the Artists Guild of Washington, and the Society of Washington Printmakers.

The canvases of 14 paintings were cleaned and varnished, and 33 frames were renovated. Under special contract, Glenn J. Martin cleaned and restored 10 paintings. Nine paintings by George Catlin were retouched and revarnished for the United States National Museum, and one was relined, cleaned, restretched, and retouched.

Mrs. Pope gave a talk, illustrated with slides showing various phases of the work involved in preparing exhibitions for travel, to the Cultural Attaches Luncheon at the Dupont Plaza Hotel on October 17, 1955, and attended meetings of the Southeastern Museums Directors' Council at Chattanooga, Tenn., and Southeastern Museum Officials in Nashville, October 10–15, 1955, and also the annual convention of the American Association of Museums in Cincinnati, Ohio, May 26–June 1, 1956.

SPECIAL EXHIBITIONS

Thirteen special exhibitions were held during the year:

July 19 through August 28, 1955.—"Paintings of Peru, Past and Present," by Kristian Krekovic, held under the sponsorship of His Excellency, the Ambassador of Peru, Sr. Don Fernando Berckemeyer, consisting of 61 paintings. A catalog was printed with private funds.

September 1 through 24, 1955.—The Fifth Exhibition of Ceramic Art, sponsored by the Kiln Club of Washington, D. C., consisting of 177 pieces (71 by local ceramic artists, 69 by invited American artists, and 37 by artists of various nations through their respective embassies or legations in Washington). Demonstrations on the potter's wheel were given daily. A catalog was privately printed.

October 24, 1955, through January 3, 1956.—An exhibition of "Ceramics of the World," in celebration of the tenth anniversary of the establishment of the United Nations was shown in the lobby of the Natural History Building. It included 71 objects from 43 nations and was assembled from articles in the Division of Ethnology dating from about 1800 to the present.

November 26 through December 18, 1955.—An exhibition of 50 watercolors of "Plant Portraits," by Ida Hrybesky Pemberton (1890–1951), inaugurating the tour scheduled by the Smithsonian Traveling Exhibition Service. A catalog was privately printed.

January 15 through February 2, 1956.—An exhibition of the Society of Washington Printmakers, consisting of 137 prints. A catalog was privately printed.

January 15 through February 2, 1956.—A Smithsonian Institution Traveling

Exhibition of 44 watercolors and prints, by Pierre Joseph Redouté (1759–1840), held under the sponsorship of His Excellency, the Ambassador of Luxembourg, Hugues Le Gallais. A catalog was privately printed.

February 19 through March 8, 1956.—The Twelfth Annual Exhibition of the Artists Guild of Washington, consisting of 51 paintings. A catalog was privately printed.

February 19 through March 8, 1956.—The Fifth Biennial Exhibition of the Washington Sculptors Group, consisting of 34 pieces of sculpture.

March 25 through April 15, 1956.—The Biennial Art Exhibition of the National League of American Pen Women consisting of 198 paintings, sculpture, prints, ceramics, textiles, jewelry, and other craftwork. A catalog was privately printed.

April 29 through May 17, 1956.—A Smithsonian Institution Traveling Exhibition of Finnish Crafts by Tapio Wirkkala and Rut Bryk, held under the sponsorship of His Excellency, the Ambassador of Finland, and Madame Nykopp, consisting of 130 pieces of sculpture, wood carvings, brass, glass, and silver designs by Mr. Wirkkala and works in ceramic by Rut Bryk.

April 29 through May 17, 1956.—A Smithsonian Institution Traveling Exhibition of 28 watercolors by Henry Wood Elliott (1846–1930). These works constitute the first pictorial record ever made of the seal herds that populated the Pribilof Islands in the 1870's.

June 3 through 24, 1956.—The Fifty-ninth Annual Exhibition of the Washington Water Color Club consisting of 149 watercolors, etchings, and drawings. A catalog was privately published.

June 2 through 24, 1956.—The Twenty-third Annual Exhibition of The Miniature Painters, Sculptors, and Gravers Society of Washington, D. C., consisting of 176 examples. A catalog was privately printed.

Respectfully submitted.

THOMAS M. BEGGS, *Director.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Freer Gallery of Art

SIR: I have the honor to submit the thirty-sixth annual report on the Freer Gallery of Art, for the year ended June 30, 1956.

THE COLLECTIONS

Twenty-five objects were added to the collection by purchase as follows:

BRONZE

55.14. Chinese, Sui dynasty (A. D. 589–618). Mirror decorated with casting in relief showing the 12 cyclical animals and other symbolic motifs; inscription of 40 characters. Diameter: 0.212. (Illustrated.)

55.16. Chinese, Northern Wei dynasty (A. D. 386–535). Gilt-bronze figure of the Buddha standing on a lotus pedestal on a 4-legged platform; removable mandorla with flames, lotuses, and animal mask in relief. 0.639 x 0.259.

LACQUER

55.24. Japanese, Tokugawa period (18th century). Writing box (*suzuribako*), decorated in high and low relief, in gold, silver, red, green, and black with mother-of-pearl and glass inlays showing the thunder god, a demon, a maiden, and a standard bearer on the cover; inside is a portrait bust of Daruma, an inkstone, and a water holder. Signed, Kajikawa. 0.206 x 0.163 x 0.243.

56.3. Japanese, Tokugawa period (18th century). Incense box and tray of cryptomeria wood with decoration in lacquer showing monkeys looking at a painting. Attributed to Ritsuō (1663–1747). 0.092 x 0.190 x 0.238.

56.4. Japanese, Kamakura or Early Ashikaga period (14th century). Box for a priest's robe (*kesa*); basketwork and black lacquer decorated in gold; a landscape scene on cover; *kesa*, band, and shoulder cord included. 0.128 x 0.389 x 0.562.

METALWORK

55.27. Indian, Mughal period (17th century). Knife made for the emperor Jahāngir; partially meteoric iron and decorated with cut design and gold inlay; inscription dated in correspondence with A. D. 1621. Length: 0.261.

55.23. Japanese, Tokugawa period (19th century). Gold ornament in the form of a wild goose sleeping on a separate base modeled as a bed of reeds. 0.032 x 0.084 x 0.038.

55.10. Syrian, Ayyūbid period (13th century). Basin of brass richly inlaid with silver, part of which has fallen out; decoration includes inscriptions in *naskhi* and *kūfic* scripts, Christian subjects, polo players, musicians, standing figures in arcades, animals, arabesques, etc. Made for the sultan Ayyūb who reigned A. D. 1239–49. 0.225 x 0.500.

55.22. Syrian, Ayyūbid period (13th century). Ewer of brass with silver inlay, some of which has fallen out; decorated with arabesques in lattice framework; *naskhi* inscriptions give the artists as Qāsim b. 'Ali and date corresponding to A. D. 1232. 0.367 x 0.213.

PAINTING

55.13. Chinese, Ch'ing dynasty (1644–1912). Landscape in ink and color on paper; by Wu Li; dated in correspondence with A. D. 1767. 0.669 x 0.321.

55.17. Chinese, Ming dynasty (1368–1644). Scroll painting in ink and full color on satin showing 24 Buddhistic figures; 20 inscriptions and 73 seals on painting; title and 2 seals on mount, dated in correspondence with A. D. 1643. 0.495 x 7.313.

55.18. Chinese, Ming or Ch'ing dynasty (17th century). Landscape in ink and color on paper; inscription and 8 seals on painting; inscription and 1 seal on mount; by Ch 'êng Sui (fl. 1630–1650). 1.433 x 0.530.

55.19. Chinese Ch'ing dynasty (1644–1912). Landscape in ink on satin; signature and two seals on painting; by Ch'a Shih-piao; dated in correspendence with A. D. 1694. 1.863 x 0.468.

55.20. Chinese, Ch'ing dynasty (1644–1912). Album containing 16 landscapes on paper, 15 in ink and color, 1 in ink; 16 inscriptions and 30 seals on paintings, 1 inscription and 4 seals on mounts; by Hua Yen; dated in correspondence with A. D. 1729. 0.229–0.238 x 0.153 x 0.163.

55.21. Chinese, Ming and Ch'ing dynasties (17th century). Album containing 10 paintings in ink on paper showing flowers, birds, insects, and fish; 9 signatures and 30 seals on paintings; 11 inscriptions and 44 seals on mounts; by Chu Ta (fl. 1634–1674 or later). 0.255 x 0.230.

55.11. Coptic, third quarter of the 12th century (Damietta, Egypt). First page of a religious codex made for the 73rd Jacobite Patriarch, Michael, son of Zaraa (A. D. 1174–89); recto: a cross; verso: the four evangelists; parchment with gold and colors; Arabic inscription in *naskhi*. 0.356 x 0.228.

55.25–55.26. Japanese, Muromachi period (1333–1568). Pair of 6-fold screens with silk panels on paper grounds; panels painted in ink depicting landscapes; grounds decorated with floral patterns in colors on gold; by Kano Motonobu (1476–1559). Each 1.752 x 3.758. (55.26 illustrated.)

POTTERY

55.12. Chinese, T'ang dynasty (618–906). Covered jar; soft, pinkish-buff clay; soft lead glazes of dark green, dark blue, yellowish-brown, and white, arranged in vertical patterns. 0.242 x 0.213. (Illustrated.)

55.15. Chinese, Ch'ing dynasty, Ch'ien-lung period (1736–1796). Writer's box of fine, white porcelain with pale, transparent celadon green glaze over delicately painted slip designs of dragon, waves, and clouds, and interlocking scroll patterns; 6-character Ch'ien-lung mark in underglaze blue on base. 0.057 x 0.222 x 0.067.

56.5–56.7. Chinese, Han dynasty (207 B. C. – A. D. 220). Mortuary figures of ladies, two standing and one kneeling; grayish clay fired hard with traces of red, brown, purple, and green pigments. Heights: 0.660, 0.662, and 0.493.

56.1. Persian, 9th–10th century, Nishapur. Bowl with design of two birds in black slip on a white ground. 0.066 x 0.218.

56.2. Persian, 12th century, Gurgan. Bowl of thin, white, vitreous, translucent ware decorated with two bands of incised ornament inside and fine holes piercing the body and mostly filled with the transparent glaze. 0.062 x 0.184.

Total number of accessions to date (including above) 10,977

REPAIRS TO THE COLLECTIONS

One hundred and forty-seven Chinese and Japanese objects were restored, repaired, or remounted by T. Sugiura. In addition to this work on the collections, Mr. Sugiura completed *t'ao* for five Chinese books and mounted five rubbings for the library; he also remounted and repaired a Japanese screen for the United States National Museum.

CHANGES IN EXHIBITIONS

Changes in exhibitions amounted to 3,012. This abnormally large number is accounted for by the redecoration of the exhibition galleries and the installation of the Charles Lang Freer Centennial Exhibition. The changes were as follows:

American art:	
Copper plates	17
Etchings	46
Lithographs	23
Oil paintings	124
Pastels and drawings	36
Watercolors	37
Whistleriana	10
Chinese art:	
Bronze	672
Gold	19
Jade	400
Lacquer	8
Marble	5
Manuscripts	1
Paintings	177
Pottery	305
Silver and silver-gilt	52
Stone sculpture	50
Christian art:	
Crystal	4
Glass	12
Gold	31
Manuscripts	47
Paintings	22
Stone sculpture	3
Indian art:	
Bronze	3
Manuscripts	20
Paintings	109
Stone sculpture	11

Japanese art:	
Bronze	3
Lacquer	72
Paintings	171
Pottery	124
Wood sculpture	2
Korean art:	
Bronze	1
Pottery	18
Near Eastern art:	
Bookbindings	25
Crystal	3
Glass	12
Manuscripts	32
Metalwork	66
Paintings	173
Pottery	59
Stone sculpture	5
Tibetan art:	
Paintings	2

LIBRARY

The library was reopened to the public on December 19, 1955, after being closed for a year for installation of steel stacks and decoration. The folio shelves are especially appreciated, as the many elephant volumes are now shelved not more than two to a shelf. These major improvements in the library facilities are due to the initiative and imagination of the librarian, Mrs. Bertha M. Usilton, who devised all the plans for the new arrangement and saw them to completion.

The geographic breakdown of Far East, Near East, South Asia, West, and Orient was discontinued in the reshelving. The Dewey decimal classification scheme controls these breakdowns in the various categories in the Western languages. Orientalia are cataloged and shelved separately as before. A thorough reading of the shelves in the shelving process revealed that only 15 books can be termed "lost" in the 33 years of the library's history.

The library is the laboratory of the entire staff, and it is here that data for correct attribution, comparative material, and recorded facts can be searched for and found. It has research material of the greatest value in the realm of Oriental art. Welcome gifts from scholars and learned institutions included a reproduction of the world by the twelfth-century geographer Idrisi, received from the Embassy of Iraq. An autographed letter of Mr. Whistler written to Thomas Way was purchased. Books, pamphlets, and periodicals now number 35,000.

Despite the fact that the number of the year's accessions was greater than the previous year, and the added labor of moving into new stacks, the accessioning and cataloging have been kept up to date.

During the Charles Lang Freer Centennial commemorating the birth of the founder of the Gallery, a special exhibition was made of the monumental writings of Prof. Osvald Sirén, who was the first recipient of the Charles Lang Freer Medal.

PUBLICATIONS

Five publications were issued by the Gallery as follows:

Title page and contents for Occasional Papers, vol. 2, 1955. (Smithsonian Publ. 4223.)

The Charles Lang Freer Medal (first presentation). Booklet containing a partial bibliography by Prof. Osvald Sirén.

Charles Lang Freer Centennial Exhibition (1856-1956). Booklet listing objects on exhibition in galleries.

First presentation of the Charles Lang Freer Medal (February 1956). Contains partial bibliography by Prof. Osvald Sirén, opening remarks by Dr. Carmichael and Mr. Wenley, presentation by Dr. Carmichael, and Prof. Sirén's address.

Pope, John Alexander: Chinese porcelains from the Ardebil Shrine, xvi + 194 pp., 142 pls., 1956. (Smithsonian Publ. 4231.)

REPRODUCTIONS

The photographic laboratory made 3,782 items during the year as follows: 2,494 prints, 374 negatives, 814 color transparencies, 64 black-and-white slides, and 36 microfilms. Total negatives on hand, 11,173; lantern slides, 9,542; 110 reproductions in the round of Freer Gallery objects were sold.

BUILDING

The general condition of the building is good. All roof areas appear to be in good condition; minor repairs were made when necessary throughout the year. The ledge of the roof was repaired, and a coating of roofing compound was applied. The copper flashing surrounding the court area was retucked and caulked. All exterior walls were waterproofed and repointed; all exterior water valves were replaced or repaired on the outside of the building and in the court. All screen doors and areaways are in good condition.

Redecoration of the interior was completed on December 9, 1955, and rubber-tile floors were installed in the library and main office. Fluorescent light fixtures were installed in all offices, work rooms, storage rooms, and corridors, with the exception of the gallery corridors where incandescent fixtures were put in.

The major work of the cabinet shop has been devoted to the making of exhibition cases for the galleries. Miscellaneous odd jobs related to storage, exhibition, restoration, crating, and maintenance of office and Gallery equipment continue as usual.

Some of the alterations in the court planting planned last year, such as reseeding, replacement of shrubs, removal of ivy, were undertaken,

and all plants, trees, and shrubs appear to be doing well and are maintaining steady growth.

Work on the installation of the long-needed air-conditioning system to safeguard the collections has begun.

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 94,276. The highest monthly attendance was in April, 12,972, and the lowest was in December, 3,209.

There were 2,172 visitors to the office for the following purposes:

For general information	855
To submit objects for examination	367
To see staff members	162
To take photographs in the court or exhibition galleries	157
To study in library	228
To see building and installations	37
To examine or borrow slides	20
To sketch in galleries	16
To use Herzfeld Archive	4
To see objects in storage:	
Far Eastern paintings	106
Far Eastern metalwork	20
Far Eastern pottery	39
Far Eastern jade, lacquer, wood, ivory, etc	20
Near Eastern paintings	9
Near Eastern metalwork	12
Near Eastern pottery	3
Near Eastern glass, bookbindings, etc	6
Christian art (Washington Mss.)	23
American art	196

AUDITORIUM

The series of illustrated lectures was continued as follows:

1955

October 18. Dr. Aschwin Lippe, Assistant Curator of Far Eastern Art, Metropolitan Museum of Art, New York. "Early Chinese Paintings in Formosa." Attendance, 110.

November 15. Dr. Sherman E. Lee, Curator of Oriental Art, Cleveland Museum of Art. "Kamakura Art in Japan." Attendance, 193.

1956

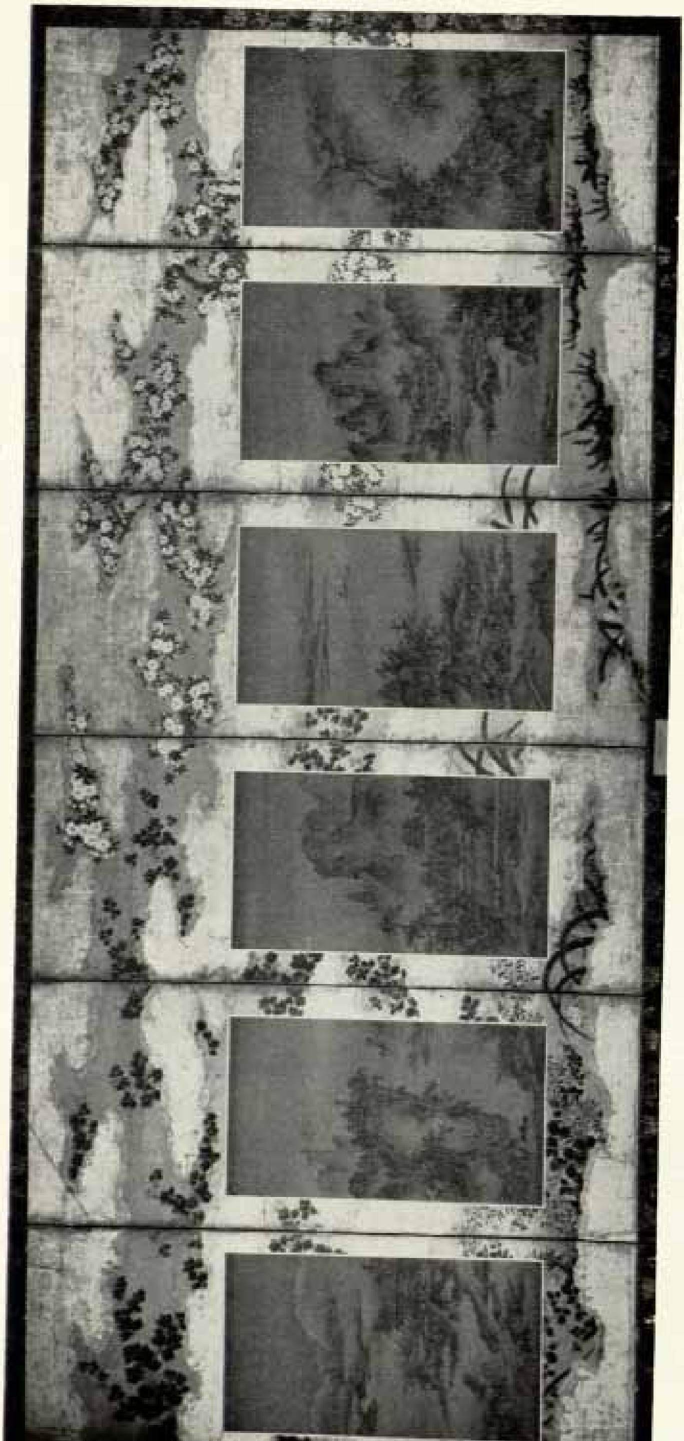
January 17. Dr. Oleg Grabar, Assistant Professor in Islamic Art, University of Michigan, Ann Arbor. "Umayyad Art, the Art of an Empire." Attendance, 171.

February 14. Prof. William F. Albright, Johns Hopkins University, Baltimore. "The Art and Architecture of the Age of Solomon." Attendance, 242.

55.14

55.12

Recent additions to the collections of the Freer Gallery of Art.



55.26

Recent addition to the collections of the Freer Gallery of Art.

1956

March 13. Mr. Chiang Yee, Columbia University, New York. "Western Scenery through Chinese Eyes." Attendance, 145.

April 17. Laurence Sickman, Director, William Rockhill Nelson Gallery of Art, Kansas City, Missouri. "Early Chinese Figure Painting." Attendance, 157.

On February 25, 1956, the auditorium was the scene of ceremonies commemorating the centennial of the birth of the Gallery's founder. This was marked by the first presentation of the Charles Lang Freer Medal "for distinguished contribution to the knowledge and understanding of Oriental civilizations as reflected in their arts" to Prof. Osvald Sirén of Stockholm. Also on the platform were Count Carl L. Douglas, Minister Plenipotentiary, representing the Ambassador of Sweden, Miss Katharine N. Rhoades, representing the Friends of the Freer Gallery named in Mr. Freer's last will and testament, the Director of the Freer Gallery of Art, and the Secretary of the Smithsonian Institution. The proceedings were opened by Dr. Carmichael, and following some remarks on the inauguration of the award by Mr. Wenley, Dr. Carmichael made the presentation. Professor Sirén responded with an address on the development of scholarship in the Far Eastern field (particularly in America) during the last 50 years and on the collecting of Chinese and Japanese art, together with some personal recollections of Mr. Freer. The presentation was followed by a reception in Gallery XVII. Attendance, 260.

Seven outside organizations used the auditorium, as follows:

1955

August 5. Dr. Remington Kellogg, Director, United States National Museum. A talk to employees of the Smithsonian Institution on "Travel in Russia." Attendance, 190.

August 19. Paul Garber, Curator, National Air Museum. Motion pictures for a group of World War I flyers. Attendance, 36.

October 11. Dr. Carmichael, Secretary, Smithsonian Institution, addressed members of the Vassar Club on "Classicism and Romanticism in Education." Attendance, 48.

1956

January 19. District of Columbia Libraries Association meeting. Mr. Wenley gave an address on "The Freer Gift and the Relation of the Library to the Museum." This was followed by a tour of the Freer Gallery library. Attendance, 44.

April 18. Howard Sollenberger brought a group from the Foreign Service Institute, State Department. Mr. Wenley gave a talk on "Background in Chinese Art, Shang through the Ming Dynasties." Attendance, 15.

May 17. United States Department of Agriculture, in conjunction with the National Safety Council. General discussion meeting and motion pictures on safety. Attendance, 30.

May 25. District of Columbia Psychological Group. Dr. Leonard Carmichael, Secretary, Smithsonian Institution, introduced the speaker, Dr. Joy Paul Guilford. Attendance, 39.

One other meeting was held in the building when the Far Eastern Ceramic Group had its fall meeting in Storage II and used the facilities of the library. Attendance, 22.

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 technical laboratory (listed below) were made on 7,258 objects as follows: for private individuals, 4,975; for dealers, 1,072; for other museums, 1,211. In all, 552 photographs were examined, and 320 Oriental language inscriptions were translated for outside individuals and institutions. By request 19 groups totaling 468 persons met in the exhibition galleries for docent service by staff members. Two groups totaling 74 persons were given docent service in the storage rooms.

Among the visitors were 70 distinguished foreign scholars or persons holding official positions in their own countries who came here under the auspices of the State Department to study museum administration and practices in this country.

In the technical laboratory 90 objects from the Freer collections and 74 from outside sources were examined. The following projects were begun: Quantitative chemical analyses of ancient Chinese bronzes; thin-section studies on Chinese porcelain bodies and glazes; study of ancient Chinese bronze-iron objects to determine means of fabrication and special behavior during soil corrosion. The following projects were continued: X-ray diffraction studies on jade objects in the Freer collections; examination of specimens of wall painting from the ancient Christian church of the Chora, Istanbul (in cooperation with Dumbarton Oaks Research Library and Collection). The following projects were completed: Spectrochemical analyses of samples from ancient Persian and Near Eastern silver objects (results to be published later); treatment and conservation of several Freer Gallery objects, mostly bronzes. During the year, 22 written reports were made and 56 verbal reports given on objects examined in the technical laboratory.

By invitation the following lectures (illustrated unless otherwise noted) were given outside the Gallery by staff members:

1955

November 8. Dr. Ettinghausen, at the Near Eastern Research Club, University of Michigan, on "The Riddle of a Famous Persian Pottery Plate." Attendance, 35.

1955

November 9. Dr. Ettinghausen, in Angell Hall, University of Michigan, on "Paintings from the Albums of the Mughal Empire." Attendance, 75.

December 14. Mr. Stern, at China House, New York City, to the Chinese Art Society of America, on "Hokusai Paintings and Drawings in the Collection of the Freer Gallery of Art." Attendance, 35.

1956

January 8. Dr. Ettinghausen, at Pierce Hall, All Souls' Unitarian Church, Washington, D. C., on "The Art of the Muslim East." Attendance, 45.

March 2. Dr. Ettinghausen, for the Photographic Roundtable, Graduate School, United States Department of Agriculture, on "Experiences of an Art Photographer under the Crescent." Attendance, 91.

March 12. Mr. Gettens, at New York State Teachers College, New Paltz, N. Y., on "Chemistry in Art and Archaeology." Attendance, 150.

March 22. Mr. Pope, at the Museum of Fine Arts, Boston, on "Ming Porcelain and Its Travels." Attendance, 110.

April 4. Mr. Stern, at the Far Eastern Association meeting in Philadelphia, on "Shiba Kōkan—Artist." Attendance, 50.

April 11. Mr. Stern, at American University, Washington, D. C., on "Hokusai Paintings and Drawings in the Freer Gallery of Art." Attendance, 60.

April 30. Mr. Stern, at the University of Virginia, Charlottesville, on "Noted Examples of Japanese Paintings and Sculpture." Attendance, 95.

May 31. Dr. Ettinghausen, before the Convegno "Volta," Accademia Nazionale dei Lincei, Villa Farvard, Florence, Italy, on "Persian Ascension Scenes of the 14th Century." Attendance, 65.

June 12. Mr. Gettens, at The Henry Francis du Pont Winterthur Museum, Winterthur, Del., on "Museum Laboratories" in connection with a 3-day conference titled, "Winterthur Seminars in Museum Operation and Connoisseurship." Attendance, 60.

On October 15 Mrs. Usilton attended a meeting of the Catalogers and Classifiers for the District of Columbia, Maryland, and Virginia, in Washington, D. C. Members of the staff traveled outside Washington on official business as follows:

1955

July 5. Mrs. Usilton in Philadelphia attended the Art Reference Round Table of the American Libraries Association.

August 15–19. Mr. Schwartz in Chicago attended the National Industrial Photographic Conference.

September 2–3. Mr. Stern in New York examined objects belonging to dealers.

October 24. Mr. Wenley in Ann Arbor attended a meeting of the Freer Fund Committee at the University of Michigan.

November 7–19. Mr. Gettens in Sarasota, Fla., examined bronze and stone sculpture at the John and Mable Ringling Museum.

November 8–10. Dr. Ettinghausen in Ann Arbor examined objects in a private collection.

November 21–25. Mr. Wenley in New York examined objects at the Metropolitan Museum of Art and belonging to dealers.

1955	
December 12–16.	Dr. Ettinghausen in New York examined objects in the New York Public Library, American Numismatic Society, and belonging to dealers.
December 14–18.	Mr. Stern in New York examined objects at the Metropolitan Museum of Art and belonging to dealers.
December 21.	Dr. Ettinghausen in Baltimore examined objects at the Walters Art Gallery.
December 21.	Mr. Gettens in Baltimore examined objects at the Walters Art Gallery.
1956	
February 7–9.	Dr. Ettinghausen in New York examined objects belonging to dealers.
March 8–12.	Mr. Stern in New York examined objects at the Metropolitan Museum of Art, the Brooklyn Museum, and belonging to dealers.
March 24–25.	Mr. Stern in Charlottesville, Va., examined objects in a private collection.
April 3–6.	Mr. Stern in Philadelphia examined objects at the Philadelphia Museum of Art.
April 9–11.	Mr. Wenley in Baltimore attended meetings of the American Oriental Society.
April 10–11.	Mr. Pope in Abilene, Kans., examined objects at the Eisenhower Museum.
April 23–25.	Mr. Gettens in New York examined objects at the Metropolitan Museum of Art, the Brooklyn Museum, and belonging to dealers. Also discussed bronze corrosion problems with officials of the International Nickel Corporation.
April 30–May 1.	Mr. Stern in Charlottesville, Va., conducted a seminar on Japanese art at the University of Virginia.
May 5.	Mr. Wenley in Boston attended meetings of the Far Eastern Ceramic Group.
May 5.	Mr. Pope in Boston presided at the all-day meeting of the Far Eastern Ceramic Group.
May 19–June 16.	Dr. Ettinghausen in Europe attended the 12th Convention of the Fondazione "Alessandro Volta" of the Accademia Nazionale dei Lincei in Rome and Florence. Also attended the opening of the International Exhibition of Iranian Art in Rome; studied manuscripts at the Royal Scottish Museum, Edinburgh, and at the British Museum, London.
May 25–27.	Mr. Wenley in Cincinnati attended meetings of the Association of Art Museum Directors held at the Cincinnati Art Museum and the Taft Museum.
June 12–14.	Mr. Gettens in Winterthur, Del., attended The Henry Francis du Pont Winterthur Museum's "Seminars in Museum Operation and Connoisseurship."
June 12–15.	Mr. Stern in Boston examined objects at the Museum of Fine Arts and in a private collection.
June 16–20.	Mr. Stern in New York examined objects at the Brooklyn Museum, the American Museum of Natural History, the Metropolitan Museum of Art, the New York Public Library, and belonging to dealers, and one private collection.
June 18–July 27.	Dr. Ettinghausen in Columbus, Ohio, taught "A Survey Course of Islamic Art" at Ohio State University.

Members of the staff held honorary posts, received recognition, 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, Department of Fine Arts, University of Michigan.
- Member of the Board of United States Civil Service Examiners at Washington, D. C., for the Smithsonian Institution.
- Member, Board of Trustees, Textile Museum, Washington, D. C.
- Member, Council of the Far Eastern Ceramic Group.
- Member, Smithsonian Art Commission.
- Member, Consultative Committee, *Ars Orientalis*.
- Chairman of the Louise Wallace Hackney Scholarship Committee of the American Oriental Society.
- Member, Committee on Japanese Studies, American Council of Learned Societies.
- On February 27, 1956, at the studios of WRC (NBC) discussed the *Freer Gallery of Art and its Collections* on the Patty Cavin radio show.

Mr. Pope:

- President, Far Eastern Ceramic Group.
- Member, Editorial Board, *Archives of the Chinese Art Society of America*.
- President, Association of the Southern Alumni of the Phillips Exeter Academy.
- Member, Art Committee, Cosmos Club.

Dr. Ettinghausen:

- Research Professor of Islamic Art, Department of Fine Arts, University of Michigan.
- Near Eastern editor, *Ars Orientalis*.
- Member, Editorial Board, *The Art Bulletin*.
- Trustee, American Research Center in Egypt.
- Member, Comitato Internazionale di Patronato, Museo Internazionale delle Ceramiche, Faenza, Italy.
- Member, Advisory Committee of *Current Research on the Middle East*, to be published by the Middle East Institute, Washington, D. C.

Mr. Gettens:

- Consultant, Advisory Board of the Intermuseum Conservation Association, Oberlin College, Oberlin, Ohio.
- Associate Editor, *Studies in Conservation*, published for the International Institute for the Conservation of Museum Objects, London.
- Abstractor for *Chemical Abstracts*, American Chemical Society.
- Socio Corrispondente, Centro de Storia della Metallurgia (Associazione Italiana di Metallurgia), Via Moscova 16, Milano, Italy.
- Member, Subcommittee for *I. I. C. Abstracts*, Chief of the American Working Party, International Institute for the Conservation of Museum Objects, London.
- Member, Planning Committee for a proposed National Conservation Laboratory for the United States.

Mr. Gettens: Member, Committee of Scientific Laboratories, International Council of Museums, 10 Parc du Cinquantenaire, Bruxelles, Belgique.
President, Washington Society, Archaeological Institute of America.

Mr. Stern: Member, Program Committee, Far Eastern Association.

On February 21, at a ceremony in the Regents' Room, Smithsonian Institution, at 4:00 o'clock, Dr. Carmichael, Secretary, presented Russell C. Mielke with a certificate of award and a check for "special and meritorious services in carrying out the duties of general maintenance foreman during Mr. Rawley's long illness and subsequent retirement, demonstrating in an outstanding manner ability to discharge these added responsibilities, sometimes under rather trying circumstances."

Respectfully submitted.

A. G. Wenley, *Director.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

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, 1956:

STATUS OF PROPOSED NATIONAL AIR MUSEUM BUILDING

At the beginning of the fiscal year the vigorous efforts by the Smithsonian Institution to obtain a site for the proposed National Air Museum building seemed about to succeed. The preferred site had been chosen after a study of the original "wineglass pattern" plan developed by the National Capital Planning Commission for improvement of the southwest Washington area. At the offices of that Commission it was agreed that the site on Independence Avenue, between 9th and 12th Streets, was most desirable for the proposed National Air Museum building. Subsequently, however, the Commission decided to adopt a plan for the development of southwest Washington proposed by the firm of Webb & Knapp, New York City. That plan eliminated the preferred National Air Museum building site in favor of a 10th Street Mall. No alternate site has yet been assigned, although several are being considered. Especial attention is being given sites close to the other museum buildings in order to provide most convenient access to the visiting public with limited time in Washington.

Although the question of a site has not been answered, nevertheless as a result of continuing efforts and cooperation the Smithsonian Institution now has a broader appreciation and better knowledge of the requirements for adequate care and housing of the National Aeronautical Collections. The architectural studies, which were generously financed by the Aircraft Industries Association and the Air Transport Association, and ably conducted by the architectural firm of McKim, Mead & White, have provided the Institution with a magnificent general internal and external plan of a building, scale drawings of floor plans, perspective renderings, and scale models of a building which is generally adaptable to any level site approximately 1,000 by 500 feet. A previous study conducted by the General Services Administration, Public Buildings Service, produced a plan adaptable to a larger area which would include outdoor exhibits and parking. As the result of the work of the past several years, therefore, the Institution is provided with the principal features which can be adapted to any chosen site.

At the close of the fiscal year, the Smithsonian Institution was proceeding with plans of buildings for other bureaus of the Institution. It was decided that as soon as other units, now occupying space in the Arts and Industries Building, are thus provided for, the space they vacate will be made available to the National Air Museum. Such space should be considered, however, only as an interim provision, and not as a permanent solution of the constantly increasing need to give adequate care and proper educational display to the Institution's marvelous collection of aircraft. Four-fifths of that collection is hidden away in storage, prevented from accomplishing its educational and inspirational function for the students, engineers, and pilots of this Nation which first gave powered and controlled wings to mankind. Aeronautics is too important to the defense, industry, and progress of our Nation to have this collection, embodying its very foundation and development, so confined and suppressed as it now is.

ADVISORY BOARD

This Board of five members, specified in the Act establishing the National Air Museum, continues to assist in the planning and operation of the Museum. Shortly after the beginning of the fiscal year, Maj. Gen. George W. Mundy, the Air Force member, was assigned to other duties away from the Washington area and was succeeded on the Board by Maj. Gen. John P. Doyle. He and his assistant for Museum matters, Maj. George C. Bales, have not only been ever ready to assign Air Force personnel to help in maintaining the Air Force planes in the exhibit, but also have directed the construction of a series of dioramas and scale-model groups being made for the National Air Museum at Wright-Patterson Air Force Base to illustrate significant events in Air Force history.

The Navy member of the Board, Rear Adm. James S. Russell, and his alternates, Capt. C. C. Case and Alfred Verville, have kept close contact with the Museum on a number of projects. These include the restoration of a World War I Curtiss N-9 training seaplane, the improved display of the series of models illustrating the development of naval aircraft, and the preservation of the original wind-tunnel models developed at the Washington Navy Yard. Associated with the latter project is the intention to construct a scale model of that wind tunnel, which was developed in 1914. The Museum is indebted also to the Navy for its continued storage of Museum material, thus relieving the Museum of this physical custody while its own premises and facilities are completely occupied.

On March 20, 1956, William B. Stout, one of the Presidential appointees to the Board, passed away at his home in Phoenix, Ariz. His constant interest and wise counsel were a most helpful resource in

conducting the work and planning of the National Air Museum. Several months before his death, Mr. Stout had brought to the Museum a group of five early experimental model aircraft devised during the late nineteenth century and including two he had made at that time, evidencing his early interest in aeronautics. He continued active experimenting and designing throughout his life, and the aeronautical world is richer because of his accomplishments. His last letters to the Museum relate to his efforts in obtaining for the Collections an example of the famous Ford-Stout trimotored transport, which was one of the mainstays of the pioneer airlines during the 1930's. In his letters, he included sketches detailing his ideas for hall arrangements and exhibit locations in the proposed National Air Museum building.

During the year, the other Presidential appointee, Grover Loening, shared his progressive ideas for improvements and expansion of the National Air Museum with the fifth member of the Board, the Secretary of the Smithsonian Institution.

STEPHENSON BEQUEST

It will be recalled that Congress authorized the Secretary of the Smithsonian Institution to accept as a gift from the late George H. Stephenson of Philadelphia a statue of Gen. William Mitchell. The development of this project is proceeding very satisfactorily. At the time the previous report was submitted, the sculptor, Bruce Moore, had completed his ⅓-size study and it has been approved by the Fine Arts Commission. This has since been enlarged in plastiline to full size, about 7 feet high. Details of the head, figure, uniform, and other features are being perfected. The Director of the National Collection of Fine Arts, Thomas M. Beggs, and the head curator of the National Air Museum inspected this enlargement on February 2, 1956, and approved it in that elementary form. While continuing his refinement of the sculpture, Mr. Moore has studied many photographs and motion pictures of General Mitchell and has had the helpful assistance and constructive criticism of persons who knew the General intimately. The sculpture will soon be ready for final inspection prior to casting.

SPECIAL EVENTS

On July 2, 1955, just 20 years after the world endurance record of 653½ hours continuous refueled flight had been established in a Curtiss Robin airplane by the Key brothers, Algene and Fred, of Meridian, Miss., that same airplane *Ole Miss*, piloted by Fred Key, completed a flight from Meridian to Washington, D. C., for presentation to the National Air Museum. This accession not only adds another event of flying history to the many outstanding accomplishments

illustrated in this Museum by original aircraft, but also provides the collection with an example of a 3-place commercial airplane which was popular in the 1930's. This record of over 27 days in the air was an impressive demonstration of the reliability of American aircraft and engines, as well as a tribute to the piloting skill and endurance of the Key brothers.

On August 18, the Civil Air Patrol, an air-youth organization sponsored by the Air Force to encourage aeronautical training and national airmindedness, chose the National Air Museum as a fitting location for paying tribute to their retiring head, Gen. Lucas V. Beau. The ceremony was held in the Aircraft Building in front of the Spad-XIII airplane, a type which General Beau had flown during World War I.

August 19 was the birth date of Orville Wright. At one time this date was designated as Aviation Day, and although that term is now generally applied to December 17, when the Wright brothers first flew in 1903, August 19 is deserving of recognition. The National Air Museum marked the day with a public lecture on World War I aviation, Col. Burling Jarrett, curator of the Army Ordnance Museum at Aberdeen, Md., being guest speaker. He showed motion pictures that he had produced with the assistance of Maj. Kimbrough Brown, USAF, recording the heroism of the famous aces, Georges Guynemer of France and Baron Manfred von Richthofen of Germany.

On September 5, 1955, at a meeting of the Early Birds in Philadelphia, this organization of pioneer pilots, who flew solo during the first 13 years of human flight, 1903–1916, designated the National Air Museum as their official depository for mementos of those fundamentally important years of aeronautics. The head curator was elected secretary of this organization. As a result, this Museum has received a number of important accessions from the membership. These include the Knabenshue airship of 1905, Boland air-speed indicator of 1910, an Elbridge and a Lawrance engine from William Parker, a group of instruments and a Daniel rotary engine from Adm. Luis de Florez, and other items included among those listed at the end of this report.

Members of the Philadelphia Flying Club came to Washington in their own planes October 30, 1955, for the purpose of seeing the Smithsonian's aircraft collection; and on April 3, 1956, a tour of the Museum by members of the Association for Childhood Education International was followed by a group discussion on the value of aeronautics as a medium in school courses. On June 13 a group of children, sponsored by Representative Peter Mack, were given a descriptive tour of the aircraft display.

The National Air Museum was represented, by invitation, at the Wright brothers memorial banquet of the Aero Club of Washington

on December 17, 1955, and at the annual banquet of the American Helicopter Society on May 2, 1956. The head curator continued to serve as a director of the National Aeronautic Association and a member of the Brewer Trophy award committee. On August 28 he received the annually awarded citation of the Air Line Traffic Association in recognition of the progress achieved by the National Air Museum in memorializing aeronautical history. During the year he gave 17 lectures on various aspects of the history and development of aeronautics as requested by various groups, including the Institute of Aeronautical Sciences at the Fairchild Aviation Division, Hagerstown, Md., and the Management Club of McDonnell Aircraft at St. Louis, Mo. Three television and three radio presentations on historical and current aspects of aeronautics were prepared by the National Air Museum during this year and broadcast from Washington stations.

For the annual meeting of the Smithsonian Institution's Board of Regents on January 13, 1956, the National Air Museum prepared a special display illustrating the development of the world's first liquid-fueled rocket by Dr. Robert H. Goddard. The main item of this display was the revised version of the world's first liquid-fueled rocket, fired March 16, 1926. This flight was a significant milestone in the development of rockets. Dr. Goddard's experiments were carried on under the auspices of the Smithsonian Institution from 1913 to 1930 and were aided by an additional Smithsonian grant in 1932. This Institution allotted funds to Dr. Goddard from a Research Corporation grant, the Smithsonian's Hodgkins fund, and from its own research sources. Clark University, the American Association for the Advancement of Science, and the Carnegie Institution of Washington also gave aid to Dr. Goddard during the 1917–1930 period. His later sponsor was the Daniel Florence Guggenheim Foundation until, in World War II, the United States Navy financed his final accomplishments. Dr. Goddard died on August 10, 1945, at age 62. This Regents display was added to the permanent exhibits of the Museum and now includes full-sized original rockets of 1934–35 and a larger rocket, about 16 feet long and 1 foot in diameter, developed 1939–41. Dr. Goddard's experiments were copied by the Germans during their development of the V–2 rocket weapon and formed the foundation for modern rocket progress.

IMPROVEMENTS AND CHANGES IN EXHIBITS

During the first part of this fiscal year several halls in the Arts and Industries Building were painted, requiring partial disassembly and covering of the suspended aircraft in those halls and the repair and reassembly of the planes after the painters had completed their work. Because of changes being made in the halls of the Arts and Industries Building, in connection with renovation of exhibits pertaining to

American history and technology, the National Air Museum was required to remove another full-sized aircraft, the William H. Martin glider of 1909, from exhibition. The same renovation program required moving the Wright brothers' first military flyer of 1909 and the Wright brothers' first transcontinental flyer of 1911 to other exhibition locations in the same building. With the assistance of working parties supplied by the Air Force, repairs were made to the Douglas World Cruiser, Loening amphibian, and Spad–XVI airplanes. Several of the fabric-covered aircraft, particularly those exhibited in the Aircraft Building, required patching.

The Museum is particularly proud of its collection of famous aeronautical trophies. Several of these, such as the Pulitzer Trophy and the Curtiss Marine Trophy, have served to stimulate progress in the past, while others, including the Robert J. Collier Trophy, Wright Brothers Memorial, Thompson, and Harmon Trophies, continue to reward those who attain excellence and to inspire others. Improvements have been made throughout the year in the display of these trophies and the associated exhibition of specimens which illustrate the basis for the individual awards. The display describing the two world flights of Wiley Post in the *Winnie Mae*, 1931 and 1933, the first time with Harold Gatty, has been improved by the addition of specimens that expand the physical records of these famous flights. The exhibition of scale models illustrating types developed by the Wright brothers and the Wright Company during the 17 years of progressive development, from their first glider of 1900 to the type "L" of 1916, has also increased in contents and educational interest. The development of our Armed Forces' aircraft, as illustrated by groups of scale models, has been expanded by important additions.

STORAGE

At the beginning of this fiscal year, the National Air Museum was busily continuing shipment of its stored collection of aircraft and aeronautical materials from the original storage area at Park Ridge, Ill., to the Suitland, Md., facility, in order to advance the project of concentrating all the Museum's stored material at one location in the Washington, D. C., area where the proposed National Air Museum building is to be constructed. A target date of January 1, 1956, had originally been set for completing this transfer, but Museum personnel at Park Ridge, under the capable management of Walter Male, beat this deadline by four months. The final load was disptached on August 27, 1955, and the storage operation there was terminated September 1.

Meanwhile, at Suitland the carloads and truckloads of material were being placed in the storage buildings by the Suitland force di-

rected by Stanley Potter, keeping pace, both in efficiency and speed, with the hard-working Park Ridge crew. The last load was stored on September 9. Most unfortunately Mr. Potter was severely injured during the unloading of one of the final deliveries and has not been able to return to work.

The construction of the largest of the Suitland buildings, which will serve as a shop for the restoration and subassembly of aircraft, was begun October 1 and completed January 27. This is 200 by 180 feet in area and will accommodate metal and woodworking machinery, engine-handling devices, stocks of material, a spray booth, a fabric and sheet-metal shop, and other equipment. During the period of about seven years while these aircraft were at Park Ridge they were unavoidably subjected to weather exposure and handling, and further affected by their recent disassembly and shipment. With the expectation of ultimately obtaining an adequate building for exhibition of the National Aeronautical Collections, it is vitally necessary to conduct a continuing program of preparing these specimens for durable, authentic, and attractive display in that building.

By the close of the fiscal year a force consisting of a foreman, two mechanics, an assistant for maintenance, and an aide had been engaged for duty at Suitland. They were setting up the individual shops, sorting material, and selecting the aircraft most in need of reconditioning.

Other projects at Suitland have included the repair of vehicular handling equipment which was strenuously used during the aircraft unloading operations, the repair of roads, and the rearrangement of aircraft storage to clear one of the 4,000-square-foot buildings for storing specimens of the Smithsonian's National Collection of Fine Arts and Division of Engineering.

The four Museum airplanes that were flown to Washington have remained at Andrews Air Force Base where they landed. They were moved to an end of a runway and at the close of the fiscal year a fence was erected around them to protect them from damage. The dismantling of the aircraft for storage of their parts at Suitland is the first project of the next fiscal year for the Suitland crew.

INFORMATIONAL SERVICES

The supplying of information on aeronautical history; technical development of aircraft; details of aircraft structure and operation; the theory of flight; the collections of aircraft, engines, and flight equipment in custody of the National Air Museum; biographies of aircraft inventors, designers, manufacturers and pilots; and the furnishing of photographs and drawings—these and other informational services require a constantly increasing amount of time by the staff

of the Museum. These requests come from visitors to the Museum who are interested in various details of the exhibits, from authors, engineers, historians, teachers, students, and others whose need for authoritative information leads them to this national depository for aeronautical materials.

Among the numerous requests for assistance and information received from other Government departments one of the most interesting is the making of a historical film by the Navy Department, Bureau of Aeronautics. It is astounding to realize that the evolution of naval aircraft from the first 45-mile-per-hour 40-horsepower "hydroaeroplane" of 1911 to the current supersonic jet-powered delta-winged fighters has taken place in the active life span of a number of naval aviators who retain keen recollections of this marvelous progress. In this motion picture the memories of these men are being recorded and illustrated by actual scenes taken from film records. The head curator was appointed a technical director for this film, and it has been a fascinating experience for him to listen to these stories in the words of those persons who were actually there when history was being made. For a number of scenes the Museum has supplied specimens which not only stimulated recollections but also illustrated the vivid descriptions. The Navy also requested assistance from the Museum in determining the identification markings of carrier-borne aircraft of the 1930's, in recalling details of the first aircraft landing aboard ship, and in dating early catapulted takeoffs.

The Coast Guard is filling in the history of its aircraft, and was pleased to obtain some needed illustrations from our reference files. The Department of Justice, investigating the origins of inventions in order to defend claims against the Government, was shown on a Museum specimen of 1909, the Olmsted monoplane, a prior development of a high-aspect-ratio elevated stabilizer, and was interested also in the use by the Japanese on their transpacific incendiary balloons of a means for automatically releasing ballast and explosives with aneroid-operated relays, as evidenced by an example in the Museum. The Central Intelligence Agency was also informed about these Japanese balloons. The Air Force, in assembling a history of Mitchel Field, was furnished with data and photographs of early air races held there, and the Signal Corps, proud of the first military airplane exhibited in the Museum, obtained help in describing its technical details and history. A consulting engineer for the Atomic Energy Commission was shown, in the files and library of this Museum, numerous accounts and illustrations of flight-training devices to assist him in preparing a curriculum for employees. The Treasury Department, preparing Defense Bonds advertisements featuring famous Americans, was shown numerous biographical references in the National Air

Museum files, and selected several to augment its program. The Voice of America made a number of phone calls to the Museum to check on details of scripts, and the Civil Aeronautics Administration received helpful suggestions for the making of scale models of airplanes used in accident investigations. These are only a few of the many requests for assistance received from Government agencies. Several Congressmen referred their constituents to the Museum or received direct assistance in answering inquiries about historic aircraft, and a research worker from the Bureau of the Budget was aided in his study of the history of aerial photography.

Seventeen schools and colleges were assisted in preparing their aeronautical courses, and numerous teachers and students consulted the Museum for facts about many aircraft and related subjects. Authors and an illustrator from the Civil Air Patrol were shown some documents on aviation engines and propellers which aided them in preparing texts. Aeronautical organizations that consulted the National Air Museum included the National Aeronautical Association, Royal Aeronautical Society, Institute of Aeronautical Sciences, Air Transport Association, Air Industries Association, Washington Junior Chamber of Commerce, and the National Aviation Education Council. Several lecturers were assisted in preparation of texts and in illustrating their talks.

Among the many interesting projects with which the Museum assisted were three motion pictures, the producers of which have expressed their appreciation, not only for help in reproducing accurate copies of historic aircraft, but also for supplying authentic facts for the script. For "The Court Martial of Billy Mitchell" help in costuming was supplied from actual uniforms of Mitchell preserved in this Museum. The *Spirit of St. Louis* itself was measured, photographed, and examined in detail to insure the accuracy of the copies of that airplane constructed for the film. The third film project was the story of the Wright brothers, and only in this Museum could the technical directors find three original examples of Wright brothers' aircraft, and a group of models from which they could scale details for the reproductions they planned to make.

The list of airlines and aircraft manufacturers who were assisted in writing their own company histories includes several which, but for the Museum records, would have left gaps in their texts. The publications that were given assistance include the National Geographic Magazine, Our Wonderful World, Reader's Digest, Life, Saturday Evening Post, American Aviation Daily, Pegasus, Skyways, and Sperryscope. Numerous authors and artists based their work on Museum material.

Maintaining this informational service is a task that has proved its worth as evidenced by the needs and responses of those assisted. This Museum is becoming increasingly recognized as a unique source for authentic information, as embodied in the aircraft and other specimens, the documentary files, the photograph collection, and in the expert knowledge of the staff. Requests for this service are increasing as it becomes more widely appreciated. An upsurge resulted from the publication of an article describing this function.[1]

This service has come to require more staff time than any other duty, and yet those other duties must somehow be performed, especially when they involve administrative requirements. Time must in some way be found also to maintain the collection, both exhibited and stored, and the associated records, to search for new material, to write texts and other descriptions of aircraft and aeronautical objects in the Museum, and to study. This constant searching for facts involves not only the acquired specimens, but also texts, both historic and current, in order that the staff's personal knowledge and familiarity with the collection—an intangible that is as valuable as any specimen—may be constantly increased. Thus, the need for adequate facilities for the National Air Museum—a building, equipment, and staff—becomes increasingly emphasized.

PUBLICATIONS

By the end of the fiscal year all work on the ninth edition of the Handbook of the National Aeronautical Collections was virtually completed, and the book came off the press in mid-August. This Handbook is a general history of aeronautics, as illustrated by the principal specimens in the collections. It contains 166 pages of text and 220 illustrations.

Progress this year on the Catalog of Aircraft has been principally through the procurement of photographs of each of the airplanes, seaplanes, gliders, rotorcraft, and experimental aircraft in the collections, and the assembling of data on each, preparatory to condensing each item to a concise description.

Several of the information leaflets that describe individual aircraft in the Museum and are used principally as inserts for correspondence were revised and multigraphed. Despite progress with supersonic aircraft, correspondence throughout the year reveals that there is still widespread interest in the most basic of aircraft, the kite, for both practical uses and sport. The Museum exhibits a number of oriental and domestic kites, including some that were made by

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[1] "The Expanding Role of the Smithsonian Institution in Aviation and Education," by Leonard Carmichael and Paul E. Garber, in Education for September 1955.

aeronautical pioneers during their early experiments. Assembly of material for a publication describing them has progressed during the year, and promising leads are being investigated for the procurement of several types of kites that should be obtained in order to complete the series.

REFERENCE MATERIAL AND ACKNOWLEDGMENTS

Documentation of the collections is an important procedure, in order to authenticate the exhibits and acquire authoritative data from which labels, catalogs, and other texts can be prepared. This material is also essential for answering the thousands of questions received each year and for serving those who come to the Museum engaged in research. Realizing that the Museum has need for such material and has facilities for keeping it in ready-reference form, a number of persons and organizations have transferred reference items to this Museum. Appreciation is expressed to the following:

Aero Digest, Washington, D. C.: An assortment of photographs and texts, acquired in connection with publication of this magazine.

Aircraft Industries Association, Washington, D. C. (through Joseph Geuting): The Aircraft Yearbook for 1955.

Andrews, Harold, Ithaca, N. Y.: A group of scale drawings by Gene Schmidt illustrating U. S. fighter airplanes of the 1920's.

Bade, Charles A., Cleveland, Ohio.: Three name plates from aircraft: American Eagle, Kenyon and Williams, and Lincoln Page.

Bowers, Peter, Seattle, Wash.: The loan of a large collection of photographs of World War I aircraft, from which copies were made for the Museum files.

Carruthers, John, Claremont, Calif.: A microfilm of a collection of documents, announcements, posters, and news accounts of balloon ascents during the nineteenth century.

Dally, Comdr. F. E., USN, Washington, D. C.: A photostatic copy of Maggs Brothers' catalog, London, 1923, illustrating and describing a collection of aeronautical prints and texts.

Draper, Col. Wm. G., USAF, Washington, D. C.: A photograph of the Aero Commander, presidential airplane, autographed by President Dwight D. Eisenhower, Colonel Draper, pilot, and Maj. John W. Mitchell, copilot.

Esso Aviation News Digest, New York, N. Y.: 103 bound volumes of aviation magazines, including Aero Digest, Air Transport, Aviation Week, Aeroplane, Flight, Aviation, and others.

Grosz, P. M., Princeton, N. J.: Copies of Ernst Udet, Mein Fliegerleben, The Skycraft Book, and The Second Boys' Book of Model Airplanes.

Hamilton, Edward G., Dearborn, Mich.: His flight log, listing flights in the Ford-Stout Liberty-engine "Air Pullman," during 1922–25 when the airmail and transport route established by Henry Ford was pioneering operations between Detroit, Chicago, and Cleveland.

Hardesty, Bergen, Frankfort, Ind.: A scale drawing of the Nieuport–28, World War I French pursuit airplane.

Hegener, Henri, Bennebroek, NH, The Netherlands: The loan of 90 photographs of World War II aircraft, from which copies were made for the Museum files.

Hildes-Heim, Erik, Fairfield, Conn.: 12 books on aeronautics and two copies of American Helicopter.

KLEMIN, MRS. ETHEL, Greenwich, Conn.: Records pertaining to aerodynamic tests performed by her husband, the late Dr. Alexander Klemin, noted aeronautical engineer and teacher.

LEWIS, CAPT. R. A., Maywood, N. J.: A 3-sheet photostat copy of the navigator's log, recording the flight of the U. S. Air Force B-29 bomber *Enola Gay*, August 6, 1945, when it carried the first atomic bomb to be dropped in warfare, over Hiroshima, Japan. Captain Lewis was copilot on this flight.

LONDON TIMES, London, England: "The Times Survey of British Aviation," prepared September 1955; review of historical and current developments in aircraft engines, airports, and related services.

MACCARTEE, CHARLES J., Orlando, Fla.: The loan of a series of negatives, from which prints were made for the Museum files, illustrating airplanes and flights at the first military aviation school and field, College Park, Md., 1910–14.

NEVIN, ROBERT, Denver, Colo.: A scale drawing of the Wright Brothers Company airplane, type "H," of 1914.

NIETO, JOSEPH, San Antonio, Tex.: Scale drawings of the U. S. Army Air Service Curtiss R3C–2 Racer of 1925, and the Air Corps Boeing P–26 of 1933.

NYE, WILLIS L., Hayward, Calif.: A scale drawing of the Douglas World Cruiser airplane, flown by pilots of the U. S. Army Air Service on the first flight around the world, 1924.

POPULAR MECHANICS MAGAZINE, Chicago, Ill.: A drawing showing details of the *Winnie Mae* airplane, including its engine and supercharger installation, and the stratosphere suit devised by Wiley Post.

RICHARDSON, CHARLES L., Hebron Conn. (through his wife and Walter D. Sherwood): A copy of "Zeppelin, fahrt um die Welt," an illustrated account of the voyage around the world by the *Graf Zeppelin* airship, 1929.

SUMPTER SMITH, MRS., Washington, D. C.: A series of scrapbooks maintained by her from 1924 to 1939 recording aeronautical events of those years.

U. S. AIR FORCE, Wright-Patterson Air Force Base, Ohio: A quantity of Technical Orders, illustrating in detail the construction of a number of recent types of aircraft in use by the Air Force.

U. S. COAST GUARD, Washington, D. C. (through Norman Rubin): A series of photographs illustrating types of aircraft used by this service.

U. S. NAVY, Washington, D. C.: A set of scale drawings of the Curtiss N–9 seaplane used during World War I for the training of naval student aviators.

VAN WEERDEN, J., Maarssen, The Netherlands: Three books on aeronautical history—from Icarus to Zeppelin, by Edgar Fuld; Mijlpalen (Milestones), by C. Van Steenderen, describing airplanes and seaplanes prior to 1918; and Zij Maakten Luchtvaartgeschiedenis, by C. Van Steenderen, Jr., describing airplanes and seaplanes of the period 1910-36.

VERVILLE, ALFRED V., Washington, D. C.: Descriptions and drawings of the "Messenger" airplane designed by the donor, 1920; one of the earliest successful military liaison and sport types.

WESTINGHOUSE ELECTRIC CORPORATION, Kansas City, Mo.: A drawing of the J–34 turbojet engine, produced by this company.

WOLFFSOHN, HANS J., Suffern, N. Y.: Copies of the magazine Flugsport.

The Museum is also pleased to acknowledge the cooperation of the Academy of Model Aeronautics, National Aeronautic Association, the National Advisory Committee for Aeronautics, Harvey Lippincott of Hebron, Conn., John H. Lundgren of St. Albans, N. Y., Robert P. McComb of Moultrie, Ga., Chris Bielstein of Arlington, Va., and Ray

Fife of Coronado, Calif., in improving the documentary files by gifts and exchanges of magazines and other data.

During the year a small room in the Aircraft Building was equipped as a depository for reference items, and as a study for use by members of the staff and visitors.

ACCESSIONS

Additions to the National Aeronautical Collections received and recorded this year total 118 specimens in 45 separate accessions from 37 sources. Those from Government departments are entered as transfers; others were received as gifts except as noted.

ATCHISON, JOS. ANTHONY, Washington, D. C.: Group of five aircraft squadron insignia illustrating the devices adopted by units of the First Pursuit Group, U. S. Army, in World War I; and four plaster sculptures showing primitive concepts of flying gods in the Hittite, Assyrian, Babylonian, and Egyptian religions (N. A. M. 870, purchased).

AUTOGIRO CO. OF AMERICA, Philadelphia, Pa. (through Franklin Institute): Pitcairn autogiro, the first aircraft of this type constructed in America, 1929 (N. A. M. 888).

BEECH AIRCRAFT CORP., Wichita, Kans.: Scale-model airplanes, 1:16, one illustrating the Beechcraft Bonanza airplane *Waikiki Beech* in which William Odom flew from Honolulu to Teterboro, N. J., March 7–8, 1949, establishing a solo distance record of 4,957.24 miles in 36 hours 2 minutes, and in which the Honorable Peter F. Mack made a solo flight around the world, Oct. 7, 1951–Feb. 7, 1952, visiting 30 nations and flying more than 30,000 miles in the interests of international good will and acquainting himself with conditions in other countries. The other model is of the Beechcraft Super 18, 6-place twin-engined monoplane in current production (N. A. M. 898).

BOLAND, JOS., Takoma Park, Md.: Replica of an air-speed meter devised and constructed by the donor in 1910 (N. A. M. 902).

BYRD, MRS. THOS., Boyce, Va.: Uniforms and military equipment of the late Gen. William Mitchell (N. A. M. 881). Two swords belonging to General Mitchell, one having been presented to him by his uncle in 1898 when Mitchell was promoted from private to lieutenant during the Spanish War and became the youngest officer in the Army; the other, his service sword (N. A. M. 904).

CLARK AUTOMOTIVE MUSEUM, Southampton, L. I., N. Y.: Two aircraft engines, an Anzani and a Caminez (N. A. M. 896).

COMMERCE, DEPARTMENT OF, CIVIL AERONAUTICS ADMINISTRATION, Washington, D. C.: Two aircraft beacons of the type used when the national airways were first established (N. A. M. 893).

DE FLOREZ, ADM. LUIS, Pomfret, Conn.: A group of early aircraft instruments which he assisted in developing during the World War I period, and a Daniel rotary, 2-cycle aircraft engine (N. A. M. 906).

DOUGLAS AIRCRAFT CO., INC., Santa Monica, Calif.: Scale models, 1:16, of the F4D-1, Skyray, and the A4D-1, Skyraider, illustrating current types of naval carrier-based fighting and attack airplanes (N. A. M. 892).

ECK, W. JOHN, Arlington, Va.: The first passenger ticket sold for the first commercial airplane flight over the North Pole area from the United States to Europe, by the Scandinavian Airlines System, Inc., November 18, 1954. The donor had the distinction of being the first passenger (N. A. M. 875).

FAIRCHILD ENGINE & AIRPLANE CORP., Hagerstown, Md.: Scale models, 1:48, illustrating the C-119 and C-123 cargo planes recently produced by this corporation for the Armed Forces (N. A. M. 874).

GARBER, PAUL E., Washington, D. C.: An aviator's helmet equipped with air tubes, hoses, and mouthpiece used for instructing student pilots (N. A. M. 913).

HADLEY, CLIFTON O., Reading, Pa.: A roll of "Penacloth" developed by the Pennsylvania Rubber Co. during the early days of flying, as a special fabric for covering the wings of airplanes. This type of fabric was used by many of the Early Birds, including the donor (N. A. M. 895).

HAMMOND, DEAN, Dearborn, Mich.: Stearman-Hammond airplane, a type developed by the donor in the early 1930's when the Department of Commerce was encouraging production of economical aircraft intended for private flying (N. A. M. 886).

HARTMAN, A. J., Burlington, Iowa: A Roberts airplane engine, 4 cylinders, 60 hp., together with the associated radiator and propeller that formed the power installation of an airplane of 1911 flown by the donor (N. A. M. 873).

KEY, ALGENE and FRED, Meridian, Miss.: The *Ole Miss*, Curtiss Robin monoplane which, June 4–July 1, 1935, established an official endurance record of 653 hours 34 minutes continuous flight, refueled in air (N. A. M. 883).

KNABENSHUE, ROY, Pasadena, Calif.: A replica of the dirigible airship which he constructed in 1905 and piloted over New York City, that being the first time a powered aircraft had flown over that metropolis (N. A. M. 894).

MAGRATH, CHRISTY, Berkeley, Mo.: An early flying model airplane of about 1910 and a structural unit of the U. S. Army's Goodyear RS-1 airship of 1932 (N. A. M. 884).

MANBECK, ESTELLE, Long Beach, Calif.: The first type of pin identifying members of the Ninety Nine's, organization of women pilots of which Amelia Earhart was cofounder. The donor was past commander of the Amelia Earhart Post #678, American Legion (N. A. M. 871).

METCALF, DR. G. W., Baltimore, Md.: 10 scale models, 1:24, illustrating airplanes used in World War I, including English, French, and German types (N. A. M. 869).

NAVY, DEPARTMENT OF THE, Washington, D. C.: The original ground-speed and drift indicator developed by Harold Gatty and used by him when, as navigator, he flew around the world with Wiley Post, June 23–July 1, 1931, received from the U. S. Naval Observatory (N. A. M. 887). Scale model, 1:16, of the Curtiss SOC-3 airplane, one of the final types of biplanes used by the Navy, several having engaged the enemy when Pearl Harbor was attacked in 1941 (N. A. M 903).

NESSEN, JOHN, Pleasant Valley, Conn.: A 6-cylinder Menasco aircraft engine, this example having been used by Charles Lindbergh in the Miles "Mohawk" airplane that he purchased and flew in England in 1937 (N. A. M. 900).

NORTH AMERICAN AVIATION, INC., Los Angeles, Calif.: Scale model, 1:16, of the F-100 Supersabre, the first fighter to attain supersonic speed in level and climbing flight. For the development of this airplane the donor was the recipient of the Robert J. Collier Trophy award for 1953 (N. A. M. 911).

OLIVER, ROWLAND S., Washington, D. C.: A toy given to the donor in 1899, illustrating an early concept of a foot-propelled parachutelike aircraft (N. A. M. 899).

OLMSTED, CHAS. M., THE FAMILY AND ESTATE OF: An original full-sized amphibious aircraft developed 1909–12, incorporating many advanced features, including retractable wheels, variable-camber wing, and elevated high-aspect-ratio tail plane (N. A. M. 872).

OLMSTED, JOHN B., Miami, Fla.: The original wind-tunnel model of an amphibious twin-pusher monoplane developed by his father, Charles M. Olmsted, 1909–1912 (N. A. M. 880).

PARKER, WM. D., Bartlesville, Okla.: An Elbridge 3-cylinder airplane engine used by the donor during some of his early flights, 1910–12; and a Lawrance 2-cylinder-opposed aircraft engine developed for installation in the "Penguin" clipped-wing training airplanes of World War I (N. A. M. 907).

PFISTER, MRS. ARTHUR, Aspen, Colo.: A Bell P–39 Airacobra airplane, a fighter type developed for use in World War II, this example having been piloted by the donor (nee Betty Haas) in postwar air races (N. A. M. 876).

PORTZ, HENRY G., Garden Grove, Calif.: Scale model, 1:16, of the Turner-Laird special racer piloted by Roscoe Turner when he won the 1939 Thompson Trophy Race at an average speed of 282.53 m. p. h., becoming the only pilot to win this famous trophy three times. (N. A. M. 905).

POST OFFICE DEPARTMENT, Washington, D. C.: A mail bag used in the Postal Aviation Service on the first continuous scheduled public-service airmail route in the world, New York-Philadelphia-Washington, 1918 (N. A. M. 889). An airplane propeller, mahogany, from one of the airmail planes operated by the Postal Aviation Service over the transcontinental mail routes about 1925, used with a Liberty engine (N. A. M. 908).

RICKER, BERNARD, Washington, D. C.: A mail bag and post card dropped from the German airship *Graf Zeppelin* when it circled over Washington after making its first transatlantic flight from Germany to Lakehurst, N. J., October 15, 1928. The donor, then 13 years old, caught this mail bag and took it to the Post Office where its contents were forwarded (N. A. M. 912).

STOUT, WM. B., Phoenix, Ariz.: A group of five early and experimental aircraft models which the donor collected or constructed, illustrating elementary helicopters of the late nineteenth century, and gliders constructed from descriptions by Octave Chanute (N. A. M. 878).

TOPPING, WILLIAM, Akron, Ohio: Scale models, 1:48, of two guided missiles, the Chance Vought "Regulus" and the Martin B–61 "Matador," which are in current production (N. A. M. 901).

UNITED AIRCRAFT CORP., PRATT & WHITNEY AIRCRAFT DIVISION, Hartford, Conn. (with assistance of Harvey Lippincott): A Bendix fuel injection unit of the type used with the Wasp Major R–4360 engines (N. A. M. 882). The original example of the J–57 twin-spool turbojet engine, a type selected to power several supersonic fighters of the U. S. Air Force and Navy and recently developed tankers and bombers, including the Boeing 707 and Douglas DC–8. The designer of this engine, Leonard S. Hobbs, was awarded the Robert J. Collier Trophy for 1952 (N. A. M. 885). An R–2000 2SD13G aircraft engine, the Pratt & Whitney Co.'s one-hundredth experimental engine which served as a basis for testing many improvements in design. This type installed in DC–4 airplanes made aircraft history as the principal powerplant of the famous Berlin airlift (N. A. M. 890). A full-sized sectionalized turbosupercharger of the type used in the Boeing B–17 superfortress bombers during World War II to enable the engines to operate efficiently at high altitudes. For development of the turbosupercharger Dr. Sanford A. Moss, of the General Electric Co., was awarded the Robert J. Collier Trophy for 1940 (N. A. M. 891). SIKORSKY AIRCRAFT DIVISION, Bridgeport, Conn.: Scale models 1:48, of the H–5 and H–19 helicopters, in current service (N. A. M. 897).

UNITED AIR LINES, Chicago, Ill.: Uniform of the type worn by the first stewardesses of this airline which was the first to employ them, 1930 (N. A. M. 879).

VOUGHT, CHANCE, AIRCRAFT, INC., Dallas, Tex.: A scale model, 1:16, of the Navy F8U "Crusader," a current type of carrier-based supersonic fighter (N. A. M. 909).

WOMEN'S NATIONAL AERONAUTIC ASSOCIATION (through Mrs. Chester S. Bleyer, Tulsa, Okla.): Scale model, 1:16, of the William B. Stout Liberty-engined "Air Pullman" with which Contract Air Mail Route #1 was inaugurated by the Ford Motor Co. between Detroit and Cleveland, 1925 (N. A. M. 877). Seven scale models, 1:16, illustrating airplanes flown in competition and in World War II service by Jacqueline Cochrane (N. A. M. 910).

Respectfully submitted.

PAUL EDWARD GARBER, *Head Curator.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

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, 1956.

In all, 742 accessions, comprising 1,710 individual animals, were 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 also for research and education. Opportunities for research are afforded students of biology, particularly vertebrate zoology, as well as artists, photographers, and writers. Methods of study that do not endanger the welfare of animals or the safety of the public are encouraged.

In addition to the regular diversified activities of carrying on all the operations of the Zoo, the 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 manuscripts for publication.

The stone restaurant building, which was constructed in the Park in 1940, is leased at $34,452 a year. This money is deposited to the credit of the Collector of Taxes, District of Columbia.

Elton Howe, for many years a watch and clock repairman in Washington but now associated with the Diamond Ordnance Laboratory at the U. S. Bureau of Standards, generously presented to the Zoo the 4-faced, 8-day clock that had stood at F Street near Thirteenth since 1922. Mr. Howe put the clock in first-class condition when it was installed, and plans to maintain it in running order as long as he can do so. It has been set up at the intersection of the concourse on the main road through the park, and was started on Monday, June 4, 1956.

FINANCES

The regular appropriation for the fiscal year was $669,300, which is carried in the District of Columbia Appropriation Act. This amount was supplemented by $21,600, which was transferred to the appropriation in accordance with Public Law 94, to cover pay increases

made necessary by the Federal Employees' Salary Increase Act of 1955, approved June 28, 1955.

THE EXHIBITS

Animals for exhibition are acquired by gift, deposit, purchase, exchange, birth, and hatching, 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 turnover, and the exhibits are constantly changing. Thus, the inventory 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, for sometimes creatures of outstanding interest at the time they were shown are no longer in the collection at the time the inventory is made.

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

The two pairs of young giraffes and the pair of young gaurs, as well as other animals brought to the Zoo in 1937 by the National Geographic Society–Smithsonian Institution Expedition, have bred so successfully that the Zoo has been able to dispose of surplus stock having a total exchange value greater than the entire cost of the trip. Such animals are exchanged with other zoos and with animal dealers for specimens that are needed for this collection.

ACCESSIONS

The Zoo is particularly fortunate in having friends who show their sincere interest by bringing in specimens or arranging for acquisitions from foreign countries.

To obtain suitable animals for exhibition extensive correspondence throughout the world and a great number of personal contacts are maintained. As a result it is frequently possible to obtain animals that are not ordinarily available through animal dealers. Some of these are gifts and some are obtained by purchase.

OUTSTANDING ACQUISITIONS

"Firsts" and rarities are always welcomed, and the Zoo acquired a gratifying number of such specimens during the year.

For the first time this Zoo has a pair of European bison, or wisents (*Bison bonasus*), which are the European counterparts of the American bison. Wisents are extinct in the wild, but a few have survived in captivity or in forest preserves in spite of wars in Europe.

After trying for several years the National Geographic Society procured for the Zoo a specimen of the very rare dwarf armadillo (*Burmeisteria retusa*) of the Bolivian region of South America. It was obtained by W. Frerking, a National Geographic Society correspondent keenly interested in the undertaking, and was flown from Santa Cruz, Bolivia, by the Pan American and National Air Lines without cost. It arrived in perfect condition, and while not a showy exhibition animal it is remarkable in form and appearance, and its great rarity makes it an outstanding "first" for this Zoo. It may be the first to be alive in the United States. It is about 7 inches long. The pink color of the body shows through the shell, there is a fringe of white hairs around the edge of the shell, and the hair of the underparts is white. The feet are pink and the front feet have very large claws for digging.

Lt. Col. Robert Traub, of the Army Medical Research Unit, who is now stationed at Kuala Lumpur, Malaya, again generously offered the Zoo a considerable assortment of animals, from which a few were selected. The most outstanding specimen was a linsang (*Prionodon linsang*) which unfortunately died only a few hours before reaching Washington. It is very rare in the wild and is not known to have been in captivity before.

The U. S. Fish and Wildlife Service, through the kindly interest of Donald L. Spencer in Alaska and William Tierre in Washington, made a noteworthy contribution of an Alaskan brown bear (*Ursus* sp.)—a female cub born about February 1955.

The Army Medical School gave the Zoo seven chimpanzees of exhibition quality.

The National Geographic Society, through Gilbert G. La Gorce, presented two beavers (*Castor canadensis*), the first the Zoo has had for some time.

Twenty specimens of a medium-size African galago (*Galago senegalensis*) were turned over to the Zoo by the Army Medical School of Walter Reed Hospital, through Dr. J. A. Morris, after they had served their purpose with the Medical Corps. They were in good condition and are useful for both exhibition and exchange.

The Army Medical School also gave three Mongolian gerbils (*Meriones unguiculatus*), which are sufficiently active during the day to be good exhibition animals. This species was on exhibition only once before.

Two interesting African small mammals, a rock rat (*Aethomys kaiseri*) and a kusu rat (*Arvicanthus niloticus*), were sent by Dr. Lawrence Kilham of the National Institutes of Health while he was engaged in research work at Entebbe, Uganda. These small mammals

have considerable external resemblance to some of the ratlike creatures of North America and are interesting for exhibition.

A Himalayan snow cock (*Tetraogallus h. himalayensis*) was given the Zoo by the Fish and Wildlife Service through Gardner Bump, who was then in Pakistan, and F. C. Lincoln of the Washington office. This is the first bird of this kind exhibited here. It is about the size and form of a domestic chicken.

The Fish and Wildlife Service also presented the first specimens of the sand grouse (*Pterocles orientalis*) the Zoo has ever had.

Two kea parrots (*Nestor notabilis*), gifts from the New Zealand Government, were brought north for the Zoo by the Naval Antarctic Expedition. These birds were at one time threatened with extinction and are now rigidly protected. They have been successfully exhibited here for many years, but these two additional specimens are most welcome.

Three emperor penguins (*Aptenodytes forsteri*) were brought to the Zoo by Malcolm Davis of the Zoo staff, who accompanied the Antarctic Expedition known as Task Force 43. He also brought back six parasitic gulls known as skuas (*Catharacta maccormicki*). The penguins died of aspergillosis within a few days.

From Dr. Juan Rivero, of the University of Puerto Rico, came three different species of the beautiful little green anolis of Puerto Rico.

The following were obtained by purchase:

An olingo, or bassaricyon (*Bassaricyon gabbi*), from the Leticia region of Colombia. For many years this rare animal has been sought in Central America and northern South America. It is a relative of the raccoons and kinkajous and bears considerable resemblance to the latter, but its ears are larger, its tail is not prehensile, and its movements suggest that it is probably more terrestrial than the kinkajou. Only a few specimens of this genus are known from widely scattered locations in Central America and northern South America. This is the first one of its kind exhibited in the Zoo and probably the first to be alive in the United States.

Two young Sumatran orangutans (*Pongo pygmaeus*), which had been deposited in the Zoo by Mr. and Mrs. Carl Krummel of Baltimore, Md.

A male, a female, and a young Saiga antelope (*Saiga tatarica*).

Fine specimens of male and female gelada baboons (*Theropithecus gelada*), the first the Zoo has had for several years. They are rare in the wild and are noteworthy among the primates in having a naked area on their red chest; in the female this area is bordered by a row of tubercles on the skin more than one-eighth of an inch in diameter, giving the impression that she wears a pink pearl necklace. The single species of this interesting genus inhabits the mountainous parts of Abyssinia.

A South American tapir (*Tapirus terrestris*), which gives the Zoo a pair of these river and swamp animals.

A pair of rib-faced deer, or muntjaks (*Muntiacus muntjak*).

A pair of beautiful young tamandua anteaters (*Tamandua tetradactyla*).

Two African wild dogs (*Lycaon pictus*). The Zoo had some of these animals several years ago, but they are not common in captivity.

Two black jaçanas (*Jacana spinosa hypomelaena*). These tiny relatives of the rails have extremely long slender toes and long legs, and are well adapted to running on vegetation floating on the surface of tropical streams and ponds. They are the first the Zoo has exhibited.

A beautiful white-and-gray Guianan crested eagle (*Morphnus guianensis*) from the Leticia region of Colombia. The species ranges from Honduras and Costa Rica south to Argentina and Bolivia but is scarce throughout its range and very rare in captivity.

Two Inca terns (*Larosterna inca*), inhabitants of the coast of Peru and Chile. These are the first that have been exhibited here and are attractive additions to the bird house.

Two whooper swans (*Cygnus cygnus*), inhabitants of Europe and Asia, but now rare.

A fine specimen of the comb duck (*Sarkidiornis melanota*), which inhabits most of Africa and southern Asia.

A specimen of an interesting Manduit's hawk-eagle (*Spizaetus ornatus*).

Surinam toads (*Pipa pipa*). These are the first of these very interesting creatures the Zoo has had for some time. They are remarkable for their method of reproduction—the male embeds the eggs in the soft spongy skin of the back of the female, where they go through the tadpole stage and emerge as little frogs.

A parrot snake (*Leptophis occidentalis*), from the Leticia region of Colombia.

During the year contact was reestablished with a collector, J. D. Handman, in Africa, who has sent several shipments of reptiles. Among the more interesting ones were flap-necked chameleons (*Chamaeleon dilepis*), striped sand snakes (*Psammophis subtaeniatus*), sharp-nosed snakes (*Rhamphiophis rostratus*), Egyptian cobras (*Naja haje*), African black cobras (*Naja melanoleuca*), boomslangs (*Dispholidus typus*), African house snakes (*Boaedon lineatum*), and plated lizards (*Gerrhosaurus major*).

Several specimens of the Amazon spotted turtle (*Podocnemis unifilis*). Heretofore these turtles have been very rare in collections, but apparently the area in which they may be common is now being explored for animals.

By exchange with the Philadelphia Zoological Society a specimen of the Cape Barren goose (*Cereopsis novaehollandiae*) was acquired.

A small but interesting collection of lizards and scorpions from the Florida Keys was obtained by exchange from Mr. and Mrs. Louis H. Babbitt.

DEPOSITS

This year, as in many years past, various individuals have deposited in the Zoo animals to which they desired to retain title. These are most acceptable additions to the exhibits. Depositors are assured that the animals will receive routine care, but the Zoo assumes no responsibility and no obligation to replace any that do not survive. The following animals were on deposit during the year:

A young red ukari (*Cacajao rubicundus*), deposited by William Schwartz. Ukaris are unusual in collections because they do not thrive in captivity, but because of the special care given this specimen it gives promise of surviving.

A number of active young chimpanzees, on deposit from the Army Medical Corps and the Johns Hopkins Medical School. They are kept here until they are needed for research work by the respective institutions. Most of them suffer no greater indignity or discomfort than having a small amount of their blood taken for testing in a medical laboratory. They provide one of the most interesting and active exhibits.

Two specimens of Branick's paca (*Dinomys branickii*) on deposit for three days. They are South American rodents that are very rare, but the Zoo had had specimens of them on two previous occasions.

Some chukar quails (*Alectornia graeca*), deposited by the Pakistan Embassy.

Ten different species of unusually attractive finches that were living together, deposited by Dean Stambaugh, St. Albans School, Washington, D. C.

An interesting collection of Cuban reptiles, deposited by David Hardy of Baltimore, Md.

A specimen of the Murray turtle (*Emydura macquariæ*), deposited by Donald Pumphrey.

DEPOSITORS AND DONORS AND THEIR GIFTS

(Deposits are marked *; unless otherwise indicated, address of donors is Washington, D. C.)

Aaron, A. H., Hyattsville, Md., domestic rabbit.

Aaron, Mrs. William H., Wheaton, Md., domestic rabbit.

Adams, Louis, timber rattlesnake.

Adgate, W. M., Bethesda, Md., 2 domestic rabbits.

Alexander, Judith, 2 red-lined turtles.

Amber, Dianne, Arlington, Va., 2 Peking ducks.

Amos, James, screech owl.

Anderberg, Sven, Hyattsville, Md., domestic rabbit.

Anderson, Bruce, Silver Spring, Md., alligator.
Anderson, R. G., Lanham, Md., 9 Peking ducks.
Ariss, Michael and John, cottontail rabbit.
Arnold, Mrs. Elting, Somerset, Md., purple grackle.
Aro, Mrs. Thomas, Arlington, Va., grass parakeet.
Atkeson, John C., Jr., Arlington, Va., sparrow hawk.
Babbitt, Lewis H., Petersham, Mass., timber rattlesnake.
Baker, Thomas G., Brentwood, Md., 9 domestic rabbits.
Baldwin, J. W., King George Co., Va., 3 raccoons.
Barber, Robin, Chevy Chase, Md., Peking duck.
Barnwell, E. L., Alexandria, Va., Peking duck.
Barrus, Russell W., Jr., Falls Church, Va., eastern skunk.
Baster, Fred, domestic rabbit.
Bayer, F. M., 10 sea snakes.
Beall, Peter W., Bethesda, Md., mole snake.
Beard, William H., skunk.
Beckett, Patricia and Charlotte, Bethesda, Md., 3 bantam fowl.
Berrell, Mrs. F. J., Peking duck.
Besby, Susan, Orange, Va., ground hog.
Bianchini, W. R., Hyattsville, Md., 2 Peking ducks.
Bigley, Georgia, *grass parakeet.
Bingham, Lt. Col. E. C., Arlington, Va., domestic rabbit.
Black, Charles N., Bladensburg, Md., alligator.
Black, T. W., Cheverly, Md., red-lined turtle.
Blankenship, William A., Bethesda, Md., squirrel monkey.
Bohrer, Ronnie, Silver Spring, Md., Peking duck.
Borkart, Mrs. Olivia, *spider monkey.
Bowen, Edward W., Hyattsville, Md., alligator.
Bowker, Albert H., domestic rabbit.
Bozzi, Mrs. Francis G., 6 barn owls.
Brantner, Lester E., Rockville, Md., gray fox.
Breazeale, Edgar B., chukar quail.
Brewer, C. M., Hyattsville, Md., caiman.
Bridge, John and Stephen, Greenbelt, Md., spotted turtle, 3 snapping turtles, pilot black snake.
Briggs, Michael, horned lizard.
Brooks, Virginia, domestic rabbit.
Brown, Helen, Louisa, Va., *owl monkey, *pig-tailed monkey.
Brown, Howard, Lexington Park, Md., bald eagle.
Bruzzess, Pvt. J. A., muscovy duck.
Butts, Dr. A. B., domestic rabbit.
Cabot, Caskie, Arlington, Va., pigeon.
Calvert, Gordon L., Silver Spring, Md., 2 domestic rabbits.
Campbell, F. W., Alexandria, Va., Peking duck.
Carpenter, W. K., Wilmington, Del., African leopard.
Carr, Mrs. Myrtle, Muirkirk, Md., green guenon.
Carroll, Mrs. Rachel, Silver Spring, Md., *white-throated capuchin monkey.
Carroll, Wyman, New Haven, Conn., gaboon viper.
Carter, Helen, *blue jay.
Chandler, Mrs. R., domestic rabbit.
Chapman, Cathy and Steve, Silver Spring, Md., 2 Peking ducks.
Charman, H. W., Kensington, Md., domestic rabbit.
Chauvenet, Allen, Silver Spring, Md., 3 opossums.
Chin, Calvin and Carol, domestic rabbit.
Christie, James, Knight, and Claude, Alexandria, Va., *night monkey.
Clarke, Patrick J., Takoma Park, Md., caiman.
Clavelli, Mrs. Anita, domestic rabbit.
Clay, Rick H., Arlington, Va., squirrel monkey.
Coiner, Robert W., Silver Spring, Md., 2 Peking ducks.
Collins, F., Falls Church, Va., hamster.
Cook, Sheila, caiman.
Cooke, M/Sgt. Russell, Jr., black-and-red marmoset, Geoffroy's marmoset.
Corbin, Mrs. Mary Lee, Beltsville, Md., ringtail capuchin.
Corvick, Mrs. William A., McLean, Va., albino robin.

Crandon Zoo, Miami, Fla., soft-shelled turtle.

Crocker, Charles D., Georgetown, British Guiana, 2 anacondas.

Crockett, Mrs. J. S., Brentwood, Md., caiman.

Crooks, Claudia, Peking duck.

Crooks, Henry A., Indian Head, Md., raccoon.

Culver, Charles E., Falls Church, Va., 3 Peking ducks.

Curtis, Dr., rhesus monkey.

Curtis, Mrs. Charles, Silver Spring, Md., 2 flying squirrels.

Danko, George J., 4 Peking ducks.

Davis, Frank K., ocelot.

Davis, Mrs. J. R., Peking duck.

Davis, Lawrence D., Hyattsville, Md., red-lined turtle.

Davis, Robert R., *kinkajou.

Davis, Skipper, Alexandria, Va., pilot black snake.

Dawson, Jane A., Rockville, Md., cottontail rabbit.

Degan, Donnie and Mary, Takoma Park, Md., 4 white-tailed pigeons.

DePrato, Joe and Jack, Langley Park, Md., 20 tree frogs, green frog, 2 toads.

Douglass, Beverly, *pale capuchin.

Drake, Mrs. Ruth H., grass parakeet.

Dunaev, Nicholas, brown capuchin, 2 caimans.

Duques, Mrs. Henry, Arlington, Va., domestic rabbit.

Ebert, Jervey S., Rockville, Md., 4 purple martins.

Eby, Cecil A., Bethesda, Md., loon.

Ekin, Mrs. C. William, Bethesda, Md., gray squirrel.

Ellis, John H., Torrington, Conn., cackling goose.

Emerson, F. A., Rockville, Md., golden pheasant.

Emmett, Edith, domestic rabbit.

Ercannilla, M., cowbird.

Ezenour, Joan, Arlington, Va., 2 domestic chickens.

Ezrine, Angy, Peking duck.

Fama, Joseph, Peking duck.

Faulstich, Albert J., domestic rabbit.

Fehrman, Ray, Silver Spring, Md., *2 collared turtledoves.

Feighery, Frank, Sr., Colvin Run, Va., alligator.

Ferguson, Geary, Alexandria, Va., coachwhip snake.

Fields, Lary, Bethesda, Md., pilot black snake.

Fisher, Viola, squirrel monkey.

Foley, John W., Kensington, Md., mud turtle, box turtle, snapping turtle, rabbit.

Fortenberry, C. G., Arlington, Va., domestic rabbit.

Foster, Daniel L., 2 red-bellied snakes.

Fox, James B., Bethesda, Md. *2 sparrow hawks, *2 red-tailed hawks, *2 duck hawks.

Fraley, Patricia, Rockville, Md., Peking duck.

Francis, Roddy, 2 domestic rabbits.

Freeman, Frank W., 4 sea horses.

Frick, Ann Tracey, Peking duck.

Frost, Mrs. W. P., Kensington, Md., domestic rabbit.

Fudge, Robert E., Dahlgreen, Va., Virginia deer.

Fuqua, Paul, Arlington, Va., snapping turtle, 2 horned lizards.

Gambone, William A., Silver Spring, Md., domestic rabbit.

Garber, Paul E., flying squirrel.

Garcia, Modesta, Silver Spring, Md., squirrel.

Garrison, T., domestic rabbit.

Gaver, Gordon, Thurmont, Md., *rhesus monkey, *4 alligators, *alligator turtle, *Javan macaque.

Gilliam, Homer, Falls Church, Va., flying squirrel.

Gingell, F. V., Fairhaven, Md., Geoffroy's marmoset.

Giuliani, Gilbert, Kensington, Md., tarantula.

Gleason, Mrs. Naomi, Silver Spring, Md., caiman.

Gooch, Donald, Takoma Park, Md., 2 eastern skunks.

Gray, Joseph B., Seat Pleasant, Md., opossum, raccoon.

Greco, James, Vienna, Va., common goat.

Greenhow, Roger, Springfield, Va., painted turtle.

Greenwood, Walter, Arlington, Va., diamond-back turtle.

Grunwell, William T., Arlington, Va., red-bellied turtle.
Gscheidle, John R., Chillum, Md., snapping turtle.
Haldeman, Jay, Bethesda, Md., domestic rabbit.
Hall, Mrs. Edna M., Arlington, Va., 2 black-widow spiders.
Hall, Raynaud, domestic rabbit.
Hammlin, Paul K., Kinston, N. C., 2 capuchin monkeys.
Hammond, James H., Chevy Chase, Md., 6 guinea pigs.
Hand, Dr. J. D., Silver Spring, Md., hog-nosed snake.
Hardy, David, Baltimore, Md., *4 Cuban iguanas, *8 curl-tail lizards, *19 Cuban boas, *10 Cuban geckos, *3 Cuban turtles, *16 Cuban toads, *Cuban racer, *4 ground boas, *Jubito or Cuban grass snake, *hutia.
Hatchman, Mrs. M. G., Bethesda, Md., pilot black snake.
Hawkins, Clayton, Java rice bird, 4 grass parakeets.
Heilman, Miriam, Chevy Chase, Md., box turtle.
Helsig, C. P., Arlington, Va., 2 Peking ducks.
Henderson, David and Elizabeth, Arlington, Va., 2 hamsters.
Henderson, H. R., caiman.
Hendley, Carroll, Bladensburg, Md., red-lined turtle.
Hennessy, Richard L., San Francisco, Calif., *Rosella parakeet.
Hewitt, Wesley, Silver Spring, Md., alligator.
Hibbert, B. L., Peking duck.
Hicks, William, 6 hamsters.
Highfield, Robert T., southern hill mynah.
Hill, James C., 2 roosters.
Hobbs, Catherine B., 2 diamond-back turtles.
Hobbs, E. E., Jr., Wheaton, Md., ring-tail capuchin monkey.
Hodge, Mrs. W. H., Silver Spring, Md., domestic rabbit.
Hoffman, Irvin H., Cabin John, Md., silver pheasant.
Hoffman, Irvin M., Bethesda, Md., 2 wood ducks, 2 silver-spangled Hamburg fowls.
Hogeboom, Mrs. G. H., Kensington, Md., black-widow spider.
Hoke, John, 2 common iguanas.
Holland, Beatrice, grass parakeet.
Homan, Coke, eastern skunk.
Hood, Maj. Gen. Reuben C., Jr., USAF, Ancon, Canal Zone, Galapagos turtle.
Horne, Douglas B., Surry, Va., copperhead snake.
Howell, Robert, Arlington, Va., 3 Java finches.
Hubbard, Robert, Arlington, Va., alligator.
Hubble, Mrs. W., rosy-faced lovebird.
Huggins, Mrs. Henry S., cottontail rabbit.
Hughes, Mrs. Hannah, domestic turkey.
Hughes, Mrs. William G., Jr., horned lizard.
Hutchinson, W. S., cockatiel.
Hynek, Frank, spiny-tailed iguana.
Ikao, Tanit, Burlington, N. J., *alligator.
Johnson, Richard W., Bethesda, Md., 2 pocket mice.
Jolley, Christian L., Rockville, Md., Butler's garter snake.
Jones, J. O., Falls Church, Va., 3 domestic rabbits.
Jones, Marie A., Silver Spring, Md., Peking duck.
Kangas, Mike, Arlington, Va., 3 ospreys.
Kastantin, J., Rockville, Md., indigo snake.
Kasten, Mrs. Marie A., 2 box turtles, 3 false map turtles, 2 red-lined turtles, Florida water turtle.
Keeping, Jim, sparrow hawk.
Kennard, Marion, domestic rabbit.
Kilham, Dr. Lawrence, National Institutes of Health, *kusu rat, *rock rat.
King, Nancy J., Peking duck.
Kirchmyer, R. H., red-lined turtle.
Klenzing, G. Stewart, Chambersburg, Pa., caiman.
Kliban, Barnett P., *2 lovebirds, *mynah, *yellow-headed parrot, *mynah.

Krumke, Karl E., III, spotted turtle, mole snake, pilot black snake, hog-nosed snake.

Krummel, Carl, Baltimore, Md., *12 white headed nuns, *2 Sumatran orangutans.

Kuntz, Dr. Robert, Navy Medical Center, 2 western box turtles, western race runner, western hog-nosed snake, 8 horned lizards.

Lang, Luisa, Chevy Chase, Md., blue-tailed skink.

Lash, Irvin F., Arlington, Va., 2 grass parakeets.

Latham, Inez F., 2 cardinals.

Latham, Joseph D., Indian Head, Md., 2 Peking ducks.

Latham, Louis, Arlington, Va., 6 opossums.

Latham, Mrs. Marté, Pittsburgh, Pa., *2 Brannick's paca.

Lawrence, Mrs. Betty, *blue jay.

Leach, Janet, Peking duck.

Leclercq, Richard P., Silver Spring, Md., wild rabbit.

Leland, Mrs. Carolyn, weeping capuchin.

Levangie, Betsy, squirrel monkey.

Liebert, Carolyn, Bethesda, Md., 2 domestic rabbits.

Linowes, David, domestic rabbit.

Lipovsky, Dr. L. J., *29 salamanders.

Lippman, Larry, Bethesda, Md., caiman.

Locke, Otto Martin, New Braunfels, Tex., 2 indigo snakes, 8 rattlesnakes.

Loeber, C. W., albino robin.

Logsdon, D. M., Annandale, Va., *opossum.

Long, Clifford F., Alexandria, Va., 32 grass parakeets.

Loving, W. H., McLean, Va., 2 domestic rabbits.

Ludwig, Charles D., Arlington, Va., *Cuban parrot.

Lumpkin, Allen, DeKay's snake.

Madeira School, caiman.

Malatics, Jerry, horseshoe crab.

March, Mr. and Mrs. Anthony, Bethesda, Md., goat.

Marden, Mr. and Mrs. Lewis, *2 flying squirrels.

Marmelstein, Allan, Silver Spring, Md., *capuchin monkey, 5 red-lined turtles.

Martin, James Robert, Norfolk, Va., *2 soft-shelled turtles.

Maske, Jerry, domestic rabbit.

Massey, C. C., Alexandria, Va., 2 Peking ducks.

Mausert, Lt. Col. Ryerson N., Falls Church, Va., 7 Rouen ducks.

Mayo, W. A., cottontail rabbit.

Mendoza, R. H., domestic rabbit.

Merchant, Mrs. R. A. Arlington, Va., domestic rabbit.

Miller, Sam, domestic rabbit.

Money, Mark L., Herndon, Va., spotted turtle.

Mora, Jeanne, Arlington, Va., domestic rabbit.

Moreland, Frances, domestic rabbit.

Mork, M. W., black iguana.

Munroe, Willard N., Jr., Rangeley Lakes, Maine, Virginia deer.

Murphy, Greer M., Chevy Chase, Md., caiman.

Murphy, Mrs. H. S., Arlington, Va., Peking duck.

Murphy, Jay, Arlington, Va., snapping turtle.

Murray, Thomas M., Green Meadows, Md., domestic rabbit.

Murrow, Mrs. J. S., raccoon.

Murrow, Roy, robin.

Musser, George, Springfield, Va., red-shouldered hawk.

Myers, Earl H., Falls Church, Va., pale capuchin monkey.

McCormick, H. W., eastern skunk.

McCune, Malcolm, Silver Spring, Md., 2 chinchillas.

McDonald, Karen, Arlington, Va., 2 cottontail rabbits.

McDonald, Tillman, Arlington, Va., prairie dog.

McGeown, A. W., Chevy Chase, Md., *crow.

McKinney, Frank D., hog-nosed snake.

McLean, Mrs. M., black-headed Gouldian finch.

McLean, Paul, domestic rabbit.

McNeil, Jean, Peking duck.

Nathan, Dick, domestic rabbit.

National Geographic Society, 2 beavers, tapafrasco or dwarf armadillo.

National Institutes of Health, Bethesda, Md., 3 squirrel monkeys, *rhesus monkey.

Nelson, Sara L., squirrel monkey.

Nelson, T. P., McLean, Va., snapping turtle.

Newkirk, George F., Bladensburg, Md., night heron.

New Zealand Government, 2 kea parrots.

Nixon, Patricia and Julie, caiman.

North Atlantic Fertilizer and Chemical Co., New York, N. Y., *5 regal pythons, *3 mangrove snakes, *3 burrowing boas.

Norton, Lorraine, domestic rabbit.

Offutt, Courtney, Silver Spring, Md., 2 squirrels.

Olmstead, R. M., Beltsville, Md., barn owl.

Pakistan, Embassy of, *20 chukar quail, *6 immature quail.

Pardue, Coolidge F., Seat Pleasant, Md., common goat.

Parker, Dorothy, Arlington, Va., 2 Peking ducks.

Parker, E. S., Fredericksburg, Va., Bantam fowl.

Parrish, Margaret, Woodbridge, Va., caiman.

Peppard, Kenneth, Alexandria, Va., Peking duck.

Phelps, Mrs. James F., Hyattsville, Md., skunk.

Pickeral, Charles, Falls Church, Va., pale capuchin.

Pickett, Grant, Arlington, Va., alligator.

Pinckard, Lois and Lucille, 2 alligators.

Pinckney, A. J., Hyattsville, Md., domestic rabbit.

Plummer, Warren, boa constrictor.

Poppen, David, Arlington, Va., caiman.

Portland Zoo, Portland, Oreg., 2 emperor geese.

Post Office Department, horned lizard.

Prosise, Mrs. Martin, Vienna, Va., 2 Peking ducks.

Puerto Rico Zoological Gardens, Mayagüez, P. R., 29 anolis lizards.

Pumphrey, Donald, Bladensburg, Md., *Murray turtle.

Queenin, Mrs. R., Jr., caiman.

Ramberg, Walter, Chevy Chase, Md., domestic goose.

Reed, Miss B. J., Silver Spring, Md., squirrel.

Reinhart, Maj. J. W., Silver Spring, Md., horned lizard.

Rhobotham children, Kensington, Md., domestic rabbit.

Rice, George H., Jr., Arlington, Va., 2 squirrel monkeys.

Richards, Randy, Falls Church, Va., crow.

Richardson, O. O., Manassas, Va., mole snake.

Richmond, Robert, Falls Church, Va., cottontail rabbit.

Riggle, Gordon, Bethesda, Md., collared lizard.

Riggs, Lowry, Rockville, Md., turtle.

River, Joseph D., raccoon.

Rivero, Dr. Juan, Puerto Rico, 30 specimens representing 3 species of anolis.

Roach, Norman C., Arlington, Va., Peking duck.

Roache, W. P., Hyattsville, Md., Canada goose.

Roberts, Mrs. J. W., 2 opossums.

Robertson, Alan, domestic rabbit.

Robins, Mrs. N. B., Bethesda, Md., mole.

Roonce, Mrs. Elizabeth, Alexandria, Va., 6 opossums.

Rosenthal, William, domestic duck.

Rubin, Carol, Alexandria, Va., Peking duck.

Rucker, Eldred B., Falls Church, Va., skunk.

Rupp, Elizabeth Ann, Arlington, Va., domestic rabbit.

Saffeld, Lester W., 2 alligators.

Sanborn, Thornton, Bethesda, Md., Peking duck.

Sanders, Ray, painted turtle.

Satchel, Mrs. R. T., Woodstock, Va., 2 bald eagles.

Scheid, Carl Patrick, *duck hawk.

Schenk, Mrs. Robert, Peking duck.

Schroeder, Louis W., Rockville, Md., black-tufted marmoset.

Schwartz, William, *ukari monkey, *squirrel monkey.

Scofield, John, *sulphur-breasted toucan.

Seegers, Mrs. Scott, McLean, Va., *2 cardinals, *wood thrush.

Shaffer, Joseph T., Alexandria, Va., Virginia deer.

Shaw, John, Chevy Chase, Md., caiman.

Sheen, Michael, Falls Church, Va., opossum.

Shepard, Mrs. H. L., domestic rabbit.

Shields, Mrs. James W., Bethesda, Md., Peking duck.

Shooshan, Mrs. H. M., Bethesda, Md., 2 doves.

Shosteck, Robert, Brookville, Md., 6 mallard ducks.

Shutt, Mrs. Evelyn, Falls Church, Va., indigo snake, tarantula.

Sichel, Peter, opossum.

Sidwell Friends School, 9 domestic rabbits, 4 bantam hens.

Silvas, Mrs. Antonette, domestic rabbit.

Sims, Jerry, Arlington, Va., DeKay's snake.

Sisk, Mark, Takoma Park, Md., caiman.

Skelly, Gerald, Ft. Belvoir, Va., *3 copperheads.

Small, Philip L., Martinsburg, W. Va., black-tufted marmoset.

Smith, Roger, Arlington, Va., flying squirrel.

Smith, T. W., Alexandria, Va., Muscovy duck.

Smith, William P., Silver Spring, Md., domestic rabbit.

Snapp, Randolph, McLean, Va., alligator.

Speakes, Meredith E., Manassas, Va., Javan macaque.

Spiller, Mrs. S. K., Peking duck.

Sprehn, Stephen, caiman.

Stagner, H. R., Bethesda, Md., domestic rabbit.

Stambaugh, Dean D., *2 owl finches, *2 Gouldian finches, *2 cordon bleu finches, *2 sharp-tailed finches, *star finch, *2 orange waxbill finches, *strawberry finch, *European goldfinch, *red-billed fire finch, *3 canaries.

Stanbury, Kenneth, Fairfax, Va., black-widow spider.

Stiles, Bill, Falls Church, Va., snapping turtle.

Stilter, Diane, Bethesda, Md., Peking duck.

Swadley, Virgil, McLean, Va., common mole.

Swank, Leslie, Arlington, Va., raccoon.

Taylor, James, 2 domestic rabbits.

Taylor, Mike, caiman.

Taylor, R. L., Chevy Chase, Md., 2 ospreys.

Tedron, R., Chevy Chase, Md., domestic rabbit.

Thomsen, Evelyn R., Alexandria, Va., 4 Peking ducks.

Thornton, Corp. Richard, Camp Lejeune, N. C., 2 Cooper's hawks.

Tift, Bruce and Barbara, 2 guinea pigs.

Tolley, Benton C., Woodacres, Md., domestic rabbit.

Tote-em-In Zoo, George Tregembo, Wilmington, N. C., corn snake, black swamp snake.

Towneley, Hanson, mockingbird.

Traub, Lt. Col. Robert, Kuala Lumpur, Malaya, 4 regal pythons, 2 two-headed snakes, gliding snake, giant gecko, linsang, binturong, Phayre's langur.

Travers, Connie, College Park, Md., mallard duck.

Travis, C. W., wood turtle, ribbon snake.

Trefflich, Henry, New York, N. Y., *king cobra.

Trew, Mrs. Fred, Chevy Chase, Md. caiman.

Troiano, Mr. and Mrs. Frank, *spider monkey.

Trotter, M. E., domestic rabbit.

Truitt, R. V., Stevensville, Md., 4 raccoons.

Tyrrell, W. B., Takoma Park, Md., opossum, pygmy rattlesnake, fence lizard, greater five-lined skink.

Tyrrell, W. B., Willows, Md., 3 pilot black snakes.

U. S. Army Medical School, 7 chimpanzees, 3 Mongolian gerbils.

Through Dr. J. A. Morris, 20 African galagos.

U. S. Department of Agriculture, race-runner snake.

U. S. Fish and Wildlife Service:

Through Gardner Bump, Karachi, Pakistan, and F. C. Lincoln, snow cock.

Through J. Stokley Ligon, Carlsbad, N. Mex., 2 sand grouse.

Through David L. Spencer, Kenai, Alaska, and William Tierre, Alaskan brown bear.

Through Bruce Stollberg, Squaw Creek Refuge, Mound City, Mo., 2 blue geese.

Vanderhoof, Jonna, Rockville, Md., horned lizard.

Van Tassel, M. E., Arlington, Va., Brazilian cardinal.

Vaughan, Merrill W., caiman.

Vigliotti, George A., Silver Spring, Md., kinkajou.

Villa, Kathy, Chillum, Md., 2 domestic rabbits.

Vincent, Michael, snapping turtle.

Virus Research Institute, Entebbe, Uganda, through Dr. J. A. Morris, Army Medical School, Walter Reed Hospital, 20 galagos.

Wadsworth, Richard, 2 grass parakeets.

Walter, Harry, College Park, Md., caiman.

Walter Reed Hospital, *5 Malayan tree shrews, 4 chimpanzees.

Walters, Billy, *chicken snake.

Watson, Dr. Joseph, Chevy Chase, Md., ring-necked dove.

Watson, William D., Kensington, Md., caiman.

Wayland, O. D., Culpeper, Va., 3 grass parakeets.

Weber, Jeanne, and Mrs. Bill Quinter, snapping turtle.

Welbon, Henry G., Tokyo, Japan, Formosan flying squirrel.

Weston, Douglas, Arlington, Va., 2 Peking ducks.

Wheeler, William J., Falls Church, Va., 2 copperheads.

Whitley, James F., *yellow-vented parrot.

Wickenheisen, Walter, Kensington, Md., Muscovy duck.

Willard, Dolores J., jaguarundi.

Williams, Bobby and Johnny, Arlington, Va., 2 Peking ducks.

Wills, Yvonne, domestic rabbit.

Witt, William, *pilot black snake, copperhead snake, 2 tree frogs, *milk snake, milk snake, king snake, 5 spotted turtles.

Wolk, Carolyn, gray squirrel.

Wonn, Clifford P., *red-blue-and-yellow macaw.

Wood, Diana, domestic rabbit.

Worthington, Mrs. Sandra, Takoma Park, Md., Peking duck.

Yarbrough, Arthur, Arlington, Va., sparrow hawk.

BIRTHS AND HATCHINGS

Conditions under which animals are kept on exhibition are usually not favorable for breeding or raising young. However, occasionally young are born or hatched that are of unusual interest to the public and are valuable as additions to the group or for exchange. Outstanding among the births at the Zoo were the following:

The herd of Nubian giraffes (*Giraffa camelopardalis*) again produced young, thus providing valuable exchange specimens.

The pygmy hippos (*Choeropsis liberiensis*) continue to produce young, the eighteenth having been born during the fiscal year.

The water civets (*Atilax paludinosus*), African relatives of the mongoose, continue to produce young.

The colony of rather attractive slender-tailed cloud rats (*Phloeomys cumingii*) continues to increase by births. The original pair have died of old age, but their progeny are carrying on.

The African porcupines (*Hystrix galeata*) continue to increase.

The crested screamers (*Chauna torquata*) again laid eggs and hatched three young, but they did not survive.

Through the painstaking care of Mario De Prato, principal keeper of the reptile house, reproduction among reptiles has been very gratifying. The most outstanding of these follow:

Eggs were laid by the flap-neck chameleon (*Chamaeleon dilepis*) on April 2, 1955, and 6 hatched on June 23. In spite of the utmost efforts the young refused to eat and so survived only a few days.

A three-horned chamelon (*Chamaeleon jacksoni*) gave birth to 16 young on January 9, 1956.

The five-lined skinks hatched six eggs August 11, 1955.

Fourteen young green water snakes (*Natrix cyclopion*) were born June 3, 1955. One egg of an indigo snake (*Drymarchon corais couperi*) was hatched, and 10 red-bellied water snakes (*Natrix erythrogaster*) were born.

An African house snake, or musaga (*Boaedon lineatum*), laid 21 eggs, and 7 of these hatched on December 11. These may be the first of their kind to have been hatched in captivity.

An Egyptian cobra (*Naja haje*) laid 19 eggs on November 4, 1955. On January 31, 1956, 3 of them hatched. Only one of the young could be induced to eat freely. It thrived on baby mice. This was the second time cobra eggs were hatched in the Zoo.

Eight rainbow boas (*Epicrates cenchria*) were born on March 12, 1956.

Following is a complete list of the births and hatchings:

MAMMALS

Scientific name	*Common name*	*Number*
Ammotragus lervia	Aoudad, or Barbary sheep	8
Anoa depressicornis	Anoa	1
Atilax paludinosus	Water civet	1
Axis axis	Axis deer	2
Bibos gaurus	Gaur	1
Bos taurus	British Park cattle	4
	West Highland cattle	1
Callosciurus sp	Southern Asiatic squirrel	2
Capra hircus	Domestic goat	2
Cercopithecus cephus	Mustached monkey	1
Cercopithecus neglectus	DeBrazza's guenon	1
Cervus canadensis	American elk	2
Cervus elaphus	Red deer	1
Cervus nippon	Sika deer	1
Choeropis liberiensis	Pygmy hippo	1
Choloepus didactylus	Two-toed sloth	1
Dama dama	Brown fallow deer	3
	White fallow deer	2

MAMMALS—Continued

Scientific name	Common name	Number
Dasyprocta punctata	Speckled agouti	3
Felis concolor	Puma	1
Felis leo	Lion	3
Felis pardus	Black leopard	1
Giraffa camelopardalis	Giraffe	1
Hippopotamus amphibius	Hippopotamus	1
Hydropotes inermis	Chinese water deer	1
Hylobates agilis x *H. lar pileatus*	Hybrid gibbon	1
Hystrix galeata	African porcupine	3
Lama glama	Llama	4
Lama pacos	Alpaca	2
Leontocebus rosalia	Golden marmoset	2
Macaca mulatta	Rhesus monkey	1
Macaca sylvanus	Barbary ape	3
Odocoileus virginianus	Virginia deer	2
Odocoileus virginianus costaricensis	Costa Rican deer	3
Ovis musimon	Mouflon	1
Pan satyrus	Chimpanzee	1
Phloeomys cumingii	Slender-tailed cloud rat	2
Thalarctos maritimus x *Ursus middendorffi.*	Hybrid bear (second generation)	4
Ursus horribilis	Grizzly bear	2

BIRDS

Scientific name	Common name	Number
Anas platyrhynchos	Mallard duck	13
Branta canadensis	Canada goose	6
Chauna torquata	Crested screamer	3
Melopsittacus undulatus	Grass parakeet	8
Nycticorax nycticorax hoactli	Black-crowned night heron	13

REPTILES

Scientific name	Common name	Number
Ancistrodon piscivorus	Water moccasin	4
Boaedon lineatum	African house snake, or musaga	7
Chamaeleon dilepis	Flap-necked chameleon	6
Chamaeleon jacksoni	Three-horned chameleon	16
Chrysemys picta	Painted turtle	7
Diadophis punctatus edwardsi	Ring-necked snake	6
Drymarchon corais couperi	Indigo snake	1
Elaphe obsoleta obsoleta	Pilot black snake	10
Epicrates cenchria	Rainbow boa	8
Eumeces fasciatus	Five-lined skink	6
Naja haje	Egyptian cobra	1
Natrix cyclopion	Green water snake	16
Natrix erythrogaster	Red-bellied water snake	10
Natrix sipedon	Water snake	29
Storeria dekayi	DeKay's snake	5

FIFTIETH ANNIVERSARY

A Siberian crane (*Grus leucogeranus*) gave its hornlike calls and high-stepping dance, with appropriate wing movements, on June 26,

1956, the 50th anniversary of its arrival in the National Zoological Park as a full-grown bird. This is a noteworthy longevity record, and apparently the bird is in such condition that it should live considerably longer.

RESEARCH

The National Zoological Park has no general research program, as such. However, the successful keeping of any animal involves more or less specific research. If the habits and requirements of a species in captivity are not well known, they must be ascertained through research, which may have to be carried out with all possible speed if a newly received animal is to survive. The problems involved may concern any or all of the following: Temperament of the animal; its need for exercise and for companionship; diseases and external and internal parasites to which it is subject; food preferences; housing, temperature, ventilation, and bedding.

If it is known in advance that a new animal is to be received, information is sought from every possible source regarding its probable requirements. Upon its arrival its age and physical condition are noted, and any tentative plans for its care are modified or elaborated as circumstances dictate. External injuries, if any, are treated, and efforts are made to rid the animal of external parasites. Internal parasites are watched for, and treatment to eliminate them is undertaken. Observations on the animal are continued and changes are made in its environment if necessary. If it refuses to eat, new foods are offered and its preferences are noted.

The relatively low mortality rate among newly received animals and the general good health of those in the collection attest the success of the research that is carried on.

In addition to the problems concerned directly with the animals, there are many others that involve research. One relates to the types of construction materials most suitable for the housing and exhibition of the animals and most economical to maintain. This calls for constant study of various types of flooring, bars, wire fabrics, cage partitions, doors, locks, and numerous other materials. Much research has also been done on paints, and over a period of more than 25 years the Zoo has tried many different kinds and has generally been among the first to make use of new paints when they are suitable.

Another problem concerns the acquisition of ornamental plants and shrubs for the Park. Some that might be entirely suitable from an esthetic standpoint cannot be utilized for reasons peculiar to the Zoo.

Incidental research carried on by Ernest P. Walker, Assistant Director, mainly in his home and on his own time, has concerned the care of small animals about which little is known and which in many cases had not been kept successfully in captivity. Outstanding among

these were several different kinds of bats, African elephant shrews, and North American shrews. His success he attributes largely to the food formula[1] he developed, which is relished not only by these animals, but by many others.

Army medical research workers interested in the raising of tree shrews because of their possible value as laboratory animals have been impressed by Mr. Walker's success with the other types of shrews and have brought tree shrews to the Zoo. Given this food, the shrews thrived on it and produced four litters of young. Indeed, the results were so promising that the food has been canned in small quantities by the National Canners Association, and two lots of it have been shipped to Malay and Borneo by the Army medical workers. Also, a small amount was recently taken to Mexico by Mr. Walker and turned over to the Pan American Sanitary Bureau, which requested this material for feeding bats they are studying in connection with research work on rabies.

Information supplied in response to the many requests received by mail, telephone, and from visitors is based on research by this Zoo, or has been assembled from various sources, and in many instances serves to facilitate scientific investigations that are being carried on by other Federal or State institutions. Occasionally animals are deposited with the Zoo by research institutions until they are needed for experimental purposes. Here they are cared for and are available to the depositors when desired. The facilities thus provided contribute indirectly to the research work of other organizations.

VETERINARIAN

For the first time since 1942 the National Zoological Park has a veterinarian—Dr. Theodore H. Reed, appointed July 15, 1955. The work of the veterinarian is threefold: to establish such a sound disease-preventive program through nutrition, sanitation, parasite control,

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[1] Ingredients: Yolk of 1 hard-boiled egg; approximately an equal amount of rather dry cottage cheese; approximately an equal amount of ripe banana; approximately an equal amount of mealworms; 6 drops of Jeculin; 6 drops of wheat-germ oil; 3 grains of Theragram.

Mix with a mortar and pestle. If the wheat-germ oil is in 3-minim capsules, put in two; also add the Theragram, which is a yellowish paste. Add a few drops of water to soften the gelatin of the wheat-germ oil capsules and to dissolve the Theragram. Then put the other ingredients in and grind all together with the pestle until a paste is formed with the chitin of the worms scattered through it.

The mealworms (*Tenebrio molitor*) are the same or similar to those that get into cereals. Cultures of them can be maintained in bran or cornmeal with the addition of banana peelings, slices of raw potato, and occasionally light sprinklings of water to moisten the bran or cornmeal very slightly but not enough to cause it to form lumps or to mildew.

laboratory examination, and environmental changes that the need for treatment and surgery is reduced to a minimum; to treat diseased and injured animals as necessary; and to carry on research looking toward better remedies and better health for the animals in captivity.

Changes in and additions to more than 92 of the diets have been made, and benefits are beginning to be evident. Two second-generation hybrid bear cubs now 6 months old were raised on synthetic bitches' milk and are developing normally. The two young gorillas continue to thrive. Nikumba, the male, weighed 17 pounds on arrival at 15 months of age, and Moka, the female, weighed 20 pounds. Their combined weight is now 100 pounds, the male being the heavier. Dr. Joseph Watson, a private physician, is consultant pediatrician for both the gorillas and orangutans.

A systematic parasite survey has been started, and treatment is given where necessary. The new anthelmintic piprizine sulfate has been used for roundworms with good results. It has the advantage of being highly effective, relatively palatable and nontoxic. A satisfactory method of treating reptiles for internal parasites is being sought, and results so far are promising.

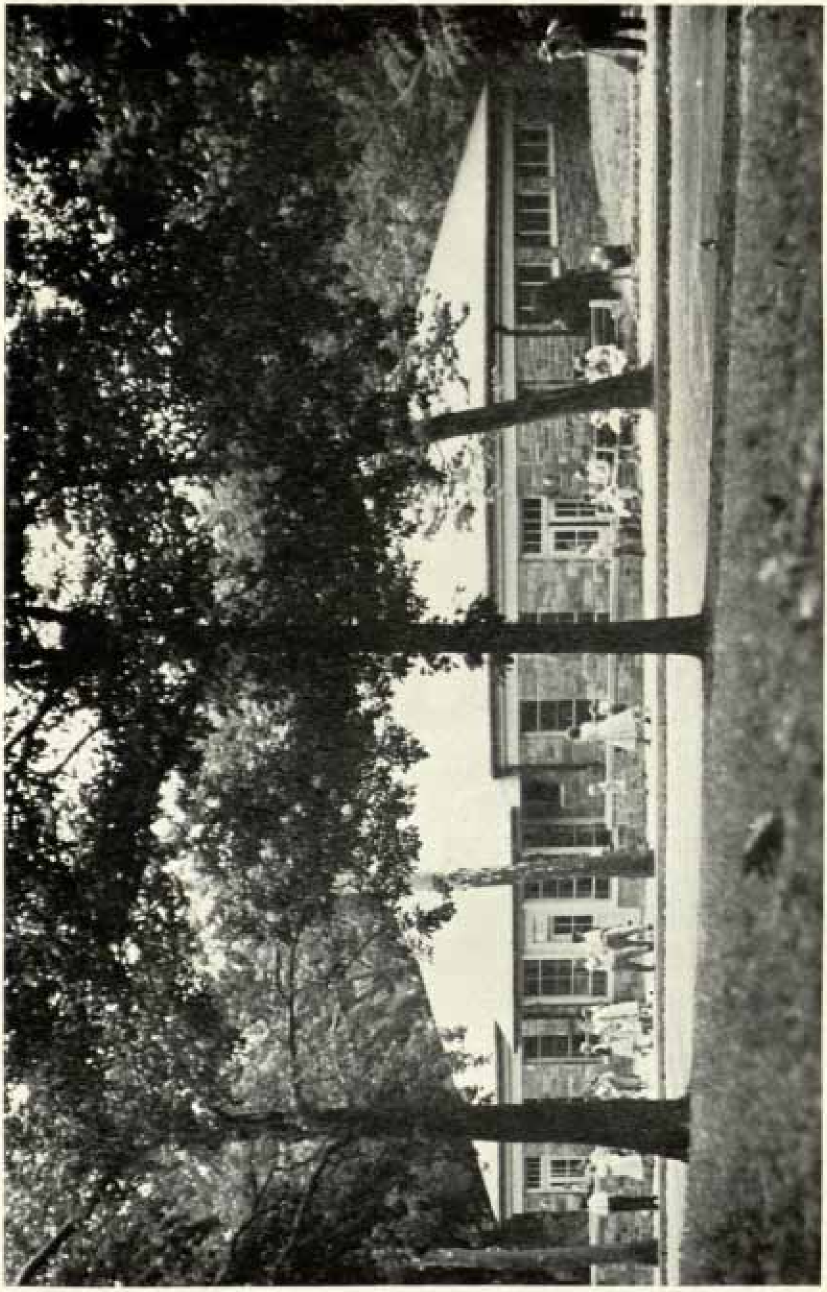
During the year 20 minor surgical cases were treated. The three major operations were the removal of a fibroma between the two lower canine teeth of a 19-year-old Bengal tiger, the reduction of an umbilical hernia on a young male chimpanzee, and the removal of a large mass (½ pint) of tapeworm cysts from the hind leg of a De Brazza's guenon. Lt. R. M. McCully, United States Air Force (Veterinarian Corps), was the chief surgeon. Two unusual surgical procedures were the removal of a marble-sized tumor from an African lungfish and the extraction of an impacted tooth from an 18-foot anaconda.

Treatment of infectious conditions has been as successful as could be expected considering the difficulty in handling some of the patients. In all, 119 mammals, 17 reptiles, and 25 birds were under treatment.

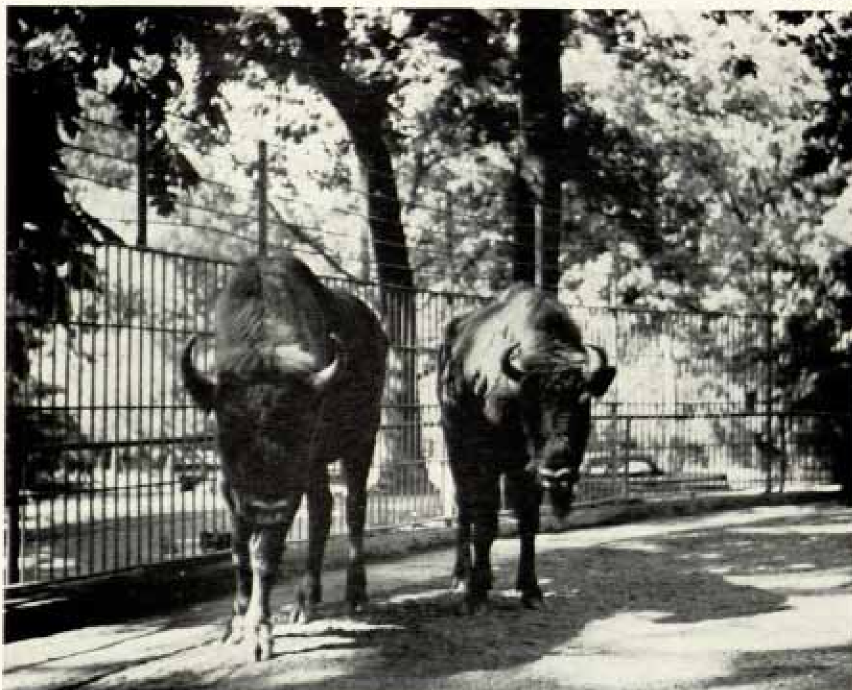
Every death that occurs at the Zoo is listed. When an animal dies every effort is made to determine the cause of death, and to profit from the findings.

The three emperor penguins received May 1, 1956, arrived infected with aspergillosis. Treatment with Mycostatin (Squibb) and Alivar (Winthrop) by inhalation with a DeVilbis nebulizer was immediately started. One penguin died within 12 hours; the other two survived 5 days. The pathological reports on the two that died last showed that the mold was not sporulating, indicating that an early treatment against the disease would have been effective had there been opportunity.

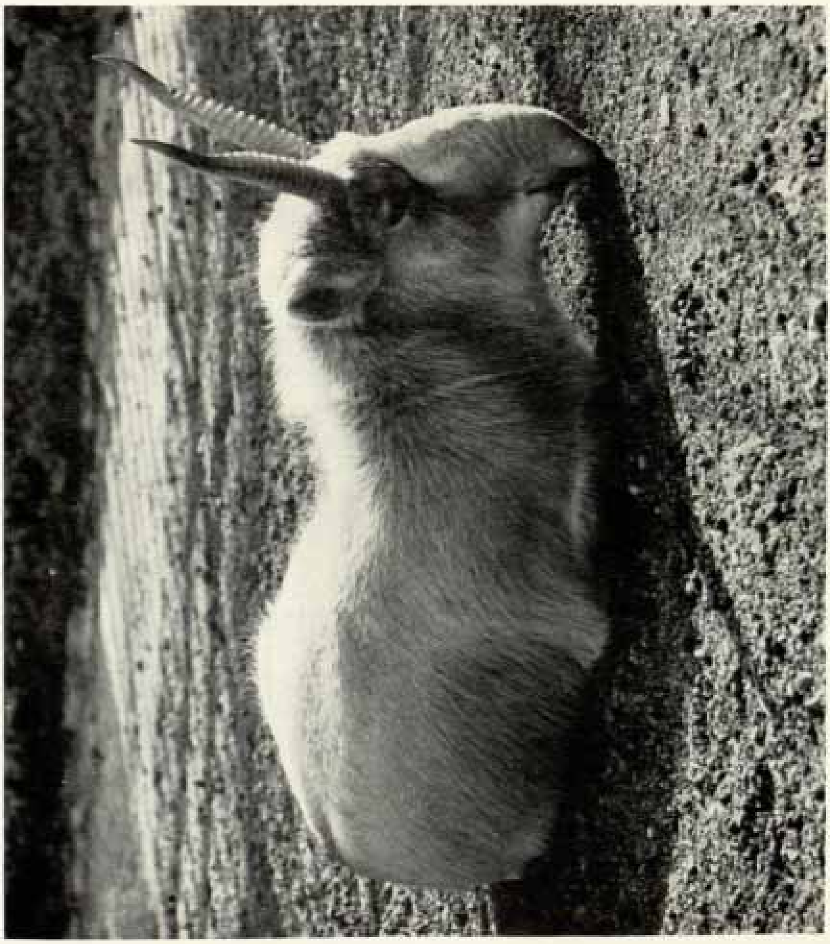
Assistance in post-mortem procedures and all histopathologic examinations were given by Drs. Eyestone and Lombard, National In-



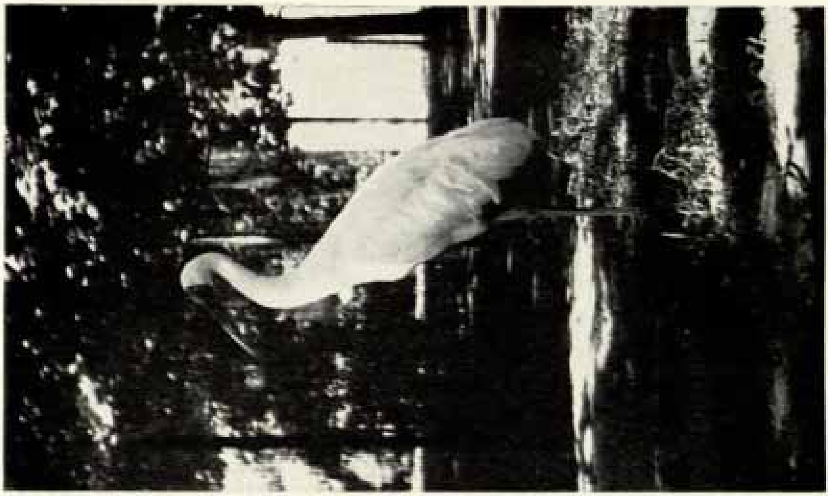
New building at National Zoological Park, opened March 15, 1956, which houses the police headquarters, women's and men's restrooms, and, in the basement, storage space and the gardener's office. Photograph by Ernest P. Walker.



Wisent, or European bison (*Bison bonasus*). These are the first of these animals to be exhibited in the National Zoological Park. Wisents are extinct in the wild and there are only a few in captivity. This picture shows the high, narrow form characteristic of the animal. They are much less massive than the American bison. The photograph suggests slightly more of a hump than these animals possess.



1. Male saiga antelope (*Saiga tatarica*) in National Zoological Park.
Photograph by Ernest P. Walker.



2. Siberian crane (*Grus leucogeranus*) still living in the Zoo after more than 50 years.

1. Dwarf armadillo (*Burmeisteria retusa*), the first that has been exhibited in the National Zoological Park. It slept through a prolonged photographing session. Such extremely sound sleep is characteristic of some of the burrowing animals. The very large digging claws of the front foot are well shown. The Spanish name "tapafrasco" for these animals means bottle cap, in allusion to the hard plate that covers the rear of the animal.

2. Young olingo (*Bassaricyon* sp.), the first exhibited in the National Zoological Park.
Photographs by Ernest P. Walker.

stitutes of Health, and the veterinary section of the Armed Forces Institute of Pathology.

IMPROVEMENTS AND MAINTENANCE

The new building containing restrooms, headquarters for the police, and office and storage space for the gardener, which was opened to the public March 15, 1956, was designed by the Department of Buildings and Grounds of the Government of the District of Columbia in accordance with provisions of law. The $197,000 appropriated for the structure was carried in the District of Columbia Public Works Appropriation for 1955. With the small unexpended balance of the appropriation a driveway and a loading platform at the storeroom in the basement of the building are to be constructed.

The routine work of maintenance and construction, which is carried on practically every day of the year, consists of such varied tasks as the removal of stoppages from drains and sewers, repairs of faucets, doors, cages, water lines, steam lines, boilers, refrigeration equipment, buildings, roads, and walks, and innumerable miscellaneous jobs necessary to keep the National Zoological Park in a safe and presentable condition. The need for the exercise of great care in working around animals requires that practically all this kind of work be done by the Zoo's own specially trained workmen, who must not only perform mechanical work but also cooperate with the keeper force so that nothing is done that will injure the animals, the public, or themselves.

All designing, construction, repair, and maintenance work done in the Park during the year were performed by the Zoo's mechanical department; but because of inadequate funds this work was limited to that most urgently needed. It has been impossible to keep pace with the deterioration of the old structures that require extensive repairs, and some of them have had to be abandoned. The mechanical shops designed and built new metal skylights for several animal houses. Extensive repairs were necessary to some of the stone buildings constructed during WPA days about 20 years ago.

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

The job of cleaning up the grounds is a major undertaking. Using all available manpower, it usually takes 5 to 10 days to pick up the trash and restore the park to a fair degree of presentability after Easter Sunday and Monday. This work has of necessity been reduced to a minimum. The lawns, shrubs, and trees cannot be kept in as

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attractive condition as they might be because of lack of maintenance funds. However, curtailment of this work results in less harm than does the neglect of structures and fences.

From time to time during the year earth has been received for the fill across the road from the large-mammal house. After the fill is completed a sidewalk will be laid on that side of the road, providing a greater measure of safety for the public. Until the fill settles, the area will be used for a car-parking site, and later paddocks will be placed on it.

The accessibility of the police headquarters in the new building has so greatly increased the demands upon the police for first aid, information, and general assistance that it has been necessary to take two men off patrol to maintain the service in the office. This leaves the regular patrol force shorthanded, even with the temporary part-time policemen that have been employed.

In addition to routine maintenance considerable reconstruction, as well as new construction, is necessary to meet the requirements of animals or changed conditions. For example, with the prospect of obtaining more penguins from the Navy Antarctic Expedition, extensive work was done on the penguin room with a view to filtering the air to remove practically all air-borne germs and spores, maintaining slightly lower temperatures, providing chilled water for the swimming pool and for hosing down the cage. As the cooling system has been in use for 20 years and it is uncertain how much longer it will continue to function, an additional cooling unit for the cage was installed. This will be used when the old system fails or must be repaired.

The two young gorillas that were given the Zoo by Russell Arundel in 1955 have outgrown two cages, and a third had to be built. This involved not only building a new wall in the great apes room in the small-mammal house, but the construction of a retirement cage and the laying of a new floor. Also, a new thermostat was installed to provide better control of the temperature in this room for the gorillas.

With the appointment of a veterinarian it became necessary to provide an office for him and a hospital for the animals. An old stone building is being adapted for the purpose and a beginning made to equip it for surgery, treatment, and laboratory work. This has required installation of a new heating plant, remodeling of cages, and painting the inside of the building.

VISITORS

Attendance at the Zoo this year reached a total of 3,788,229, an all-time high record. In general this figure is based on estimated rather than on actual counts, but the following actual counts made by members of the police force on certain days are of interest: Reptile house,

Sunday, September 4, 1955, 11,813 persons; the next day, Labor Day, 9,661 at the same building; small-mammal house, Sunday, April 29, 1956, 9,517 visitors. On Sunday, June 3, 1956, a check of cars entering the Connecticut Avenue gate in 1 hour recorded 200 cars with 669 passengers.

Estimated number of visitors for fiscal year 1956

July (1955)	547, 500	February	180, 950
August	460, 300	March	199, 585
September	388, 720	April	470, 274
October	344, 000	May	435, 300
November	188, 700	June	364, 000
December	81, 550		
January (1956)	127, 350	Total	3, 788, 229

Groups came to the Zoo from schools in Formosa and 32 States, some as far away as Alabama, California, Florida, and Maine.

Number of groups from schools

Locality	Number of groups	Number in groups	Locality	Number of groups	Number in groups
Alabama	19	1, 279	Minnesota	5	173
Arkansas	1	28	Mississippi	4	205
Colorado	1	14	New Hampshire	1	46
Connecticut	10	704	New Jersey	19	1, 380
Delaware	7	226	New York	101	6, 589
District of Columbia	141	8, 049	North Carolina	186	11, 123
Florida	13	1, 789	Ohio	38	1, 965
Georgia	48	10, 437	Pennsylvania	236	11, 964
Illinois	5	172	South Carolina	73	2, 202
Indiana	8	540	South Dakota	1	32
Kansas	1	38	Tennessee	61	2, 973
Kentucky	11	606	Vermont	1	24
Louisiana	3	124	Virginia	562	32, 956
Maine	16	686	West Virginia	29	2, 833
Maryland	543	33, 431	Wisconsin	3	294
Massachusetts	11	657			
Michigan	8	631	Total	2, 168	134, 479

About 2 p. m. each day the cars then parked in the Zoo are counted 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 District of Columbia, Maryland, and Virginia cars come to the Zoo to bring guests from other States. The tabulation for the fiscal year 1955 is as follows:

	Percent		Percent
Maryland	28. 1	Ohio	1. 3
Virginia	22. 7	West Virginia	1. 0
District of Columbia	22. 4	Massachusetts	0. 9
Pennsylvania	6. 9	Florida	0. 9
New York	2. 9	California	0. 8
North Carolina	2. 6		
New Jersey	1. 4		91. 9

The remaining 8.1 percent came from Alaska, Austria, British Columbia, Canada, Canal Zone, Costa Rica, England, France, Germany, Hawaii, Italy, Japan, Mexico, Newfoundland, Philippine Islands, and Puerto Rico.

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

Parking spaces in the Zoo now accommodate 1,079 cars when the bus parking place is utilized, and 969 cars when it is not used.

COOPERATION

At all times special efforts are made to maintain friendly contacts with other Government and State agencies, private concerns and individuals, and scientific workers for mutual assistance. As a result the Zoo receives much help and advice and many valuable specimens, and in turn it furnishes information and, whenever possible, specimens it does not need.

Special acknowledgment is due the United States Dispatch Agent in New York City, Howard Fyfe, an officer of the State Department, who has frequently been called upon to clear shipments of animals coming from abroad. This he has done, often at great personal inconvenience, and the animals have been forwarded to Washington without the loss of a single specimen.

U. S. Marshal Carlton G. Beall turned over to the Zoo 50 bags of rice and 200 pounds of poultry that had been condemned by the court. The National Institutes of Health, the Army Medical Center, the Navy Medical Center, and the Nutritional Laboratory of the Department of Agriculture gave the Zoo mice, rats, guinea pigs, rabbits, and other animals no longer suitable for their purposes. These are valuable foods for many animals. The poultry division of the Department of Agriculture gave a considerable number of day-old chicks that were hatched in connection with certain of its experiments. These are a highly desirable addition to the diet of many animals. The Fish and Wildlife Service also gave some young chicks.

Dr. John C. Pearson, of the Fish and Wildlife Service's aquarium, in the Commerce Building, has traded specimens and given much valuable assistance and advice.

Samuel M. Poiley, associate chief of the animal production section, National Institutes of Health, continued to supply surplus laboratory animals, some of which were desirable additions to the exhibition collection.

C. W. Phillips and P. R. Achenbach of the National Bureau of Standards and R. W. Seiders of the General Services Administration gave the Zoo valuable advice in connection with many of the problems incidental to improving conditions in the penguin cage.

The National Institutes of Health, the Armed Forces Institute of Pathology, the Johns Hopkins Medical School, and the Neurophysiology section of Walter Reed Medical School have given valuable assistance and advice in the treatment and handling of animals. The zoological division of the U. S. Department of Agriculture Research Center, Beltsville, Md., continued to identify parasites found on the animals.

Dr. Charles G. Curbin, associate veterinarian, medical division, bureau of medicine, Food and Drug Administration, has supplied the Zoo with surplus medicines, and the following commercial firms have been extremely kind in furnishing drugs for use and for clinical trials:

Lederle Laboratories.
Schenley Laboratory, Inc. (pharmaceutical division).
E. R. Squibb & Sons.
UpJohn Co.
Wyeth Laboratories.

The DeVilbiss Co. lent equipment for experimental purposes.

At the request of the Pan American Sanitary Bureau, a branch of the World Health Organization, Ernest P. Walker, Assistant Director of the Zoo, went to Mexico to photograph bats. Mr. Walker has specialized in the photographing of mammals and has taken many pictures of bats, both flying and at rest. Certain species in Central and South America have been found to be involved in the spread of rabies. There have been no satisfactory photographs or drawings that could be used by public health workers and others to determine and demonstrate the kind of bats that they might be studying or discussing. Therefore, they desired photographs that could be used in this work. Mr. Walker left Washington October 31 and returned December 22.

NEEDS OF THE ZOO

Because of the natural deterioration of structures and equipment, and rising costs, the need for more funds for maintenance, repair, and improvements becomes more critical every year. The newest of the exhibition buildings are 19 years old, the reptile house is 25 years old, and the bird house is 28 years old. These and the buildings and other structures that were erected during the depression days now require a constantly increasing amount of repairs. It has recently been necessary to abandon 10 enclosures that have deteriorated to such an extent that they can no longer be repaired. Large areas of the grounds have had to be neglected entirely, or given scant care, in order that

the meager funds available may be used to maintain the areas most used by the public.

Additional funds are most urgently needed for personnel, maintenance, installations, and the following construction:

Buildings:

A new administration building to replace the 151-year-old historic landmark that is still in use as an office building but that is neither suitably located nor well adapted for the purpose.

A building to house antelopes and other hoofed animals that require a heated building.

A fireproof service building for receiving animals shipped in, quarantining them, and caring for those in ill health or those that cannot be placed on exhibition.

Enclosures:

Enclosures and pools for beavers, otters, seals, and nutrias, which cannot be adequately cared for or exhibited under existing conditions.

New paddocks for the exhibition of such animals as deer, sheep, goats, and other hoofed animals, to provide for the exhibition of a greater assortment of these attractive and valuable animals.

Installations:

A new ventilation system for the bird house.

A vacuum pump to provide more efficient and economical operation of the heating system in the reptile house.

An air compressor for general use about the park, particularly for freeing sewers of stoppages, operating air hammers, blowing out boiler tubes, and for use in excavation and construction work.

Additional parking space to be developed on about 14,000 square yards of land in several different locations, mainly near the creek.

An additional coal bunker for storage of a reserve supply of coal.

Personnel and maintenance:

1 assistant director. 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.

1 general mechanic to assist the maintenance personnel in what has hitherto been a losing race in trying to keep pace with natural deterioration in the structures.

6 laborers for the mechanical force to replace 6 who were reallocated by the Wage Board to the position of truck drivers, thus cutting the laborer force from 13 to 7—a number way below the minimum

necessary to carry on even the most urgently needed work that must be done in the Zoo every day in the year.

1 gardener (foreman) and 1 laborer for the gardener's crew for proper maintenance of the grounds, removal of dead or fallen tree limbs and other safety hazards.

2 attendants for the public restrooms to maintain these rooms in a clean and sanitary condition and to prevent vandalism.

2 policemen to serve as station clerks in the new police headquarters.

3 property and supply clerks to comply with the requirements of keeping property and inventory records, in accordance with the program laid down by the General Services Administration.

ANIMALS IN THE COLLECTION ON JUNE 30, 1956

MAMMALS

Scientific name	*Common name*	*Number*
MONOTREMATA		
Tachyglossidae:		
Tachyglossus aculeatus	Echidna, or spiny anteater	2
MARSUPIALIA		
Didelphiidae:		
Caluromys philander	Woolly opossum	2
Phalangeridae:		
Petaurus norfolcensis	Lesser flying phalanger	3
Trichosurus vulpecula	Vulpine opossum	1
Phascolomyidae:		
Lasiorhinus latifrons	Hairy-nosed wombat	3
Vombatus hirsutus	Mainland wombat	1
Macropodidae:		
Dendrolagus inustus	Tree kangaroo	1
Hypsiprymnodon moschatus	Rat kangaroo	5
Macropus giganteus	Gray kangaroo	3
Macropus rufus	Red kangaroo	1
Protemnodon agilis	Wallaby	1
Protemnodon bicolor	Swamp wallaby	2
Protemnodon dorsalis	Black-striped wallaby	1
INSECTIVORA		
Erinaceidae:		
Erinaceus europaeus	European hedgehog	1
PRIMATES		
Lemuridae:		
Galago crassicaudatus	Galago	4
Galago senegalensis	African galago	2
Lemur macaco	Acoumba lemur	2
Lemur mongoz	Mongoz lemur	1
Lorisidae:		
Nycticebus coucang	Slow loris	3
Perodicticus potto	Potto	1

Scientific name	*Common name*	*Number*
Cebidae:		
Ateles fuscicep robustus	Colombian black spider monkey	1
Ateles geoffroyi geoffroyi or *griscesens*	Spider monkey	1
Ateles geoffroyi vellerosus	Spider monkey	1
Aotus trivirgatus	Night monkey	5
Cacajao rubicundus	Red ukari	1
Callimico goeldii	Goeldi's marmoset	1
Cebus albifrons	Brown capuchin monkey	6
Cebus capucinus	White-throated capuchin monkey	3
Cebus fatuellus	Capuchin monkey	4
Lagothrix lagotricha	Woolly monkey	3
Saimiri sciureus	Squirrel monkey	8
Callithricidae:		
Callithrix geoffroyi	Geoffroy's marmoset	1
Callithrix penicillata	Black-tufted marmoset	1
Cebuella pygmaea	Pigmy marmoset	2
Leontocebus rosalia	Golden marmoset	5
Marikina nigricollis	Black and red marmoset	1
Cercopithecidae:		
Allenopithecus nigroviridis	Allen's monkey	3
Cercocebus albigena	Gray-cheeked mangabey	1
Cercocebus aterrimus	Black-crested mangabey	4
Cercocebus aterrimus opdenboschii	Crested mangabey	1
Cercocebus chrysogaster	Golden-bellied mangabey	1
Cercocebus fuliginosus	Sooty mangabey	4
Cercocebus galeritus agilis	Agile mangabey	1
Cercocebus torquatus	Red-crowned mangabey	2
Cercopithecus aethiops pygerythrus	Vervet guenon	2
Cercopithecus aethiops sabaeus	Green guenon	6
Cercopithecus aethiops sabaeus × *C. a. pygerythrus.*	Hybrid, green guenon × vervet guenon.	2
Cercopithecus cephus	Mustached monkey	4
Cercopithecus diana	Diana monkey	3
Cercopithecus diana roloway	Roloway monkey	1
Cercopithecus neglectus	De Brazza's guenon	3
Cercopithecus nictitans	White-nosed guenon	1
Cercopithecus nictitans petaurista	Lesser white-nosed guenon	1
Cercopithecus preussi	Preussi's guenon	1
Colobus polykomos	White-tailed colobus	1
Comopithecus hamadryas	Hamadryas baboon	2
Macaca irus mordax	Javan macaque	2
Macaca maurus	Moor macaque	1
Macaca mulatta	Rhesus monkey	14
Macaca nemestrina	Pig-tailed monkey	2
Macaca philippinensis	Philippine macaque	2
Macaca sinica	Toque or bonnet monkey	1
Macaca speciosa	Red-faced macaque	1
Macaca sylvanus	Barbary ape	12
Mandrillus sphinx	Mandrill	2
Papio comatus	Chacma baboon	1
Papio cynocephalus	Golden baboon	2
Presbytis phayrei	Spectacled langur	1
Theropithecus gelada	Gelada baboon	2

Scientific name	*Common name*	*Number*
Pongidae:		
Gorilla gorilla	Gorilla	2
Hylobates agilis × *H. lar pileatus*	Hybrid gibbon	1
Hylobates hoolock	Hoolock	1
Hylobates lar	White-handed gibbon	5
Hylobates moloch	Wau-wau gibbon	1
Pan satyrus	Chimpanzee	14
Pongo pygmaeus abelii	Bornean orangutan	1
Pongo pygmaeus pygmaeus	Sumatran orangutan	2
ENDENTATA		
Myrmecophagidae:		
Myrmecophaga tridactyla	Giant anteater	1
Tamandua tetradactyla	Tamandua	2
Bradypodidae:		
Choloepus didactylus	Two-toed sloth	4
Dasypodidae:		
Burmeisteria retusa	Tapafrasco, or dwarf armadillo	1
Chaetophractus villosus	Hairy armadillo	1
LAGOMORPHA		
Leporidae:		
Oryctolagus cuniculus	Domestic rabbit	10
Sylvilagus floridana	Cottontail rabbit	1
RODENTIA		
Sciuridae:		
Callosciurus sp	Southern Asiatic squirrel	1
Callosciurus caniceps	Golden-backed squirrel	2
Callosciurus erythraeus	Pallas's squirrel	1
Callosciurus nigrovittatus	Southern Asiatic squirrel	6
Citellus undulatus kennicottii	Arctic ground squirrel	2
Cynomys ludovicianus	Prairie dog	20
Glaucomys volans volans	Eastern flying squirrel	10
Menetes berdmorei	Berdmore's squirrel	1
Ratufa indica	Giant Indian squirrel	1
Sciurus niger	Fox squirrel	1
Tamias striatus	Eastern chipmunk	1
Heteromyidae:		
Perognathus parvus olivaceus	Pocket mouse	1
Castoridae:		
Castor canadensis	Beaver	1
Cricetidae:		
Mesocricetus auratus	Hamster	6
Muridae:		
Acomys caharinus	Egyptian spiny mouse	10
Aethomys kaiseri	Rock rat	1
Arvicanthus niloticus	Kusu rat	1
Cricetomys gambianus	Giant pouched rat	4
Meriones unguiculatus	Mongolian gerbil	3
Phloeomys cumingii	Slender-tailed cloud rat	1
Rattus infraluteus	Kinabalu tree rat	1
Rattus sabanus	Large spiny-backed tree rat	1

Scientific name	*Common name*	*Number*
Gliridae:		
Graphiurus murinus	Dormouse	1
Hystricidae:		
Acanthion brachyurum	Malay porcupine	1
Hystrix galeata	African porcupine	5
Caviidae:		
Cavia porcellus	Guinea-pig	8
Hydrochoeridae:		
Hydrochoerus hydrochoeris	Capybara	4
Dasyproctidae:		
Cuniculus paca	Paca	5
Dasyprocta	Agouti	13
Dasyprocta punctata	Speckled agouti	6
Dinomys branickii	Branick's paca	2
Chinchillidae:		
Chinchilla chinchilla	Chinchilla	2
Lagidium viscaccia	Peruvian viscaccia	1
Capromyidae:		
Myocastor coypus	Coypu	2
CARNIVORA		
Canidae:		
Canis antarcticus	Dingo	1
Canis lupus nubilus	Wolf	4
Canis mesomelas	Black-backed jackal	1
Canis niger rufus	Red wolf	1
Fennecus zerda	Fennec fox	2
Lycaon pictus	African hunting dog	2
Nyctereutes procyonoides	Raccoon dog	6
Otocyon megalotis	Big-eared fox	4
Speothos venaticus	Bush dog	2
Urocyon cinereoargenteus	Gray fox	11
Vulpes fulva	Red fox	18
	Platinum fox	4
Ursidae:		
Euarctos americanus	Black bear	2
Helarctos malayanus	Malay sun bear	3
Selenarctos thibetanus	Himalayan bear	2
Selenarctos thibetanus japonicus	Japanese black bear	1
Selenarctos thibetanus ussuricus	Korean bear	2
Thalarctos maritimus	Polar bear	1
Thalarctos maritimus × *Ursus middendorffi*.	Hybrid bear, first generation	4
	Hybrid bear, second generation	3
Tremarctos ornatus	Spectacled bear	1
Ursus sp	Alaskan brown bear	2
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	2
Ursus sitkensis	Sitka brown bear	3

Scientific name	*Common name*	*Number*
Procyonidae:		
Ailurus fulgens	Lesser panda	2
Bassaricyon gabbi	Olingo	1
Bassariscus astutus	Ringtail, or cacomistle	2
Nasua narica	Coatimundi	4
Nasua nasua	Red coatimundi	1
Potos flavus	Kinkajou	6
Procyon lotor	Raccoon	19
Mustelidae:		
Mustela eversmanni	Albino ferret	2
Mustela frenata noveboracensis	Weasel	3
Pteronura brasiliensis	Flat-tailed otter	2
Spilogale phenax	California spotted skunk	2
Taxidea taxus	Badger	1
Tayra barbara	Tayra	2
Cryptoproctidae:		
Cryptoprocta ferox	Fossa	1
Viverridae:		
Arctictis binturong	Binturong	1
Atilax paludinosus	Water civet	4
Civettictis civetta	African civet	1
Genetta genetta	Genet	2
Genetta genetta neumanii	Genet	2
Herpestes ichneumon	African mongoose	2
Ichneumia albicauda	White-tailed mongoose	2
Paguma larvata taivana	Formosan masked civet	1
Viverra tangalunga	Ground civet	1
Hyaenidae:		
Crocuta crocuta germinans	Spotted hyena	2
Hyaena hyaena	Striped hyena	2
Felidae:		
Acinonyx jubata	Cheetah	2
Felis chaus	Jungle cat	2
Felis concolor	Puma	10
Felis leo	Lion	9
Felis ocreata	Kaffer cat	2
Felis onca	Jaguar	3
Felis pajeros	Pampas cat	1
Felis pardalis	Ocelot	1
Felis pardus	African leopard	4
	Black leopard	2
Felis serval	Serval cat	1
Felis tigris	Bengal tiger	3
Felis wiedi	Margay cat	1
Lynx canadensis	Lynx	1
Lynx rufus	Bob cat	2
PINNIPEDIA		
Otariidae:		
Otaria flavescens	Patagonian sea-lion	2
Zalophus californianus	Sea-lion	2

Scientific name	*Common name*	*Number*
	TUBULIDENTATA	
Orycteropodidae:		
Orycteropus afer	Antbear, or aardvark	1
	PROBOSCIDEA	
Elephantidae:		
Elephas maximus	Indian elephant	2
	PERISSODACTYLA	
Equidae:		
Equus asinus	Burro, or donkey	1
Equus burchelli antiquorum	Chapman's zebra	1
Equus burchelli boehmi	Grant's zebra	3
Equus grevy	Grevy's zebra	3
Equus kiang	Asiatic wild ass, or kiang	1
Equus onager	Onager	1
Equus przewalskii	Mongolian wild horse	2
Tapiridae:		
Acrocodia indica	Indian tapir	2
Tapirus terrestris	Brazilian tapir	2
Rhinocerotidae:		
Diceros bicornis	African rhinoceros	2
Rhinoceros unicornis	Great Indian one-horned rhinoceros.	1
	ARTIODACTYLA	
Suidae:		
Sus scrofa	European wild boar	1
Tayassuidae:		
Pecari tajacu angulatus	Collared peccary	2
Hippopotamidae:		
Choeropsis liberiensis	Pygmy hippo	6
Hippopotamus amphibius	Hippopotamus	3
Camelidae:		
Camelus bactrianus	Bactrian camel	2
Camelus dromedarius	Single-humped camel	1
Lama glama	Llama	8
Lama glama guanico	Guanaco	4
Lama pacos	Alpaca	4
Vicugna vicugna	Vicuña	1
Cervidae:		
Axis axis	Axis deer	5
Cervus canadensis	American elk	6
Cervus elaphus	Red deer	4
Cervus nippon	Sika deer	8
Cervus nippon manchuricus	Dybowsky's deer	2
Dama dama	Brown fallow deer	19
	White fallow deer	11
Elaphurus davidianus	Père David's deer	2
Hydropotes inermis	Chinese water deer	4
Muntiacus muntjak	Rib-faced deer	2
Odocoileus virginianus	Virginia deer	14
Odocoileus virginianus costaricensis	Costa Rican deer	5

Scientific name	Common name	Number
Giraffidae:		
Giraffa camelopardalis	Nubian giraffe	5
Giraffa camelopardalis reticulata	Reticulated giraffe	1
Antilocapridae:		
Antilocapra americana	Pronghorn antelope	1
Bovidae:		
Ammotragus lervia	Aoudad	18
Anoa depressicornis	Anoa	2
Bibos gaurus	Gaur	5
Bison bison	American bison	7
Bison bonasus	European bison, or wisent	2
Bos indicus	Zebu	2
Bos taurus	West Highland or Kyloe cattle	5
	British Park cattle	12
Bubalus bubalis	Water buffalo	1
Capra aegagrus cretensis	Cretian agrimi goat	1
Capra hircus	Domestic goat	12
Cephalophus nigrifrons	Black-fronted duiker	1
Hemitragus jemlahicus	Tahr	2
Ovis musimon	Mouflon	3
Poephagus grunniens	Yak	5
Pseudois nayaur	Blue sheep	1
Saiga tatarica	Saiga antelope	3
Syncerus caffer	African buffalo	3
Taurotragus oryx	Eland	2

BIRDS

SPHENISCIFORMES

Speniscidae:		
Aptenodytes patagonica	King penguin	4
Pygoscelis adeliae	Adelie penguin	1
Spheniscus humboldti	Humboldt's penguin	8

STRUTHIONIFORMES

Struthionidae:		
Struthio camelus	Ostrich	1

RHEIFORMES

Rheidae:		
Rhea americana	Rhea	2

CASUARIIFORMES

Casuariidae:		
Casuarius unappendiculatus unappendiculatus	One-wattled cassowary	1
Dromiceiidae:		
Dromiceius novaehollandiae	Emu	4

PELECANIFORMES

Pelecanidae:		
Pelecanus erythrorhynchus	White pelican	6
Pelecanus occidentalis occidentalis	Brown pelican	2
Pelecanus onocrotalus	Rose-colored pelican	3
Phalacrocoracidae:		
Phalacrocorax auritus albociliatus	Farallon cormorant	1

Scientific name	*Common name*	*Number*
	CICONIIFORMES	
Ardeidae:		
Florida caerulea	Blue heron	2
Leucophoyx thula	Snowy egret	3
Notophoyx novaehollandiae	White-faced heron	1
Nycticorax nycticorax hoactli	Black-crowned night heron	3
Tigrisoma lineatum	Tiger bittern	3
Balaenicipitidae:		
Balaeniceps rex	Shoebill	1
Cochleariidae:		
Cochlearius cochlearius	Boat-billed heron	2
Ciconiidae:		
Dissoura episcopus	Woolly-necked stork	1
Leptoptilus crumeniferus	Marabou stork	1
Leptoptilus javanicus	Lesser adjutant	2
Threskiornithidae:		
Ajaia ajaja	Roseate spoonbill	2
Eudocimus alba	White ibis	3
Eudocimus ruber	Scarlet ibis	3
Mycteria americana	Wood ibis	1
Plegadis autumnalis	Glossy ibis	2
Threskiornis melanocephala	Black-headed ibis	1
Phoenicopteridae:		
Phoenicopterus antiquorum	Old World flamingo	1
Phoenicopterus chilensis	Chilean flamingo	2
Phoenicopterus ruber	Cuban flamingo	1
	ANSERIFORMES	
Anhimidae:		
Chauna torquata	Crested screamer	5
Anatidae:		
Aix sponsa	Wood duck	7
Aix sponsa × *Aythya americana*	Hybrid, wood duck × red-headed duck.	2
Anas acuta	Pintail duck	4
Anas crecca carolinensis	Green-winged teal	3
Anas discors	Blue-winged teal	3
Anas platyrhynchos	Mallard duck	15
	Rouen duck	6
	White mallard duck	1
Anas platyrhynchos × *A. p. domestica*	Hybrid, mallard × Peking duck	24
Anas platyrhynchos domestica	Peking duck	50
Anas platyrhynchos × *A. acuta*	Hybrid, mallard duck × American pintail duck.	1
Anas poecilorhyncha	Indian spotted-bill duck	1
Anas rubripes	Black duck	1
Anser albifrons	White-fronted goose	2
Anser anser domesticus	Domestic Chinese goose	5
Anseranus semipalmata	Australian pied goose	1
Aythya americana	Red-headed duck	4
Aythya valisineria	Canvasback duck	3
Branta canadensis	Canada goose	44

Scientific name	*Common name*	*Number*
Anatidae—Continued		
Branta canadensis canadensis × *Chen caerulescens*	Hybrid, Canada goose × blue goose.	2
Branta canadensis minima	Cackling goose	14
Branta canadensis occidentalis	White-cheeked goose	29
Cairina moschata	Muscovy duck	12
Cereopsis novaehollandiae	Cape Barren goose	2
Chen atlantica	Snow goose	7
Chen caerulescens	Blue goose	3
Chen hyperborea	Lesser snow goose	2
Chen rossi	Ross's goose	4
Chenopis atrata	Black swan	3
Chloephaga leucoptera	Upland goose	2
Coscoroba coscoroba	Coscoroba	1
Cygnus columbianus	Whistling swan	4
Cygnus cygnus	Whooper swan	2
Cygnus olor	Mute swan	2
Dendrocygna autumnalis	Black-bellied tree duck	35
Dendronessa galericulata	Mandarin duck	2
Eulabeia indica	Indian bar-headed goose	6
Mareca americana	Baldpate	1
Netta rufina	Red-crested pochard	1
Nyroca affinis	Lesser scaup	1
Philacte canagica	Emperor goose	2
Plectropterus gambensis	Spur-winged goose	1
Sarkidiornis melanota	Comb duck	1
Somateria mollissima	Eider duck	1
Tadorna tadorna	European shell duck	1
FALCONIFORMES		
Cathartidae:		
Cathartes aura	Turkey vulture	4
Coragyps atratus	Black vulture	6
Gyps rueppelli	Rüppell's vulture	2
Pseudogyps africanus	Vulture	1
Sarcoramphus papa	King vulture	1
Sagittariidae:		
Sagittarius serpentarius	Secretarybird	2
Accipitridae:		
Buteo jamaicensis	Red-tailed hawk	7
Buteo lineatus	Red-shouldered hawk	1
Buteo poecilochrous	Buzzard eagle	1
Buteo swainsoni	Swainson's hawk	1
Haliaeetus leucocephalus	Bald eagle	10
Haliaeetus leucogaster	White-breasted sea eagle	1
Haliastur indus	Brahminy kite	1
Harpia harpyja	Harpy eagle	1
Milvago chimachima	Yellow-headed milvago	1
Milvago chimango	Chimango	2
Milvus migrans parasitus	African yellow-billed kite	2
Morphnus guianensis	Guianan crested eagle	1
Pandion haliaetus carolinensis	Osprey	6
Pithecophagus jefferyi	Monkey-eating eagle	1
Spizaetus ornatus	Manduit's hawk-eagle	2

Scientific name	*Common name*	*Number*
Falconidae:		
Falco mexicanus	Prairie falcon	1
Falco peregrinus anatum	Duck hawk	1
Falco sparverius	Sparrow hawk	2
Polyborus plancus	South America caracara	3
GALLIFORMES		
Megapodiidae:		
Alectura lathami	Brush turkey	1
Cracidae:		
Crax alberti	Blue-cered curassow	2
Crax panamensis	Panama curassow	1
Phasianidae:		
Alectornis graeca	Chukar quail	2
Argusianus argus	Argus pheasant	1
Chrysolophus amherstiae	Lady Amherst pheasant	3
Chrysolophus pictus	Golden pheasant	4
Colinus virginianus	Bobwhite quail	1
	Red bobwhite quail	1
Crossoptilon auritum	Blue-cered pheasant	1
Gallus gallus	Red jungle fowl	3
	Long-tailed fowl	2
	Fighting fowl	7
	Bantam chicken	26
	Silky bantam	1
	Silver-spangled Hamburg fowl	1
	Belgian bearded bantam	1
Gennaeus leucomelanus	Nepal pheasant	2
Hierophasis swinhoii	Swinhoe's pheasant	1
Lophortyx californica vallicola	California valley quail	1
Lophortyx gambelii	Gambel's quail	1
Pavo cristatus	Peafowl	8
Phasianus colchicus torquatus	Ring-necked pheasant	5
	White ring-necked pheasant	3
Pterocles orientalis	Sand grouse	2
Tetraogallus h. himalayensis	Snow cock	1
Numididae:		
Numida meleagris	White guinea fowl	3
Meleagrididae:		
Meleagris gallopavo	Domestic turkey	1
GRUIFORMES		
Gruidae:		
Anthropoides virgo	Demoiselle crane	1
Balearica pavonina	West African crowned crane	1
Balearica regulorum gibbericeps	East African crowned crane	1
Grus canadensis	Florida sandhill crane	1
Grus leucogeranus	Siberian crane	1
Psophiidae:		
Psophia crepitans	Gray-backed trumpeter	2

Scientific name	*Common name*	*Number*
Rallidae:		
Fulica americana	American coot	4
Gallinula chloropus cachinnans	Florida gallinule	4
Laterallus leucopyrrhus	Black-and-white crake	1
Porphyrio poliocephalus	South Pacific swamp hen	1
Rallus limicola limicola	Virginia rail	1
Eurypygidae:		
Europyga helias	Sun bittern	2
Cariamidae:		
Cariama cristata	Cariama, or seriama	2
Otididae:		
Chlamydotis undulata macqueenii	MacQueen's bustard	2
CHARADRIIFORMES		
Recurvirostridae:		
Himantopus mexicanus	Black-necked stilt	1
Burhinidae:		
Burhinus bistriatus	South American thick-knee	2
Haematopodidae:		
Haematopus ostralegus	Oystercatcher	2
Charadriidae:		
Belonopterus cayennensis	South American lapwing	2
Charadrius vociferus	Killdeer	1
Stercorariidae:		
Catharacta maccormicki	MacCormick's skua	5
Laridae:		
Larosterna inca	Inca tern	2
Larus atricilla	Laughing gull	1
Larus delawarensis	Ring-billed gull	2
Larus dominicanus	Kelp gull	2
Larus novaehollandiae	Silver gull	14
COLUMBIFORMES		
Columbidae:		
Columba livia	Domestic pigeon	3
Columba nigrirostris	Black-billed pigeon	1
Gallicolumba luzonica	Bleeding-heart dove	6
Geopelia cuneata	Diamond dove	3
Goura victoria	Crowned pigeon	2
Lophophaps ferruginea	Red-plumed pigeon	6
Streptopelia decaocto	Ring-necked dove	41
Streptopelia tranquebarica	Blue-headed ring dove	3
Zenaida asiatica	White-winged dove	2
Zenaidura macroura	Mourning dove	5
PSITTACIFORMES		
Psittacidae:		
Agapornis fischeri	Yellow-collared lovebird	3
Agapornis personata	Masked lovebird	5
Agapornis roseicollis	Rosy-faced lovebird	1
Amazona aestiva	Blue-fronted parrot	2
Amazona auropalliata	Yellow-naped parrot	3
Amazona finschi	Finsch's parrot	1

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Scientific name	*Common name*	*Number*
Psittacidae—Continued		
Amazona leucocephala	Cuban parrot	1
Amazona ochrocephala	Yellow-headed parrot	1
Amazona oratrix	Double yellow-headed parrot	4
Anodorhynchus hyacinthinus	Hyacinthine macaw	1
Ara ararauna	Yellow-and-blue macaw	4
Ara chloroptera	Red-and-blue macaw	3
Ara macao	Red-blue-and-yellow macaw	2
Aratinga canicularis	Petz's parakeet	1
Aratinga pertinax	Rusty-cheeked parrot	4
Callocepthalon fimbriatum	Gang-gang cockatoo	4
Calyptorhynchus magnificus	Banksian cockatoo	2
Domicella garrula	Red lory	1
Eclectus pectoralis	Eclectus parrot	1
Forpus cyanopygius	Little green parakeet	1
Kakatoe alba	White cockatoo	2
Kakatoe ducrops	Solomon Islands cockatoo	1
Kakatoe galerita	Sulphur-crested cockatoo	8
Kakatoe leadbeateri	Leadbeater's cockatoo	10
Kakatoe moluccensis	Great red-crested cockatoo	1
Kakatoe sanguineus	Bare-eyed cockatoo	5
Melopsittacus undulatus	Grass parakeet	48
Nestor notabilis	Kea parrot	3
Nymphicus hollandicus	Cockatiel	3
Pionus menstruus	Blue-headed conure	1
Platycercus elegans	Pennant's parakeet	3
Platycercus eximius	Rosella parakeet	1
Poicephalus senegalus	Yellow-vented parrot	1
Polytelis swainsoni	Barraband's parakeet	2
Psittacula eupatria	Red-shouldered parakeet	1
Psittacula krameri	Kramer's parakeet	1
Psittacus erithacus	African gray parrot	2
Trichoglossus moluccanus	Rainbow lorikeet	3
CUCULIFORMES		
Cuculidae:		
Eudynamys scolospacea	Koel	1
Musophagidae:		
Crinifer africanus	Plantain-eater	2
Tauraco corythaix	South African turaco	1
Tauraco donaldsoni	Donaldson's turaco	1
Tauraco persa	Purple turaco	1
STRIGIFORMES		
Tytonidae:		
Tyto alba pratincola	Barn owl	8
Strigidae:		
Bubo virginianus	Great horned owl	8
Bubo virginianus elutus	Colombian great horned owl	1
Ketupa ketupu	Malay fishing owl	1
Otus asio	Screech owl	2
Strix varia varia	Barred owl	16

Scientific name	*Common name*	*Number*
CAPRIMULGIFORMES		
Podargidae:		
Podargus strigoides	Frogmouth	1
TROGONIFORMES		
Trogoniidae:		
Pharomachus mocino	Quetzal	2
Priotelus temnurus	Cuban trogan	3
CORACIIFORMES		
Alcedinidae:		
Dacelo gigas	Kookaburra	5
Bucerotidae:		
Aceros plicatus	Wreathed hornbill	1
Aceros undulatus	Malayan hornbill	1
Anthracoceros coronatus	Pied hornbill	1
Buceros bicornis	Concave-casqued hornbill	1
Buceros hydrocorax	Philippine hornbill	1
Bucorvus abssinicus	Abyssinian ground hornbill	1
Bycanistes subcylindricus	Black-and-white casqued hornbill.	1
Tockus jacksoni	Jackson's hornbill	1
Momotidae:		
Momotus lessoni	Motmot	2
PICIFORMES		
Ramphastidae:		
Andigena bailloni	Baillon's toucanet	1
Pteroglossus torquatus	Ringed toucanet	4
Ramphastos carinatus	Sulphur-breasted toucan	2
Ramphastos toco	Toco toucan	3
PASSERIFORMES		
Cotingidae:		
Chasmorhynchus nudicollis	Bellbird	1
Rupicola rupicola	Orange cock-of-the-rock	2
Rupicola sanguinolenta	Scarlet cock-of-the-rock	1
Tyrannidae:		
Pitangus sulphuratus	Kiskadee flycatcher	2
Corvidae:		
Corvus alba	White-breasted crow	1
Corvus brachyrhynchos	Crow	3
Corvus corax principalis	Raven	1
Corvus insolens	Indian crow	2
Cyanocitta cristata	Blue jay	2
Gymnorhina hypoleuca	White-backed piping crow	1
Pica nuttalli	Yellow-billed magpie	1
Pica pica hudsonica	Magpie	3
Urocissa caerulea	Formosan red-billed pie	1
Ptilonorhynchidae:		
Ptilonorhynchus violaceus	Satin bowerbird	3
Timaliidae:		
Garrulax bicolor	White-headed laughing thrush	2

Scientific name	*Common name*	*Number*
Pycnonotidae:		
Pycnonotus leucogenys	White-cheeked bulbul	1
Mimidae:		
Mimus polyglottos	Mockingbird	1
Mimus polyglottos leucopterus	Western mockingbird	1
Turdidae:		
Geokichla citrina	Orange-headed ground thrush	1
Platycichila flavipes	Yellow-footed thrush	1
Thamnolaea cinnemomeiventris	Cliff chats	2
Turdus migratorius	Robin	1
	Albino robin	1
Sturnidae:		
Acridotheres tristis	Jungle mynah	1
Gracula religiosa	Hill mynah	2
Gracula religiosa indica	Lesser hill mynah	2
Lamprocolius purpureus	Burchell's glossy starling	3
Spreo superbus	Tricolored or superb starling	1
Sturnia malabarica	Gray-headed mynah	1
Sturnus vulgaris	Starling	1
Ploceidae:		
Aidemosyne modesta	Plum-headed finch	1
Amadina fasciata	Cut-throat weaver finch	11
Cayleyna picta	Painted finch	1
Diatropura procne	Giant whydah	5
Estrilda amandava	Strawberry finch	2
Estrilda angolensis	Cordon bleu finch	4
Estrilda astrild	Red-eared waxbill	1
Estrilda cinerea	Common waxbill	4
Estrilda melpoda	Orange-cheeked waxbill	7
Estrilda senegala	Fire finch	1
Euplectes afra	Yellow-crowned bishop weaver	14
Euplectes oriz	Red bishop weaver	7
Lonchura leucogastroides	Bengali finch	4
Lonchura maja	White-headed nun	25
Lonchura malacca	Black-throated munia	2
Lonchura punctulata	Spice finch	1
Padda oryzivora	Java finch	3
Plocepasser mahali	Mahali weaver	1
Ploceus baya	Baya weaver	14
Ploceus vitellinus	Vitelline masked weaver	3
Poephila acuticauda	Shaft-tailed finch	2
Poephila gouldiae	Gouldian finch	1
	Black-headed Gouldian finch	4
Poephila guttata castanotis	Zebra finch	41
Poephila ruficauda	Star finch	1
Quelea quelea	Red-billed weaver	1
Steganopleura bichenovii	Bicheno's finch	3
Steganuara paradisea	Paradise whydah	11
Icteridae:		
Agelaius icterocephalus	Yellow-headed marshbird	1
Icterus giraudi	Giraud's oriole	1
Icterus icterus	Troupial	2

Scientific name	*Common name*	*Number*
Icteridae—Continued		
Quiscalus quiscula	Purple grackle	1
Xanthocephalus xanthocephalus	Yellow-headed blackbird	1
Xanthornus decumanus	Crested oropendola	1
Thraupidae:		
Calospiza ruficapilla	Brown-headed tanager	1
Ramphocelus dimidiatus	Crimson tanager	6
Ramphocelus passerini	Passerini's tanager	4
Thraupis cana	Blue tanager	7
Thraupis leucoptera	White-edged tanager	2
Fringillidae:		
Carduelis carduelis	European goldfinch	5
Carpodacus mexicanus frontalis	House finch	1
Paroaria cucullata	Brazilian cardinal	1
Paroaria gularis nigro-genis	Black-eared cardinal	4
Poospiza torquata	Ringed warbling finch	2
Serinus canarius	Canary	19
Sicalis luteola	Saffron finch	6
Sporophila gutturalis	Yellow-billed finch	13

REPTILES

LORICATA

Crocodylidae:		
Alligator mississipiensis	Alligator	20
Alligator sinensis	Chinese alligator	2
Caiman sclerops	Caiman	16
Crocodylus acutus	American crocodile	3
Crocodylus cataphractus	Narrow-nosed crocodile	1
Crocodylus niloticus	African crocodile	1
Crocodylus porosus	Salt-water crocodile	1
Osteolaemus tetraspis	Broad-nosed crocodile	3
Tomistoma schlegeli	Gavial	1

SAURIA

Gekkonidae:		
Gecko smithi	Giant gecko	1
Tarentola mauritanica	Gecko	1
Gerrhosauridae:		
Gerrhosaurus major	Plated lizard	8
Iguanidae:		
Anolis carolinensis	American anolis	15
Anolis cristatellus	Little crested anolis	5
Anolis equestris	Giant anolis	2
Anolis krugi	Krug's anolis	5
Anolis stratulus	West Indian anolis	4
Ctenosaura acanthura	Spiny-tailed iguana	5
Cyclura macleayi	Cuban iguana	1
Cyclura stejnegeri	Mona Island iguana	1
Iguana iguana	Common iguana	5
Sceloporus undulatus	Fence lizard	1
Helodermatidae:		
Heloderma horridum	Mexican beaded lizard	2
Heloderma suspectum	Gila monster	6

Scientific name	*Common name*	*Number*
Varanidae:		
Varanus niloticus	African monitor	1
Varanus varius	Australian lace monitor	2
Teiidae:		
Tupinambis nigropunctatus	Black tegu	2
Scincidae:		
Chalcides sepoides	Three-fingered skink	3
Egernia luctuosa	Mourning skink	2
Egernia whitei	White's skink	8
Eumeces fasciatus	Greater five-lined skink	2
Scincus officinalis	Sand skink	12
Trachysaurus rugosus	Stump-tailed lizard	1
Chameleontidae:		
Chamaeleon dilepis	Flap-necked chameleon	1
SERPENTES		
Boidae:		
Boa enydris cookii	Cook's tree boa	1
Boa enydris enydris	Tree boa	1
Constrictor constrictor	Boa constrictor	1
Constrictor imperator	Emperor boa	2
Epicrates angulifer	Cuban boa	4
Epicrates cenchria	Rainbow boa	5
Epicrates inornatus	Puerto Rican boa	1
Eryx thebaicus	Sharp-tailed sand boa	1
Eunectes murinus	Anaconda	7
Python molurus	Indian rock python	1
Python regius	Ball python	4
Python reticulatus	Regal python	5
Python sebae	African python	2
Colubridae:		
Acrochordus javanicus	Elephant trunk snake	1
Arizona elegans	Faded snake	1
Boaedon lineatum	African house snake, or musaga	2
Boiga dendrophila	Mangrove snake	1
Carphophis amoena	Worm snake	26
Diadophis punctatus edwardsi	Ring-necked snake	1
Dispholidus typus	Boomslang	6
Drymarchon corais couperi	Indigo snake	7
Elaphe guttata	Corn snake	1
	Albino corn snake	1
Elaphe obsoleta confinis	Southern pilot black snake	1
Elaphe obsoleta obsoleta	Pilot black snake	14
Elaphe quadrivittata	Chicken snake	2
Heterodon contortrix	Hog-nosed snake	1
Lampropeltis doliata	Scarlet king snake	1
Lampropeltis getulus californiae	California king snake	2
Lampropeltis getulus floridana	Florida king snake	1
Lampropeltis getulus getulus	King snake	1
Lampropeltis getulus splendida	Sonoran king snake	1
Lampropeltis rhombomaculata	Mole snake	2
Lampropeltis triangulum	Milk snake	2
Leptophis occidentalis	Parrot snake	1

Scientific name	*Common name*	*Number*
Colubridae—Continued		
Natrix cyclopion	Green water snake	2
Natrix erythrogaster	Red-bellied water snake	2
Natrix sipedon subsp	Water snake	3
Natrix sipedon fasciata	Southern banded water snake	1
Natrix sipedon pictiventris	Florida water snake	1
Natrix sipedon sipedon	Water snake	2
Natrix taxispilota	Brown water snake	4
Natrix tessellata	Tessellated snake	1
Psammophis subtaeniatus	Striped sand snake	1
Rhamphiophis rostratus	Sharp-nosed snake	2
Storeria dekayi	DeKay's snake	2
Storeria o. occipitomaculata	Red-bellied snake	1
Thamnophis sauritus	Ribbon snake	1
Thamnophis sirtalis	Garter snake	3
Thelotornis kirtlandii	African twig snake	1
Zamenis florulentus	Egyptian racer	2
Elapidae:		
Naja haje	Egyptian cobra	18
Naja hannah	King cobra	1
Naja melanoleuca	Black cobra	1
Naja naja	Indian cobra	5
Crotalidae:		
Ancistroden contortrix contortrix	Southern copperhead snake	1
Ancistrodon contortrix mokeson	Northern copperhead snake	1
Ancistrodon piscivorus	Water moccasin	1
Crotalus atrox	Texas diamondback rattlesnake	4
Crotalus horridus	Timber rattlesnake	1
Sistrurus miliarius	Pygmy rattlesnake	1
TESTUDINATA		
Chelyidae:		
Batrachemys nasuta	South American side-necked turtle	2
Chelodina longicollis	Australian side-necked turtle	3
Chelys fimbriata	Matamata turtle	2
Hydraspis sp	South American side-necked turtle	1
Hydromedusa tectifera	Small side-necked turtle	2
Phrynops geoffroyana	Geoffroy's side-necked turtle	1
Phrynops hilarii	Large side-necked turtle	15
Platemys platycephala	Flat-headed turtle	5
Kinosternidae:		
Kinosternum cruentatum	South American mud turtle	1
Kinosternon subrubrum	Mud turtle	12
Sternotherus odoratus	Musk turtle	10
Chelydridae:		
Chelydra serpentina	Snapping turtle	15
Emydidae:		
Batagur baska	Indian fresh-water turtle	1
Chrysemys picta	Painted turtle	31
Clemmys guttata	Spotted turtle	6
Clemmys insculpta	Wood turtle	4
Clemmys marmorata marmorata	Pacific pond turtle	1
Cyclemys amboinensis	Kura kura box turtle	1

Scientific name	*Common name*	*Number*
Emydidae—Continued		
Emydura kreffti	Krefft's turtle	3
Emydura macquariae	Murray turtle	8
Emys orbicularis	European pond turtle	3
Graptemys barbouri	Barbour's turtle	7
Graptemys geographica	Map turtle	3
Graptemys pseudogeographica	False map turtle	4
Kinixys belliana	Hinge-back turtle	2
Malaclemys terrapin centrata	Southern diamondback turtle	4
Pseudemys decussata	Cuban water turtle	1
Pseudemys elegans	Mobile turtle	12
Pseudemys floridana	Florida water turtle	8
Pseudemys floridana suwannensis	Suwannee turtle	7
Pseudemys ornata	Central American turtle	2
Pseudemys rubriventris	Red-bellied turtle	4
Pseudemys scripta	Red-lined turtle	12
Pseudemys scripta callirostris	South American red-lined turtle	12
Pseudemys scripta troostii	Cumberland turtle	10
Rhinoclemmys punctularia	South American red-headed turtle	1
Terrapene carolina	Box turtle	50
Terrapene carolina triunguis	Three-toed box turtle	3
Terrapene o. ornata	Western box turtle	2
Pelomedusidae:		
Phrynops gibba	South American gibba turtle	3
Pelomedusa galeata	African water turtle	1
Pelusios nigricans	African black mud turtle	8
Pelusios sinuatus	African snake-neck turtle	8
Podocnemis unifilis	Amazon spotted turtle	15
Testudinidae:		
Testudo sp.	Galapagos turtle	1
Testudo elephantina	Giant Aldabra turtle	2
Testudo ephippium	Galapagos turtle	4
Testudo marginata	Margined turtle	1
Testudo tabulata	South American turtle	1
Testudo vicina	Galápagos turtle	1
Trionychidae:		
Trionyx ferox	American soft-shelled turtle	7
Trionyx triunguis	African soft-shelled turtle	2

AMPHIBIANS

CAUDATA

Salamandridae:		
Diemictylus pyrrhogaster	Red-bellied newt	31
Diemictylus viridescens	Red-spotted newt	5
Taricha torosa	California newt	2
Amphiumidae:		
Amphiuma means	Congo eel	1

SALIENTIA

Dendrobatidae:		
Dendrobates tinctoria	Arrow-poison frog	2
Bufonidae:		
Bufo americanus	American toad	4
Bufo marinus	Giant toad	7

Scientific name	*Common name*	*Number*
Bufonidae—Continued		
Bufo paracnemis	Rococo toad	1
Bufo peltocephalus	Cuban toad	7
Bufo viridis	European toad	1
Leptodactylidae:		
Ceratophrys calcarata	Colombian horned frog	2
Ceratophrys ornata	Argentine horned frog	1
Hylidae:		
Hyla cinerea	Green tree frog	3
Hyla crucifer	Spring peeper	4
Hyla squirella	Squirrel tree frog	4
Hyla versicolor	Gray tree frog	2
Microhylidae:		
Microhyla carolinensis	Narrow-mouthed toad	2
Pipidae:		
Pipa pipa	Surinam toad	4
Ranidae:		
Rana adspersa	African bull frog	15
Rana clamitans	Green frog	4

FISHES

Acanthodoras spinosissimus	Talking catfish	1
Acanthophthalmus semicinctus	Large kuhlii	3
Anabas testudineus	Climbing perch	5
Astronotus ocellatus	Peacock cichlid	4
Barbus everetti	Clown barb	2
Betta sp	Fighting fish	1
Brachygobius xanthozonus	Bumblebee-fish	2
Corydoras hastatus	Corydoras	15
Electrophorus electricus	Electric eel	1
Hyphessobrycon innesi	Neon tetra	9
Labeo chrysophekadion	Black sharkfish	2
Lebistes reticulatus	Guppy	25
	Flag-tailed guppy	35
Lepidosiren paradoxa	South American lungfish	1
Metynnis sp	Metynnis	3
Plecostomus plecostomus	Armored catfish	2
Protopterus annectens	African lungfish	2
Quintana atrizona	Cuban mosquitofish	1
Serrasalmus niger	Piranha	1
Sternarchella schottii	African knifefish	3
Tanichthys albonubes	White Cloud Mountain fish	1
Xiphophorus helleri	Green swordtail	4

ARACHNIDS

Eurypelma sp	Tarantula	1
Latrodectus mactans	Black-widow spider	1

INSECTS

Blabera sp	Giant cockroach	100

MOLLUSKS

	Pond snails	10

STATUS OF THE COLLECTION

Class	Species or subspecies	Individuals
Mammals	246	786
Birds	300	1,212
Reptiles	148	625
Amphibians	21	107
Fish	22	123
Arachnids	2	2
Insects	2	100
Mollusks	1	10
Total	742	2,965

Animals on hand July 1, 1955	3,140
Accessions during the year	1,710
Total number of animals in collection during the year	5,120
Removals for various reasons such as death, exchanges, return of animals on deposit, etc.[2]	2,155
In collection on June 30, 1956	2,965

[2] The Zoo is given many small creatures that have been pets in homes where they are no longer welcome, or where circumstances necessitate giving them up. These include ducks, chickens, and rabbits given to children at Easter time, parakeets, alligators, caimans, guinea-pigs, etc. Also many of the common local wild things that are found by children or adults who think the creatures need help are brought to the Zoo. This includes a wide array, but particularly gray squirrels, cottontail rabbits, opossums, skunks, raccoons, foxes, woodchucks, blue jays, robins, sparrows, box turtles, as well as other less plentiful forms. The quantity of these received far exceeds the need for exhibition animals and facilities to care for them; therefore, some are used in exchange for other animals that are needed, and some are liberated. During the past year there were 215 individuals of 19 different kinds of such unneeded animals brought in. These were accessioned and therefore are recorded, which accounts in part for the large number of removals listed.

Respectfully submitted.

W. M. Mann, *Director.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

Report on the Canal Zone Biological Area

SIR: It gives me pleasure to present herewith the annual report on the Canal Zone Biological Area for the fiscal year ended June 30, 1956. The principal portion of this report was prepared by James Zetek, who retired from the position of resident manager of this bureau on May 30, 1956. Mr. Zetek has been succeeded by Dr. Carl B. Koford who assumed his duties as resident naturalist on June 30, 1956.

SCIENTISTS AND THEIR STUDIES

During the fiscal year 51 scientists, not including the Corrosion Conference group, came to the laboratory. Some of these, such as the research team from the University of Oslo, stayed for extended periods. In addition, there were many scientists who wanted to "get acquainted" with the island and had scheduled a one-day stopover to inspect the laboratory and the forest area.

Investigator	*Principal interest or special study*
Altman, Stuart, Walter Reed Medical Center.	Biology of mammals and birds, particularly howler monkeys.
Athern, D. D., Woods Hole Oceanographic Institution.	General biological survey.
Blew, Oscar, U. S. Forest Service.	Evaluation of reports on termite resistance tests.
Coursan, Blair, General Biological Supply House.	Bird and mammal studies.
Davis, Malcolm, National Zoological Park.	Biological survey.
Enders, Robt. K., Swarthmore College.	Histochemical studies and mammals surveys.
Enger, E. S., University of Oslo.	Member of Dr. Scholander's research group.
Gillespie, David M., Ohio State University.	Assistant to Dr. Hartman.
Haas, Theodore P., Philadelphia College of Pharmacy.	Plant studies.
Hartman, Frank A., Ohio State University.	Muscle studies of birds and adrenal gland.
Hartman, Armaguedon, El Volcán, Chiriquí.	Assistant to Drs. Enders and Wislocki.
Henry, Mr. and Mrs. T. R., Washington, D. C.	Obtaining press release material for the Smithsonian Institution.

Investigator	*Principal interest or special study*
Heed, Dr. and Mrs. Wm. B., The Genetics Foundation, Austin, Tex.	Survey and collection of wild *Drosophila* for gene research.
Horning, Dr. and Mrs. E. C., National Heart Institute, Bethesda, Md.	Survey for future chemical studies.
Hoover, Mr. and Mrs. I. C., Arlington, Va.	Ornithological studies.
Hyman, Dr. Libbie, American Museum of Natural History.	General survey, especially of the soil fauna.
Johnson, H. R., U. S. Forest Service.	Examination of tests of treated woods against termite attacks.
Krog, John, University of Oslo.	Associate of Dr. Scholander.
Leivestad, Helge, University of Oslo.	Member of Dr. Scholander's research group.
Lloyd, Ivan M., Eastman Kodak Tropical Research Laboratory.	Deterioration and corrosion studies.
Lufburrow, R. A., Woods Hole Oceanographic Institution.	General biology.
Lundy, W. E., Assistant treasurer, Panama Canal.	Continuing studies of the birds, mammals, and insects.
Olivares, Ismael, Eastman Kodak Tropical Research Laboratory.	Fungi as affecting photographic equipment.
Pinney, Roy, New York City.	Photography of wildlife.
Reed, Mrs. Albert C., Salt Pines, Cape Cod, Mass.	Ornithology.
Rettenmeyer, Mr. and Mrs. Carl, University of Kansas.	Soil organisms and general entomology.
Riegel, Mr. and Mrs. H. J., Dwight, Ill.	Study of birds.
Ruud, Berthe, University of Oslo.	Member of Dr. Scholander's research group.
Scholander, Dr. and Mrs. Per, University of Oslo.	Heat regulation in sloths and other mammals.
Schrader, Dr. Sally Hughes, Columbia University.	Cytological studies.
Stoutamier, Warren P., Fort Myers, Fla.	Wildlife protection studies.
Serafin, Mitrotti, Eastman Kodak Tropical Research Laboratory.	Corrosion and deterioration studies.
Soper, Cleveland C., Eastman Kodak Tropical Research Laboratory.	Corrosion and deterioration studies.

Investigator	*Principal interest or special study*
Swift, Paul F., Eastman Kodak Tropical Research Laboratory.	Physical and chemical studies related to corrosion and deterioration.
Verity, Erwin, Walt Disney Production.	Photography and study of mammals.
Verrall, A. F., U. S. Forest Service.	Inspection of controls for corrosion and termite installations.
Warren, James W., Walter Reed Army Medical Center.	Study of fungus-growing ants.
Weber, Neal A., Swarthmore College.	Study of fungus-growing ants.
Wetmore, Dr. and Mrs. Alexander, Smithsonian Institution.	Continuation of bird studies.
Wilmar, Mr. and Mrs. H., Walt Disney Production.	Photography and study of mammals.
Wislocki, Louis, Swarthmore College.	Associate of Dr. Enders.
Zeigler, John N., Woods Hole Oceanographic Institution.	General biological observations.
Corrosion Conference (a group of United States scientists).	Annual conference on island.

VISITORS

The visitors who spent at least a day on Barro Colorado Island [1] this year totaled 440. The majority of these were local people, but there were some who came by plane or boat to the mainland and had included a side trip to the laboratory in their plans. As in other years, all appeared to be very enthusiastic, and many expressed the wish that they could stay longer or return again at some later time.

RAINFALL

In 1955, during the dry season (January through April) rains of 0.01 inch or more fell on 44 of the 120 days (128 hours) and amounted to 10.78 inches, as compared to 5.84 inches during 1954.

During the wet season of 1955 (May through December) rains of 0.01 inch or more fell on 202 of the 245 days and amounted to 103.64 inches as compared to 99.85 inches during 1954.

During 1955 rain fell on 246 days (975 hours), and averaged only 0.45 inch per day, almost 0.12 inch per hour.

March was the driest month of 1955 (0.21 inch) and November the wettest (17.14 inches). The wettest year of record (31 years) was

[1] Anyone contemplating a visit to this unique spot in the American Tropics should communicate with the Secretary of the Smithsonian Institution, Washington 25, D. C., or with the Resident Naturalist of the Canal Zone Biological Area, Drawer "C," Balboa, Canal Zone.

1935 with 143.42 inches, and the driest year of record was 1930 with only 76.57 inches.

The maxima of record for short periods were 5 minutes 1.30 inches; 10 minutes 1.65 inches; 1 hour 4.11 inches; 2 hours 4.81 inches.

TABLE 1.—*Annual rainfall, Barro Colorado Island*

Year	*Total inches*	*Station average*	*Year*	*Total inches*	*Station average*
1925	104.37	------	1941	91.82	108.41
1926	118.22	113.56	1942	111.10	108.55
1927	116.36	114.68	1943	120.29	109.20
1928	101.52	111.35	1944	111.96	109.30
1929	87.84	106.56	1945	120.42	109.84
1930	76.57	101.51	1946	87.38	108.81
1931	123.30	104.69	1947	77.92	107.49
1932	113.52	105.76	1948	83.16	106.43
1933	101.73	105.32	1949	114.86	106.76
1934	122.42	107.04	1950	114.51	107.07
1935	143.42	110.35	1951	112.72	107.28
1936	93.88	108.98	1952	97.68	106.94
1937	124.13	110.12	1953	104.97	106.87
1938	117.09	110.62	1954	105.68	106.82
1939	115.47	110.94	1955	114.42	107.09
1940	86.51	109.43			

TABLE 2.—*Comparison of 1954 and 1955 rainfall, Barro Colorado Island (inches)*

Month	Total		Station average	Years of record	Excess or deficiency	Accumulated excess or deficiency
	1954	1955				
January	1.24	9.05	2.08	30	+6.97	+6.97
February	1.29	0.46	1.22	30	−0.76	+6.21
March	0.21	0.90	1.16	30	−0.26	+5.95
April	3.10	0.37	3.07	31	−2.70	+3.25
May	11.09	10.58	10.83	31	−0.25	+3.00
June	12.06	13.54	11.25	31	+2.29	+5.29
July	15.05	11.49	11.56	31	−0.07	+5.22
August	12.92	11.36	12.27	31	−0.91	+4.31
September	11.19	9.27	9.93	31	−0.66	+3.65
October	13.14	16.33	13.75	31	+2.58	+6.23
November	17.14	18.35	19.02	31	−0.67	+5.56
December	7.25	12.72	10.95	31	+1.77	+7.33
Year	105.68	114.42	107.09	------	------	+7.33
Dry season	5.84	10.78	7.53	------	------	+3.25
Wet season	99.84	103.64	99.56	------	------	+4.08

BUILDINGS, EQUIPMENT, AND IMPROVEMENTS

When the new laboratory building was constructed, the contractor could not obtain United States lumber for the flooring, and lumber cut and milled in Chiriquí, Panama, had to be used. During the year dry-wood termite infestation was observed, and though the damage was not extensive and appeared to be spreading slowly, immediate steps were undertaken to correct this condition. All the floor paint was scraped off and two very liberal brushings of Penta W–R were applied and allowed to soak in thoroughly. Since this treatment was given, no further signs of termite activity have been seen.

Water and electrical installations in this new building were completed, and the large darkroom is almost finished. It is expected that the building will soon be used to its full capacity and effectiveness.

All the screening on the original large laboratory was replaced with plastic screening, as expert advice had indicated this type was exceptionally good. Unfortunately, experience did not bear out that recommendation as rats ate the plastic with gusto, and cigarettes which accidently came into contact with the screen caused holes to develop immediately. It is planned to replace all the plastic screening with the aluminum type.

Some of the lumber and other materials needed for rebuilding and repairing the laborers' quarters were purchased. This project includes the installation of indoor toilet facilities, a luxury to the laborers, but an added health protection factor on the island.

The roof of the Haskins Library Building appeared to be in poor condition, but a careful examination revealed that the damage was superficial, and the only repair needed was scraping and painting the existing covering. These projects were carried out thoroughly, and the roof is now in excellent condition. The runoff from the roof of this building is not used as a means of water supply, and so painting it presents no problem in this respect.

The new electric water heater furnishes hot water for the kitchen and shower baths and is proving to be a valuable addition. Though hot water cannot be used too freely when a large number of scientists are on the island, it has been a welcome convenience for all.

The 110–120-volt, 60-cycle, overhead electrical installation, completed in 1955, is giving satisfactory service. Excellent arrangements were made during the year for the maintenance and repair of the Diesel generators. A Caterpillar generator was obtained on transfer, and when this third unit is installed it is expected that no interruptions in the electric supply will be experienced.

Materials were purchased for building dry closets, electrically heated, in the various buildings. Some dehumidifiers have been installed, and they are doing an excellent job of drawing incredible amounts of water from each room.

The large wooden water tank north of the old laboratory was in danger of collapsing, and so some temporary, emergency repairs had to be made until the water-supply problem can be resolved. During the year it was discovered that a spring on the Snyder-Molino trail may be the solution. Before this can be determined, possible contamination from rain drainage during the wet season will have to be eliminated in order to obtain a good sample of water for analysis.

Minor necessary repairs were made to the launch *Moon*. Local regulations make it necessary to equip the speedboat with life preservers.

Further safety measures were taken by obtaining spotlights for the launch and by having all the fire extinguishers recharged by the Fire Division.

The dock proper is joined to a large platform covered with corrugated roofing and used for storage purposes. A portion of the roofing caved in because of rot-infested roof timbers. This damage was quickly repaired, and the new lumber was treated with preservatives to retard decay.

URGENT REQUIREMENTS

The most urgent requirement of the island, which has been referred to in the preceding section, is a safe and permanent supply of drinking water. This problem is expected to be resolved during the coming fiscal year.

The island dock still presents a perennial problem, but funds have been made available to provide for its relocation. Engineering studies will be made to determine the most suitable location for rebuilding the dock so that the silting of the channel will not present an annual problem.

The construction of the dry rooms referred to earlier in this report is urgently required so that scientists may store in safety such property as suitcases, cameras and their carrying cases, winter clothing, and shoes.

Since the termite infestation of the floor in the new building has been eliminated, the floors must be repainted soon.

The engine and hoist, which provide the only means of lifting heavy shipments of supplies and equipment from the dock to the laboratory level, must be replaced as soon as possible. Though the existing equipment has given many years of fine service, it is now worn out, breakdowns are frequent, and repairs are more and more difficult to make.

Only two of the trail-end houses, the Drayton and the Fuertes, are in usable condition, the others being in a very bad state of disrepair and so cannot be used.

Now that better facilities are available for preserving books, much work has to be done on the existing library, such as the rebinding and repair of old, valuable, and irreplaceable publications and the binding of series of scientific journals. Essential scientific reference texts and publications which are not included in the existing collection should be procured. Provision must be made to accommodate library material being transferred from the Balboa office to the island. Some of this is property of the bureau, but a large portion of it represents the personal collection of Mr. Zetek who has indicated that he plans to donate these fine publications to the island library. His generosity is greatly appreciated.

The laboratory in the new building and its related storerooms have to be equipped and properly organized. Funds have been provided

to obtain some of the required equipment and supplies, but more will be required.

An annual requirement, and one which is always a pressing problem in any tropical environment, is the constant need of painting all exterior and interior surfaces regularly to prevent wood rot.

FINANCES

The following institutions again contributed their table subscriptions, which were received with sincere appreciation inasmuch as without them the uninterrupted operation of the laboratory could not be accomplished:

Eastman Kodak Co.	$1,000.00
New York Zoological Society	300.00
Smithsonian Institution	300.00

Donations are also gratefully acknowledged from the following: Eugene Eisenmann, C. M. Goethe, D. S. Lee, and Harry C. Nichols.

A concerted effort must soon be made to interest additional groups in supporting a table subscription. Though the needs of the laboratory are great, its improved facilities are such that any participating group would find that an outlay of $300 or $400 would reap unforeseen dividends in the form of sound tropical research accomplishments.

The rate for one-day visits to the island is $3 per person. Such visitors are met by launch at Frijoles and taken to the island and back again in time to board the evening train home. The fee also covers the noon meal and a guided trip into the forest.

Scientists from institutions which contribute to the support of the island through an annual table subscription are charged $4 per person per day. For others the fee is $5 per person per day. These rates provide for the two launch trips to and from the island, three consecutive meals, and lodging.

ACKNOWLEDGMENTS

Thanks are due the Canal Zone Government, its executive secretary and staff, the Customs and Immigration officials, the officials and employees of the Panama Railroad, and also the Police Division, for their excellent cooperation. The Panama Canal Company, particularly Mr. P. Alton White, chief of the Dredging Division, and his technical staff were also of great assistance.

Particular mention is made also of Dr. Cleveland C. Soper, director of the Eastman Kodak Company's Tropical Research Laboratory, and his efficient technical and clerical staff who despite their heavy research program found time to help with the problems of the CZBA, especially when emergencies arose. Without such kind and unfailing assistance the Area could not function as it does.

412575—57——12

Special appreciation must be expressed for the constant cooperation and efficiency of Mrs. Adela Gomez, particularly when Mr. Zetek was hospitalized on February 23, 1956, and the burden of managing and operating the bureau fell on her shoulders.

Respectfully submitted.

J. E. GRAF,
Assistant Secretary, Smithsonian Institution.

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

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, 1956:

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.

The number of packages of publications received for transmission during the year increased by 14,983 to the yearly total of 1,161,855 but the weight of the packages decreased by 9,904 to the yearly total of 803,056 pounds. The average weight of the individual package decreased to 11.14 ounces, as compared to the 11.34-ounce average for the fiscal year of 1955.

The publications received from foreign sources for addressees in the United States and from domestic sources for shipment abroad are classified as shown in the following table:

Classification	*Packages*		*Weight*	
	Number	*Number*	*Pounds*	*Pounds*
United States parliamentary documents sent abroad	668,968		253,375	
Publications received in return for parliamentary documents		6,968		11,579
United States departmental documents sent abroad	250,166		245,776	
Publications received in return for departmental documents		7,219		17,132
Miscellaneous scientific and literary publications sent abroad	165,769		191,655	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		62,765		83,539
Total	1,084,903	76,952	690,806	112,250
Grand total	1,161,855		803,056	

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 foreign addressees by direct mail. Distribution in the United States of the publications received through the foreign exchange bureaus is accomplished primarily by mail, but by other means when more economical. The number of boxes shipped to the foreign exchange bureaus was 3,064, or 228 more than for the previous year. Of these boxes 986 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 228,394.

There was allocated to the International Exchange Service for transportation $45,040. With this amount it was possible to effect the shipment of 837,188 pounds, which was 37,188 pounds more than was shipped the previous year. However, approximately 11,000 pounds of the full sets of United States Government documents accumulated during the year because the Library of Congress had requested suspension of shipment to certain foreign depositories.

Ocean freight rates to the Mediterranean ports were increased by 10 percent in June and the freight rates to and from the New York piers were increased by a 10-cent arbitrary in April.

The total outgoing correspondence was 2,497 letters, exclusive of information copies.

With the exception of Taiwan, no shipments are being made to China, North Korea, Outer Mongolia, Communist-controlled area of Viet-Nam, Communist-controlled area of Laos, or the Haiphong Enclave.

On May 14 the International Exchange Service received from the East German Exchange Service a shipment of 179 packages. This was the first shipment received from East Germany since 1939. On June 7 an announcement was received that another shipment containing 181 packages was in transit.

With certain exceptions the regulations of the Bureau of Foreign Commerce, Department of Commerce, provide that each package of publications exported bear a general license symbol and legend, "Export License Not Required." The International Exchange Service accepts for transmission to foreign destinations only those packages of publications that fall within the exception and those packages of publications to which the general license symbol and legend have been applied by the consignor.

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.[1]
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: National Central Library, Taipei, Taiwan.
National Chengchi University, Taipei, Taiwan.[2]
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Biblioteca Nacional, San José.
CUBA: Ministerio de Estado, Canje Internacional, Habana.
CZECHOSLOVAKIA: National and University Library, Prague.[1]
DENMARK: Institut Danios des Échanges Internationaux, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Staatsbibliothek, Berlin.
Free University of Berlin, 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.[1]
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.[3]

[1] Shipment suspended.
[2] Changed from National Library of Peiping, Peiping, China.
[3] Receives two sets.

MEXICO: Secretaría de Relaciones Exteriores, Departmento de Información para el Extranjero, México, D. F.

NETHERLANDS: Royal Library, The Hague.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Utenriksdepartmentets Bibliothek, Oslo.

PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.

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

POLAND: Bibliothèque Nacionale, Warsaw.[1]

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.[1]

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.

ANGLO-EGYPTIAN SUDAN: Gordon Memorial College, Khartoum.

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: Secretary to the Government of India, Bombay.[4]
  BIHAR AND ORISSA: Revenue Department, Patna.
  UNITED PROVINCES OF AGRA AND OUDH:
    University of Allahabad, Allahabad.
    Secretariat Library, Uttar Pradesh, Lucknow.
  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.
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: Central Secretariat Library, Karachi.
PANAMA: 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.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 76 copies of the Federal Register and 88 copies of the Congressional Record. This is a decrease from the preceding year of 16 copies of the Federal Register and of 6 copies 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 Poder Judicial, Mendoza.[5]
  Boletín Oficial de la República Argentina, Ministerio de Justica e Instrucción Pública, Buenos Aires.
  Cámara de Disputados 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]
  WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.
BRAZIL:
  Biblioteca da Camera dos Deputados, Rio de Janeiro.
  Secretaria de Presidencia, Rio de Janeiro.[6]

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[4] Changed from Undersecretary to the Goverament of Bombay.
[5] Federal Register only.
[6] Congressional Record only.

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.[8]

CHINA:

Legislative Yuan, Taipei, Taiwan.[8]

Taiwan Provincial Government, Taipei, Taiwan.

CUBA:

Biblioteca del Capitolio, Habana.

Biblioteca Pública Panamericana, Habana.[8]

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.

FRANCE:

Bibliothèque Assemblée Nationale, Paris.

Bibliothèque Conseil de la République, Paris.

Library, Organization for European Economic Cooperation, Paris.[8]

Research Department, Council of Europe, Strasbourg.[8]

Service de la Documentation Étrangère, Assemblée Nationale, Paris.[8]

GERMANY:

Amerika-Institut der Universität München, München.[8]

Archiv, Deutscher Bundesrat, Bonn.

Bibliothek der Instituts für Weltwirtschaft an der Universität Kiel, Kiel-Wik.

Bibliothek Hessischer Landtag, Wiesbaden.[8]

Der Bayrische Landtag, Munich.[8, 7]

Deutscher Bundesrat, Bonn.[8]

Deutscher Bundestag, Bonn.[8]

Hamburgisches Welt-Wirtschafts-Archiv, Hamburg.

GOLD COAST: Chief Secretary's Office, Accra.[8]

GREAT BRITAIN:

Department of Printed Books, British Museum, London.[8]

House of Commons Library, London.[8]

Printed Library of the Foreign Office, London.

Royal Institute of International Affairs, London.[8]

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.

HUNGARY: National Library, Budapest.[8]

INDIA:

Civil Secretariat Library, Lucknow, United Provinces.[8]

Indian Council of World Affairs, New Delhi.[8]

Jammu and Kashmir Constituent Assembly, Srinagar.[8]

Legislative Assembly, Government of Assam, Shillong.[8]

Legislative Assembly Library, Lucknow, United Provinces.

Legislative Assembly Library, Trivandrum.[8]

Madras State Legislature, Madras.[8]

Parliament Library, New Delhi.[8]

Servants of India Society, Poona.[8]

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[7] Three copies.

[8] Added during year.

IRELAND: Dail Eireann, Dublin.
ISRAEL: Library of the Knesset, Jerusalem.
ITALY:
- Biblioteca Camera dei Deputati, Rome.
- Biblioteca del Senato della Republica, Rome.
- European Office, Food and Agriculture Organization of the United Nations, Rome.[5]
- International Institute for the Unification of Private Law, Rome.[6]

JAPAN:
- Library of the National Diet, Tokyo.
- Ministry of Finance, Tokyo.[6]

JORDAN: Parliament of the Hashemite Kingdom of Jordan, Amman.[6]
KOREA: Secretary General, National Assembly, Pusan.
LUXEMBOURG: Assemblée Commune de la C. E. C. A., Luxembourg.
MEXICO:
- Dirección General Información, Secretaría de Gobernación, México, D. F.
- Biblioteca Benjamin Franklin, 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.
- GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.
- 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.
- NAYARIT: Gobernador de Nayarit, Tepic.
- NUEVO LEÓN: Biblioteca del Estado, Monterrey.
- OAXACA: Periódico Oficial, Palacia de Gobierno, Oaxaca.[5]
- PUEBLA: Secretaría General de Gobierno, Puebla.
- QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.
- SINALOA: Gobernador del Estado de Sinaloa, Culiacán.
- SONORA: Gobernador del Estado de Sonora, Hermosillo.
- TAMAULIPAS: Secretaría General de Gobierno, Victoria.
- VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.
- YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NETHERLANDS: Koninklijke Bibliotheek, The Hague.[6]
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Library of the Norwegian Parliament, Oslo.
PANAMA: Biblioteca Nacional, Panama City.[6]
PORTUGUESE TIMOR: Repartição Central de Administração Civil, Dili.[5]
SWITZERLAND: Bibliothèque, Bureau International du Travail, Geneva.[5]
- International Labor Office, Geneva.[5, 6]
- Library, United Nations, Geneva.

UNION OF SOUTH AFRICA:
- CAPE OF GOOD HOPE: Library of Parliament, Cape Town.
- TRANSVAAL: State Library, Pretoria.

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[6] Two copies.

UNION OF SOVIET SOCIALIST REPUBLICS: Fundamental'nila Biblioteka Obschestvennykh Nauk, Moscow.*

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

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 by mail.

LIST OF EXCHANGE SERVICES

AUSTRIA: Austrian National Library, Vienna.

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

CHINA: National Central Library, Taipei, Taiwan.

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

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

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 (Eastern): Deutsche Staatsbibliothek, Berlin.

GERMANY (Western): Notgemeinschaft der Deutschen Wissenschaft, Bad Godesberg.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 83/84 Berwick Street, London, W. 1.[10]

HUNGARY: National Library, Széchényi, Budapest.

INDIA: Government Printing and Stationery, Bombay.

INDONESIA: Minister of 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.

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[10] Between the United States and England only.

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery 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 Stationery 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. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the National Gallery of Art

Sir: I have the honor to submit, on behalf of the Board of Trustees, the nineteenth annual report of the National Gallery of Art, for the fiscal year ended June 30, 1956. 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. On September 22, 1955, Samuel H. Kress, trustee and President of the Gallery, died, and Rush H. Kress was elected a general trustee to succeed him. Chester Dale was elected President of the Gallery. The four other general trustees continuing in office during the fiscal year ended June 30, 1956, were Ferdinand Lammot Belin, Duncan Phillips, Chester Dale, and Paul Mellon. The Board of Trustees held its annual meeting on May 1, 1956. Chester Dale was reelected President and Ferdinand Lammot Belin Vice President, to serve for the ensuing year.

David E. Finley retired as Director of the Gallery on June 30, 1956, and John Walker, Chief Curator of the Gallery, was elected by the Board of Trustees as Director to succeed Dr. Finley effective July 1, 1956. The other executive officers of the Gallery continuing in office as of June 30, 1956 are:

Huntington Cairns, Secretary-Treasurer.
Ernest R. Feidler, Administrator.
Huntington Cairns, General Counsel.
Macgill James, Assistant Director.

The three standing committees of the Board, as constituted at the annual meeting May 1, 1956, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Earl Warren, Chairman.
Chester Dale, Vice Chairman.
Ferdinand Lammot Belin.
Secretary of the Smithsonian Institution, Dr. Leonard Carmichael.
Paul Mellon.

FINANCE COMMITTEE

Secretary of the Treasury, George M. Humphrey, Chairman.
Chester Dale, Vice Chairman.
Secretary of the Smithsonian Institution, Dr. Leonard Carmichael.
Ferdinand Lammot Belin.
Paul Mellon.

ACQUISITIONS COMMITTEE

PERSONNEL

On June 30, 1956, full-time Government employees on the staff of the National Gallery of Art numbered 312, as compared with 301 employees as of June 30, 1955. The United States Civil Service Regulations govern the appointment of employees paid from appropriated public funds.

APPROPRIATIONS

For the fiscal year ended June 30, 1956, the Congress of the United States appropriated for the National Gallery of Art $1,436,000, 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 Joint Resolution of Congress approved March 24, 1937 (20 U. S. C. 71–75; 50 Stat. 51). The following obligations were incurred:

Personal services (including $409,143 for guard protection)	$1, 265, 700. 00
Other than personal services	170, 268. 65
Unobligated balance	31. 35
Total	$1, 436, 000. 00

ATTENDANCE

There were 1,013,246 visitors to the Gallery during the fiscal year 1956—an increase of 198,314 over the attendance for the fiscal year 1955. The average daily number of visitors was 2,791.

FIFTEENTH ANNIVERSARY CELEBRATION

March 17, 1956, was the fifteenth anniversary of the opening of the National Gallery of Art. On that date a special night opening was held from 9:00 p. m. until midnight. As part of the celebration a special exhibition was arranged of important paintings and sculpture acquired in the last five years by the Samuel H. Kress Foundation. The Samuel H. Kress Collection of Renaissance Bronzes, installed in three specially prepared rooms, was also opened to the public. The number of guests attending the special evening exhibition was 11,690.

ACCESSIONS

There were 477 accessions by the National Gallery of Art as gifts, loans, or deposits during the fiscal year 1956.

GIFTS

A total of 112 paintings and 22 sculptures of the highest quality, which had been given to the National Gallery of Art by the Samuel H. Kress Foundation in 1952, were placed on permanent exhibition, some of them in galleries newly finished for them. Especially notable in this generous gift were the following:

Artist	*Title*
Botticelli	Giuliano de' Medici.
Master of Heiligenkreuz	The Death of St. Clare.
Altdorfer	The Fall of Man.
Memling	St. Veronica.
Desiderio	Tabernacle.
Verrocchio, Circle of (possibly Leonardo).	Madonna and Child with a Pomegranate.
Bosch	Death and the Miser.
Giorgione	The Holy Family.
Titian	Ranuccio Farnese.
Dürer	Portrait of a Clergyman.
Fra Angelico and Fra Filippo Lippi	The Adoration of the Magi.
Tiepolo	Apollo Pursuing Daphne.
Chardin	The Kitchen Maid.
Bruegel, Pieter the Elder	The Temptation of St. Anthony.

In exchange for these 134 outstanding masterpieces, the National Gallery of Art returned to the Samuel H. Kress Foundation 266 paintings and 2 sculptures which had previously been given to the Gallery by the Foundation and which had become less suitable for the Gallery's collection.

During the year, the following gifts or bequests were also accepted by the Board of Trustees:

PAINTINGS

Donor	*Artist*	*Title*
Mrs. A. J. Beveridge	Drouais	Marquis d'Ossun.
Count C. C. Pecci-Blunt	Corot	L'Etang de Ville d'Avray.
Dr. and Mrs. Walter Timme.	Rembrandt	Old Woman Plucking a Fowl.
Howard Sturges	Tiepolo	Small oval ceiling design.
Col. and Mrs. E. W. Garbisch.	A. E. Zeliff	The Barnyard.
Col. and Mrs. E. W. Garbisch.	L. Sachs	The Herbert Children.
Col. and Mrs. E. W. Garbisch.	Unknown	Mounting of the Guard.
Col. and Mrs. E. W. Garbisch.	Unknown	Allegory of Freedom.
Col. and Mrs. E. W. Garbisch.	Unknown	Miss Arnold Holding an Apple.
Col. and Mrs. E. W. Garbisch.	Unknown	Miss Arnold Knitting.

Donor	*Artist*	*Title*
Col. and Mrs. E. W. Garbisch.	Unknown	Henry Wells.
Col. and Mrs. E. W. Garbisch.	Susane Walters	Memorial to Nicholas Catlin.
Col. and Mrs. E. W. Garbisch.	Samuel Jordan	Eaton Family Memorial.
Col. and Mrs. E. W. Garbisch.	A. A. Lamb	Emancipation Proclamation.
Col. and Mrs. E. W. Garbisch.	A. R. Stanley	Eliza Wells.
Col. and Mrs. E. W. Garbisch.	Unknown	New England Village.
Col. and Mrs. E. W. Garbisch.	J. C. Robinson	Portrait of an Old Man.
Col. and Mrs. E. W. Garbisch.	J. C. Robinson	Portrait of an Old Lady.
Col. and Mrs. E. W. Garbisch.	C. Hofmann	View of Benjamin Reber's Farm.
Col. and Mrs. E. W. Garbisch.	Attributed to Stettinius.	Wellington.
Col. and Mrs. E. W. Garbisch.	Samuel Enredy	Van Reid.
Col. and Mrs. E. W. Garbisch.	Samuel Enredy	Jane L. Van Reid.
Col. and Mrs. E. W. Garbisch.	Erastus S. Field	Portrait of a Man.
Col. and Mrs. E. W. Garbisch.	Erastus S. Field	Portrait of a Lady.
Col. and Mrs. E. W. Garbisch.	Unknown	Columbia.
Col. and Mrs. E. W. Garbisch.	Unknown	Dr. Alva Cook.
Col. and Mrs. E. W. Garbisch.	Unknown	General Washington on White Charger.
Col. and Mrs. E. W. Garbisch.	Unknown	The Hobby Horse.
Col. and Mrs. E. W. Garbisch.	Unknown	Portrait of a Young Man Wearing White Stock.

SCULPTURE

Winston Guest	Benin style, Nigeria	Bronze Cock.
Mrs. Herbert N. Straus	Attributed to Verrocchio.	Alexander the Great.

PRINTS AND DRAWINGS

Howard Sturges	Gabriel de St. Aubin	"La Parade Chez Nicollet."
Howard Sturges	Watteau	The Violin Player.
Howard Sturges	Gainsborough	Cart and Horse.
Howard Sturges	Cosway	Lady's Portrait.
Howard Sturges	Tiepolo	Mother, Child and Angel.
Howard Sturges	Tiepolo	Ceiling design.

Donor	Artist	Title
Howard Sturges	Chardin	Baby's Portrait.
Howard Sturges	Guardi	Classic Ruins.
Howard Sturges	Guardi	Classic Ruins.
Howard Sturges	Guardi	Venice.
Howard Sturges	Guardi	Venice.
Howard Sturges	Bérard, C.	French Soldier and Child.
Howard Sturges	Canaletto	Grand Canal, Venice.
W. G. Russell Allen	Rembrandt	19 etchings.
George Matthew Adams	Legros	51 prints.

EXCHANGE OF WORKS OF ART

The Board of Trustees accepted the offer of Lessing J. Rosenwald to exchange a Gauguin woodcut entitled "Interior de Case" for a finer impression of the same work.

WORKS OF ART ON LOAN

In connection with the fifteenth anniversary of the opening of the National Gallery of Art, 96 works of art from the Samuel H. Kress Collection were lent to the Gallery. Notable among these were the following:

Artist	Title
Andrea del Sarto	Charity.
Bellini, Giovanni	The Infant Bacchus.
Carpaccio	Madonna and Child.
Clouet, François	Diane de Poitiers.
David, Jacques-Louis	Napoleon in His Study.
Fragonard	Blindman's Buff.
Fragonard	The Swing.
Ghirlandaio, Domenico	Madonna and Child.
El Greco	Christ Cleansing the Temple.
Grünewald	The Small Crucifixion.
Memling	The Presentation in the Temple.
Pontormo	Monsignor della Casa.
Rubens	Decius Mus Addressing the Legions.
Saenredam	Cathedral of St. John at 'S-Hertogenbosch.
Tintoretto	The Conversion of St. Paul.
Titian	Doge Andrea Gritti.
Titian	St. John the Evangelist on Patmos.
Benedetto da Maiano	Madonna and Child.
Bernini, Gian Lorenzo	Cardinal Francesco Barberini.
Nino Pisano	The Archangel Gabriel.
Nino Pisano	The Virgin Annunciate.

During the fiscal year 1956 the following works of art were also received on loan by the Gallery:

From:	*Artist*
Chester Dale, New York, N. Y.:	
Isaac de Peyster	F. V. Doornick.
Anne de Peyster	F. V. Doornick.
The Sacrament of the Last Supper	Salvador Dali.
Claiborne Pell, Washington, D. C.:	
The Jolly Flatboatmen	Bingham.
Mr. and Mrs. C. B. Wrightsman, Palm Beach, Fla.:	
La Causette	Pissarro.
Portrait of a Young Girl	Vermeer.
Sketch for staircase ceiling in Würzburg	Tiepolo.
Robert Woods Bliss, Washington, D. C.:	
Thirty-seven objects of Pre-Columbian art.	

WORKS OF ART ON LOAN RETURNED

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

To:	*Artist*
J. H. Whittemore Co., Naugatuck, Conn.:	
Three Ballet Girls Behind the Scenes	Degas.
Chester Dale, New York, N. Y.:	
Isaac de Peyster	F. V. Doornick.
Anne de Peyster	F. V. Doornick.
Portrait of a Young Woman in Riding Dress	David d'Avignon.
Col. and Mrs. Edgar W. Garbisch, New York, N. Y.:	
Fourteen American primitive paintings.	
Robert Woods Bliss, Washington, D. C.:	
Nine objects of Pre-Columbian art.	
Samuel H. Kress Foundation, New York, N. Y.:	
Sacrifice of Iphigenia	Tiepolo.
Adoration	Titian.
St. Christopher	Massys.
Sir Robert Sheffield	Mabuse.
Lady Sheffield	Mabuse.
Landscape	Ruysdael, Salomon.

WORKS OF ART LENT

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

To:	*Artist*
Boston Museum of Fine Art, Boston, Mass.:	
Repose	Sargent.
Mrs. William C. Endicott	Sargent.
Pennsylvania State University, State College, Pa.:	
Flax Scutching Bee	Linton Park.
Traveling Exhibition Service, Smithsonian Institution, Washington, D. C.:	
Flax Scutching Bee	Linton Park.
Peale Museum, Baltimore, Md.:	
Portrait of Richardson Stuart	Rembrandt Peale.

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To:	*Artist*
Woodlawn Plantation, Virginia:	
General Washington at Princeton	C. P. Polk.
Cincinnati Art Museum, Cincinnati, Ohio:	
The Return of Rip Van Winkle	Quidor.
Birmingham Museum of Art, Birmingham, Ala.:	
Portrait of a Young Man Wearing White Stock	Unknown.
Houston Museum of Fine Arts, Houston, Tex.:	
Vermont Lawyer	Horace Bundy.
View of Benjamin Reber's Farm	C. Hofmann.
The Sargent Family	Unknown.
Fruit and Flowers	Unknown.
Columbia	Unknown.
Virginia Museum of Fine Arts, Richmond, Va.:	
Tête-à-Tète	Boucher.
La Petite Loge	Moreau le Jeune.
Washington County Museum, Hagerstown, Md.:	
Twenty-five American portraits.	

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year 1956:

American Primitive Paintings. From the Collection of Edgar William and Bernice Chrysler Garbisch. Continued from previous fiscal year, through August 1, 1955.

Miniatures and Prints. From the Lessing J. Rosenwald Collection. Continued from previous fiscal year, through August 1, 1955.

American Paintings. From the Collection of the National Gallery of Art. August 7 through September 18, 1955.

German Drawings—Masterpieces from Five Centuries. Through the cooperation of the Federal Republic of Germany, the Staatliche Graphische Sammlung in Munich, and the German Embassy in Washington. October 10 through October 31, 1955.

A Collection of Contemporary German Prints. Presented by the people of the Federal Republic of Germany to the United States of America. November 9, 1955, through January 4, 1956.

Asian Artists in Crystal. From Steuben Glass. In addition to the Asian crystal, designs by contemporary American glassmakers were exhibited by the Corning Museum of Glass. January 18 through February 19, 1956.

Masterpieces of Graphic Art. From the Lessing J. Rosenwald Collection. January 21 through April 9, 1956. Reopened May 23, 1956.

Exhibition of Paintings and Sculpture Acquired by the Samuel H. Kress Foundation, 1951–1956. Opened on the occasion of the Fifteenth Anniversary of the Opening of the National Gallery of Art. Evening celebration March 17, 1956. Public opening March 18, 1956, to continue on indefinite loan.

The Sacrament of the Last Supper. By Salvador Dali. First exhibition. Placed on view March 31, 1956, on indefinite loan.

A Century and a Half of Painting in Argentina. Exhibition assembled under the direction of a committee including the Counselor in charge of Cultural Affairs of the Argentine Embassy in Washington. April 17 through May 17, 1956.

TRAVELING EXHIBITIONS

Rosenwald Collection.—Special exhibitions of prints from the Rosenwald Collection were circulated to the following places during the fiscal year 1956:

Michigan State University, Mich.:
 Ten German prints.
 October–November 1955.

Marion Koogler McNay Art Institute, San Antonio, Tex.:
 Thirteen Degas prints.
 October–November 1955.

University of Nebraska Art Galleries, Lincoln, Nebr.:
 Exhibition of work of Ernst Barlach.
 October–November 1955.

Norfolk Museum, Norfolk, Va.:
 Two illuminations, Anonymous Flemish, XV Century.
 November 1955.

Museum of Modern Art, New York, N. Y.:
 Nolde, "The Prophet."
 November 1955–January 1956.

Lowe Gallery, Coral Gables, Fla.:
 Fifty-seven prints and drawings for prints.
 December 1955.

Henry Gallery, University of Washington, Seattle, Wash.:
 Exhibition of work of Ernst Barlach.
 December 1955–January 1956.

American Federation of Arts—Traveling Exhibition:
 Exhibition of Abraham Bosse.
 1956.

Art Institute, Dayton, Ohio:
 Exhibition of work of Ernst Barlach.
 January–February 1956.

Michigan State College, Mich.:
 Thirty-three Italian prints, XV Century–XVIII Century.
 January–February 1956.

Four Arts Society, Palm Beach, Fla.:
 Exhibition of Gauguin prints.
 February 1956.

Smith College, Northampton, Mass.:
 Exhibition of Abraham Bosse.
 February–March 1956.

Denver Art Museum, Denver, Colo.:
 Prints by Bosse, Callot, Hollar.
 Spring, 1956.

Atlanta Art Association, Atlanta, Ga.:
  Ninety-three Toulouse-Lautrec prints.
  March–April 1956.
Busch-Reisinger Museum, Harvard University, Cambridge, Mass.:
  Exhibition of work of Ernst Barlach.
  March–April 1956.
Contemporary Arts Museum, Houston, Tex.:
  Exhibition of Steinlen and Munch.
  March–April 1956.
Watkins Gallery, American University, Washington, D. C.:
  Exhibition "Art and Theatre."
  March–April 1956.
Citizens' Committee for Children of N. Y. C., Inc., New York, N. Y.:
  Gaugin exhibition.
  April–May 1956.
City Art Museum of St. Louis, St. Louis, Mo.:
  Sixty XV-Century woodcuts and engravings.
  April–May 1956.
Corcoran Gallery of Art, Washington, D. C.:
  Meryon, "Malingre Cryptogramme."
  April–May 1956.
Museum of Art, University of Oregon, Eugene, Oreg.:
  Exhibition of "Music."
  April–May 1956.
Philadelphia Art Alliance, Philadelphia, Pa.:
  Klee, Lautrec, and Biddle.
  May–June 1956.
Rijksmuseum, Amsterdam, Holland:
  Three Rembrandt drawings.
  Opened May 1956.

Index of American Design.—During the fiscal year 1956, 28 traveling exhibitions of original watercolor renderings of this collection, with 42 bookings, were sent to the following States:

State	Number of exhibitions	State	Number of exhibitions
Arkansas	1	Michigan	4
California	2	Minnesota	1
District of Columbia	1	New York	1
Florida	1	North Carolina	5
Illinois	2	Pennsylvania	2
Iowa	1	South Carolina	3
Kansas	1	Tennessee	1
Kentucky	1	Texas	4
Maine	1	Wisconsin	1
Maryland	1	Virginia	6
Massachusetts	2		

CURATORIAL ACTIVITIES

The Curatorial Department accessioned 118 gifts to the Gallery during the fiscal year 1956. Advice was given regarding 324 works of art brought to the Gallery for expert opinion and 61 visits to

collections were made by members of the staff in connection with offers of gift or for expert opinion. About 1,550 inquiries requiring research were answered verbally and by letter. John Walker, Chief Curator of the Gallery, gave a lecture at the Newark, N. J., Museum before the opening of an exhibition of Old Masters from American Collections. He also lectured to Miss Porter's School in Farmington, Conn., on the Kress paintings which were placed on exhibition on March 17. Miss Elizabeth Mongan assisted with seminar courses on prints at Beaver College, Bryn Mawr College, and Swarthmore College. She also lectured to school and adult groups in and around Philadelphia. Erwin O. Christensen gave a lecture on the decorative arts in the National Gallery to an adult women's group at the University of Maryland. He also delivered one of the Sunday afternoon Gallery lectures on the decorative arts. John Pancoast gave one of the regular weekly tours on the Italian Sculpture in the Samuel H. Kress Collection. Hereward Lester Cooke lectured at Washington University in St. Louis on "Picasso in the Chester Dale Collection."

Mr. Cooke assisted in the judging of seven art exhibitions during the course of the year in Maryland, Virginia, and the District of Columbia.

Mr. Walker served as trustee of the American Federation of Arts, the American Academy in Rome, and the Bureau of University Travel. He also served on the following committees: Dumbarton Oaks Visiting Committee; Harvard University Press Visiting Committee; Advisory Council, University of Notre Dame. Mr. Walker is also a member of the United States National Commission for UNESCO. Perry B. Cott served as a member of the Board of Governors of the Archaeological Institute of America, Washington Society. Katharine Shepard served as secretary of this organization and was official delegate to its General Meeting in Chicago.

For the first half of the year members of the curatorial staff were intensively engaged in the preparation of new installations and rehanging of the Samuel H. Kress Collection, which was opened to the public on March 18. These included 26 galleries containing paintings, 6 galleries containing sculpture, and 3 rooms especially designed for the exhibition of Renaissance bronzes. These installations were under the supervision of the Director, Dr. Finley; the Chief Curator, Mr. Walker; and Mr. Cott.

RESTORATION

Francis Sullivan, Resident Restorer of the Gallery, made regular and systematic inspection of all works of art in the Gallery's collections and on loan at the Gallery, and periodically removed dust and bloom as required. Mr. Sullivan relined 12 paintings, cleaned and

restored 21 paintings, and gave special treatment as required on 10 paintings. Fourteen paintings were X-rayed as an aid in research. The X-ray developing baths were redesigned, and experiments were continued with the application of 27H and other synthetic varnishes developed by the National Gallery of Art Fellowship at the Mellon Institute of Industrial Research, Pittsburgh, Pa. Proofs of all color reproductions of Gallery paintings were checked and approved, and technical advice on the conservation of paintings was furnished to the public upon request.

Mr. Sullivan also gave advice on and special treatment to works of art belonging to other Government agencies including The White House, the Freer Gallery of Art, and the Smithsonian Institution.

PUBLICATIONS

John Walker wrote the text for a portfolio of paintings which was published by the Harry N. Abrams Co. in the spring. Mr. Cott contributed an article to the Orange Disc, published by the Gulf Oil Co. Mrs. Fern R. Shapley was coauthor with Dr. William Suida of the painting section of the catalog, "Paintings and Sculpture from the Kress Collection acquired by the Samuel H. Kress Foundation, 1951–1956." Mr. Pancoast compiled the text of the sculpture section of the same catalog. An article by Mrs. Shapley on "The Holy Family" by Giorgione appeared in the winter issue of the Art Quarterly. She also wrote an article on the Gallery acquisitions 1945–54 which was published in The Studio. Mr. Christensen's book entitled "Primitive Art" was published by Crowell-Studio in the fall. He also revised the Gallery handbook on Chinese porcelains. Mr. Cooke contributed an article to the College Art Journal on "The Exhibition of German Drawings at the National Gallery of Art."

Mr. Cooke wrote an article for the Burlington Magazine entitled "Three Unknown Drawings by G. L. Bernini." He also prepared a series of ten short articles for publication in the Ladies Home Journal. Three of these articles have appeared this year. An article by Mr. Cooke entitled, "Il Museo e gli Artisti" appeared in Atti del convegno di Museologia, Ministry of Public Instruction, Rome. Mr. Cooke prepared the texts for 20 brief articles which were published to accompany reproductions of paintings in the Samuel H. Kress Collection, which are on sale in Kress stores throughout the country.

During the past fiscal year the Publications Fund published 44 new 11-x-14″ color reproductions and a new color postcard, and made plates of two prints for new Christmas folders; four additional new color postcards were also on order. Three more large collotype reproductions of paintings on exhibition, distributed by a New York publisher, were placed on sale.

Portfolio No. 5 entitled "Masterpieces of the Samuel H. Kress Collection, 1956" was published, as well as a catalog of the 1956 exhibition of paintings acquired by the Samuel H. Kress Foundation. A fourth printing of Handbook No. 1, "How to Look at Works of Art; the Search for Line," was on order, and a book entitled "A Gallery of Children" covering paintings of children in the National Gallery was placed on sale.

Exhibition catalogs of the Asian Artists in Crystal, German Drawings, and A Century and a Half of Painting in Argentina exhibitions were distributed.

EDUCATIONAL PROGRAM

The attendance for the general tours, Congressional tours, "Tours for the Week," and "Pictures of the Week," totaled 45,797, while that for the 42 auditorium lectures on Sunday afternoons was approximately 9,470 during the fiscal year 1956.

Tours, lectures, and conferences arranged by appointment were given to 299 groups and individuals. The total number of people served in this manner was 7,290. This is an increase of 43 groups and 1,248 people served over last year. These special appointments were made for such groups as representatives from leading high schools, universities, museums, other governmental agencies, and distinguished visitors.

Three separate training programs for selected members of the Junior League and the American Association of University Women of Arlington County and Montgomery County were carried forward during the year in connection with the programs of those organizations to assist school children in tours of the Gallery. This training was under the general supervision of the Curator in Charge of Education and the specific supervision of members of the Education Department staff.

Lecture programs on "American Cultural Life" were prepared for librarian members of the USIA and for members of the State Department, who may act as cultural attachés on overseas duty. The lectures for these are given by three members of the Education Department, joined by the Curator of the Index of American Design and a representative from the National Trust for Historic Preservation in America.

The staff of the Education Office delivered 9 lectures in the auditorium on Sunday afternoons, while 33 were given by guest speakers. During April and May, Prof. Ernst H. Gombrich, lecturer at the Warburg Institute in London and Slade Professor of Fine Arts at Oxford, delivered the Fifth Annual Series of seven A. W. Mellon Lectures in the Fine Arts, on the theme "The Visible World and the Language of Art."

During the past year 184 persons borrowed 4,996 slides from the lending collection. The centers throughout the country which distribute the National Gallery of Art film, report that approximately 55,538 viewers throughout the country saw the film in 298 bookings.

Members of the Education Department prepared and recorded 34 broadcasts for use during intermission periods of the National Gallery concerts.

The printed Calendar of Events announcing all Gallery activities and publications is distributed monthly to a mailing list of approximately 5,100 names.

LIBRARY

The most important acquisitions to the Library this year were 2,140 books, pamphlets, periodicals, subscriptions and photographs purchased from private funds made available for this purpose. Gifts included 296 books, pamphlets, and periodicals, while 663 books, pamphlets, periodicals, and bulletins were received on exchange from other institutions. More than 400 persons other than Gallery staff spent time in the Library for study or research during this fiscal year. More than 600 reference requests were answered by telephone.

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 staff and other departments of the Gallery; for the dissemination of knowledge to qualified sources; for exchange with other institutions; for reproduction in scholarly works; and for sale at the request of any interested individual.

INDEX OF AMERICAN DESIGN

The Curator in Charge of the Index of American Design continued to take part in the orientation program for United States Information Agency personnel with a series of eleven 50-minute illustrated lectures given in the National Gallery auditorium.

A new project of lecture notes for 20 loan sets of 2-x-2″ color slides was begun, for the purpose of making the slide sets more useful to students and lecturers. Arrangements have been made to offer Index slide sets for sale to individuals and institutions.

Approximately 668 persons (566 of whom were new users) studied Index material during the fiscal year for the purpose of special research, exhibition, gathering material for publication and design, and by those wanting to become familiar with the collection.

There were 37 sets of 2-x-2″ color slides (consisting of 1,444 slides in all) circulated in 84 bookings in 18 States and Alaska.

Mr. Christensen contributed two articles to historical bulletins and delivered seven lectures to art and museum groups throughout the country.

MAINTENANCE OF BUILDING AND GROUNDS

The building, its mechanical equipment, and the grounds were maintained at the established standard throughout the year.

Rolling screens in art storage room G–35 were installed by contract in June 1956. A cold house was constructed by the Gallery staff in the southwest moat area to control the development of plants propagated in the greenhouse, thereby making available a wider variety of flower and plant decorations for the Garden Courts and special events.

Gallery 25 was altered so that the Titian painting "Saint John on Patmos" could be exhibited on the ceiling with special lighting.

Two additional gallery rooms, galleries 49 and 50, were completed in March 1956.

A portion of the Library area was remodeled, and the space divided into three rooms in which the Samuel H. Kress collection of Renaissance bronzes has been installed.

OTHER ACTIVITIES

Forty Sunday evening concerts were given during the fiscal year 1956 in the East Garden Court. The National Gallery Orchestra, conducted by Richard Bales, played 11 concerts at the Gallery. Two of the orchestral concerts were made possible by the Music Performance Trust Fund of the American Federation of Musicians. Between May 13 and June 10, 1956, five Sunday evenings were devoted to the Gallery's Thirteenth American Music Festival. All the concerts were broadcast in their entirety by Station WGMS–AM and FM, Washington, and the Good Music Network. The National Gallery concert on June 10, 1956, featured the premiere performance of Richard Bales' "The Union," a cantata on music of the North during the years 1861–1865. During the fiscal year 16 works by American composers were given their first Washington performance; and 4 were given world premieres.

The Photographic Laboratory of the Gallery produced 11,148 prints, 300 black-and-white slides, 1,131 color slides, 170 color transparencies, in addition to 1,868 negatives, color-separation negatives, infrared and ultraviolet photographs, and X-ray shadowgraphs; also 1,705 lantern slides were bound.

During the fiscal year 4,246 copies of 16 press releases were issued in connection with Gallery activities, while 190 permits to copy, and 171 permits to photograph in the Gallery were also issued.

OTHER GIFTS

Gifts of money were made during the fiscal year 1956 by the Old Dominion Foundation, the Avalon Foundation, Lessing J. Rosenwald, Douglas Dillon, Mrs. George M. Humphrey, and Louis B. Fleming.

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, 1956, 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.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

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, 1956:

The acquisitions section recorded the receipt of 78,715 publications during the year, the larger number of which came, as usual, from scientific, technical, and cultural organizations all over the world, in exchange for Smithsonian publications. There were 237 new exchanges arranged, and issuing agencies, new and old, were generous in supplying 3,124 publications, mostly parts of periodicals and other serials, needed to fill gaps in the collections.

In moving its quarters from the Arts and Industries Building, the American Association of Museums generously turned over to the library more than 30,000 books, periodicals, and pamphlets which had served their purpose in the offices of the Association. Many items from this rich collection have already been added to the library, some 12,000 pieces found to be duplicates or otherwise not needed were sent to the United States Book Exchange for exchange credit, and the checking and processing of the remainder of the material are still in progress.

The library is greatly indebted to other organizations and to the many individual donors who sent multiple or single gifts of books and papers. Many members of the staff of the Institution were thoughtful and generous in making gifts of books and papers frequently throughout the year.

From the estate of the late Gerrit S. Miller, Jr., came 537 volumes selected from Mr. Miller's large personal library. The majority of them were works on mammals and other zoological subjects, but the others reflected the catholic interests and cultivated tastes of this distinguished former member of the Smithsonian staff.

Mrs. John P. Marble's gift of 157 handsomely bound volumes of journals and individual works on geochemistry, from the library of her late husband, was also a noteworthy addition.

Probably no library ever has enough money for the purchase of books, and the Smithsonian library is certainly no exception. Faced with the responsibility of serving the whole Institution with the literature needed by the curators and other specialists working in many different subject fields, books and journals that cannot be obtained in exchange or as gifts must be selected with great care for purchase from

limited funds. The general principle of selection is that priority shall be given to important works of reference for the common use of all, and to primary sources of special information. After buying 575 books and subscribing to 426 periodicals, funds for the year were exhausted, leaving large numbers of requisitions still unprocessed in the acquisitions section.

There was little opportunity to reduce the library's continuing file of desiderata among the out-of-print source books so important in museum work. Far too seldom are there funds available when one or another of these works appears, unpredictably, in the old-book market. The library has no interest in acquiring collectors' items, per se, but a good many of the most-needed older books, especially in the fields of natural history and the fine arts, fall into that category and are likely to be prohibitively costly. One of the library's continually recurring problems is how to get the use of rare books not in its own collections. Rare books seldom can be borrowed from other libraries, microfilms are not very satisfactory, especially when they must be read and referred to in comparison with specimens, and photostats of more than a few pages are likely to be almost as expensive as the original works.

The library added 5,918 publications to the Smithsonian Deposit, and sent more than 20,000 other publications to the Library of Congress without recording them individually. These included doctoral dissertations, foreign and state documents, and miscellaneous books, papers, and periodicals on subjects not pertinent to the work of the Institution. There were 657 medical dissertations sent to the Armed Forces Medical Library.

The catalog section classified and cataloged 4,748 volumes, entered 20,534 periodicals, and filed 29,553 catalog cards. In the latter part of the year, the staff of the section, after an initial survey of the very large accumulation of wholly or incompletely cataloged material in the library of the Bureau of American Ethnology, made a very good beginning in sorting and arranging it for processing or other disposition. With the advice of the Director of the Bureau, 2,675 of the pieces so far handled were discarded. The work will be continued, as time permits, during the coming year.

The library recorded the loan of 9,276 volumes, 1,127 of which were interlibrary loans to 88 different libraries throughout the United States. The record of intramural loans never represents more than a fractional part of the circulation of books and periodicals among members of the staff of the Institution. Publications assigned to the different sectional libraries for filing circulate freely within the section, without being counted, except in the Division of Insects where

there is a member of the library staff in charge of the sectional library. Most of the 4,247 currently acquired publications assigned to sectional libraries during the year probably circulated within the respective sections, in addition to the circulation of the books and periodicals previously assigned. No reasonably accurate numerical estimate of the actual use of books throughout the Institution can be made.

The reference service of the library is the most difficult to measure statistically. To say that more than 13,000 reference questions were answered is to give no idea of the time, ingenuity, and imagination required to find the answers to many of the more perplexing questions asked. There was a time, not too long ago, when little was expected of librarians except to be custodians of books. The prime requirement of the library nowadays is service from and through books. Many years ago, Lord Rayleigh said, "By a fiction as remarkable as any to be found in law, what has once been published . . . is usually spoken of as 'known' and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory." All the modern refinements of cataloging and the invention of fabulous fact-finding push-button machines are directed toward making "rediscovery" easy, but in the last analysis the ultimate dependence is still upon human brains and skills.

For the first time in many years, a much-increased allotment for library binding made it possible not only to send current periodicals to the bindery as soon as each volume was completed, but to reduce the arrearage of binding or rebinding of older periodicals and books to a very considerable extent. It is gratifying to report that 8,016 volumes were sent to the bindery, and that 1,386 worn and fragile volumes requiring special handling were expertly repaired in the library.

There were several major changes in the staff during the year. The death of Mrs. Hope Hanna Simmons, chief of the acquisitions section, on June 16, 1956, was a sad loss. Mrs. Simmons had served the library most efficiently since 1927.

Miss Minna Gill, chief of the catalog section, resigned on November 30, 1955, and Mrs. Ruth W. Dawson, also of the catalog section, retired on December 31, after more than 30 years of service. Miss Ruth Blanchard was appointed chief of the catalog section on January 23, 1956.

The most serious handicaps to good library service continue to be the scattered and inefficiently arranged housing of the library, overcrowding of the shelves, the need for a larger staff of trained assistants, and for more money to buy books.

SUMMARIZED STATISTICS

ACCESSIONS

	Volumes	Total recorded volumes, 1956
Smithsonian Deposit at the Library of Congress	855	586, 447
Smithsonian main library (including former Office and Museum libraries)	3, 106	300, 383
Astrophysical Observatory (including Radiation and Organisms)	141	14, 842
Bureau of American Ethnology	387	35, 977
National Air Museum	98	433
National Collection of Fine Arts	161	13, 870
National Zoological Park	0	4, 205
Total	4, 748	956, 157

Unbound volumes of periodicals, and reprints and separates from serial publications, of which there are many thousands, have not been included in these totals.

EXCHANGES

New exchanges arranged	237
Specially requested publications received	3, 124

CATALOGING

Volumes cataloged	4, 748
Catalog cards filed	29, 553

PERIODICALS

Periodical parts entered	20, 534

5,089 were sent to the Smithsonian Deposit.

CIRCULATION

Loans of books and periodicals	9, 276

Circulation in sectional libraries is not counted except in the Division of Insects.

BINDING AND REPAIR

Volumes sent to the bindery	8, 016
Volumes repaired in the library	1, 386

Respectfully submitted.

LEILA F. CLARK, *Librarian.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on Publications

SIR: I have the honor to submit the following report on the publications of the Smithsonian and its branches for the year ended June 30, 1956:

The publications of the Smithsonian Institution are issued partly from federally appropriated funds (Smithsonian Reports and publications of the National Museum, the Bureau of American Ethnology, the National Collection of Fine Arts, and the Astrophysical Observatory) and partly from private endowment funds (Smithsonian Miscellaneous Collections, publications of the Freer Gallery of Art, and some special publications). The Institution also edits and publishes under the auspices of the Freer Gallery of Art the series Ars Orientalis, which appears under the joint imprint of the University of Michigan and the Smithsonian Institution. The second volume in this series was ready to go to the printer at the end of the year. In addition, the Smithsonian publishes a guide book, a picture pamphlet, postcards and a postcard folder, a color-picture album, color slides, and popular publications on scientific and historical subjects related to its important exhibits and collections for sale to visitors. Through its publication program the Smithsonian endeavors to carry out its founder's expressed desire for the diffusion of knowledge.

During the year the Institution published 13 papers and title page and contents of 3 volumes in the Miscellaneous Collections; 1 Annual Report of the Board of Regents and separates of 18 articles in the Report Appendix; 1 Annual Report of the Secretary; reprints of 3 papers in the Miscellaneous Collections and 1 Report separate; and 1 special publication.

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 and 1 Bulletin.

The Smithsonian Institution Traveling Exhibition Service, under the National Collection of Fine Arts, published special catalogs for 6 of its circulating exhibits, and a catalog of its available exhibits for 1956–1957.

The Freer Gallery of Art issued title page and contents of volume 2 of its Occasional Papers series, and 4 special publications.

There were distributed 424,389 copies of publications and miscellaneous items. Publications: 58 Contributions to knowledge, 32,131 Miscellaneous Collections, 9,126 Annual Reports and 16,561 pamphlet copies of Report separates, 629 War Background Studies, 19,463 special publications, 231 reports of the Harriman Alaska Expedition, 61,060 publications of the National Museum, 17,018 publications of the Bureau of American Ethnology, 30,351 publications of the National Collection of Fine Arts, 37 publications of the Astrophysical Observatory, 19 publications of the Freer Gallery of Art, 4,137 reports of the American Historical Association, and 1,906 publications not issued by the Smithsonian Institution. Miscellaneous: 202 sets and 10,013 prints of North American Wildflowers and 1 Pitcher Plant volume, 44,933 Guide Books, 19,713 picture pamphlets, 74,571 postcards and 12,180 postcard folders, 4,260 photo sets, 8,482 color slides, 10,621 color picture albums, 47,765 information leaflets, 23 New Museum of History and Technology pamphlets, and 98 statuettes.

The 1956 allotment from Government funds of $162,000 for printing and binding was entirely obligated at the close of the year.

The Astrophysical Observatory during the year inaugurated a new series entitled Smithsonian Contributions to Astrophysics, which will publish the results of the research of the Observatory and its collaborators, with particular emphasis on problems of the study of the sun, the earth, and the solar system. At the close of the year the first number of the new series was in press, consisting of a group of papers under the general title "New Horizons in Astronomy" and supported jointly by the National Science Foundation.

SMITHSONIAN PUBLICATIONS

Smithsonian Miscellaneous Collections

VOLUME 126

No. 1. The Bromeliaceae of Brazil, by Lyman B. Smith. 290 pp., 129 figs. (Publ. 4184.) September 7, 1955. ($3.50.)

VOLUME 127

Chazyan and related brachiopods, by G. Arthur Cooper. Pt. I, text, pp. i–xvi+1–1024; Pt. II, plates (269), with legends, pp. 1025–1245. (Publ. 4253.) June 12, 1956. ($20.00.)

VOLUME 128

No. 5. Revision of some Recent foraminiferal genera, by Alfred R. Loeblich, Jr., and Helen Tappan. 37 pp., 4 figs. (Publ. 4214.) July 21, 1955. (45 cents.)

No. 7. Lower Cambrian ptychopariid trilobites from the conglomerates of Quebec, by Franco Rasetti. 35 pp., 6 pls. (Publ. 4216.) Aug. 11, 1955. (60 cents.)

No. 8. A review of the upper Eocene Artiodactyla of North America, by C. Lewis Gazin. 96 pp., 18 pls., 2 figs. (Publ. 4217.) September 28, 1955. ($1.60.)

No. 9. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska, by G. E. MacGinitie. 201 pp., 8 pls., 3 figs. (Publ. 4221.) November 30, 1955. ($2.25.)

VOLUME 131

No. 1. Leading operations of the Smithsonian Astrophysical Observatory, 1895–1955, by C. G. Abbot. 8 pp. (Publ. 4222.) September 22, 1955. (15 cents.)

No. 2. The last cruise of H. M. S. *Loo*, by Mendel L. Peterson. 55 pp., 17 pls., 3 figs. (Publ. 4224.) November 23, 1955. ($1.00.)

No. 3. Synonymical notes on neotropical flies of the family Tabanidae (Diptera), by G. B. Fairchild. 38 pp. (Publ. 4225.) January 11, 1955. (60 cents.)

No. 4. New Cretaceous Brachiopoda from Arizona, by G. Arthur Cooper. 18 pp., 4 pls. (Publ. 4227.) December 21, 1955. (45 cents.)

No. 5. A checklist of fossil and prehistoric birds of North America and the West Indies, by Alexander Wetmore. 105 pp. (Publ. 4228.) January 25, 1956. (70 cents.)

No. 6. Paleocene mammalian faunas of the Bison Basin in south-central Wyoming, by C. Lewis Gazin. 57 pp., 16 pls., 2 figs. (Publ. 4229.) February 28, 1956. ($1.00)

VOLUME 132

An index to the genera and species of the Foraminifera, Parts 1 and 2, by Charles Davies Sherborn, with foreword by Alfred R. Loeblich. (Reprint of Smithsonian Miscellaneous Collections Publs. 856 and 1031.) 485 pp. (Publ. 4226.) August 18, 1955. ($3.50.)

ANNUAL REPORTS

Report for 1954.—The complete volume of the Annual Report of the Board of Regents for 1954 was received from the printer October 17, 1955:

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, 1954. ix+455 pp., 77 pls., 29 figs. (Publ. 4190.)

The general appendix contained the following papers (Publs. 4191–4208):

The nature of the upper atmosphere, by H. S. W. Massey.
Solar influence on the earth, by John W. Evans.
Fifty years of flying progress, by Grover Loening.
Tektites and the lost planet, by Ralph Stair.
On comparing the brain with machines, by D. M. MacKay.
A glimpse of incomprehensibles, by George W. Corner.
The electron microscope in biology, by Ralph W. G. Wyckoff.
The spread of the cattle egret, by Alexander Sprunt, Jr.
The migration of mammals, by L. Harrison Matthews.
The flight of animals, by James Gray.
Botanical studies in Fiji, by Albert C. Smith.
The romance of domesticated plants, by Glenn W. Blaydes.
The scientific detection of crime, by Charles Sannié.
The great Piltdown hoax, by William L. Straus, Jr.
Our State names, by John P. Harrington.
Shanidar cave, a Paleolithic site in northern Iraq, by Ralph S. Solecki.
Medicine, warfare, and history, by John F. Fulton.
Harriet Lane Johnston and the National Collection of Fine Arts, by Thomas M. Beggs.

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Report for 1955.—The Report of the Secretary, which will form part of the Annual Report of the Board of Regents to Congress, was issued January 13, 1956:

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, 1955. ix+173 pp., 7 pls. (Publ. 4230.)

Reprints

Utilizing heat from the sun, by C. G. Abbot. Smithsonian Misc. Coll., vol. 98, No. 5, 11 pp., 4 pls., 1 fig. (Publ. 3530.) (30 cents.)

Smithsonian Physical Tables, compiled by W. E. Forsythe. Smithsonian Misc. Coll., vol. 120 (whole vol.). (Publ. 4169.) ($10.00.)

Solar variation a leading weather element, by C. G. Abbot. Smithsonian Misc. Coll., vol. 122, No. 4, 35 pp., 22 figs. (Publ. 4135). (60 cents.)

Solar radiation as a power source, by C. G. Abbot. Smithsonian Ann. Rep. 1943, 9 pp., 3 pls., 3 figs. (Publ. 3742.)

The Smithsonian Institution. 35 pp., 15 pls. (Publ. 4145.) 1956. (50 cents.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

Report

The United States National Museum annual report for the year ended June 30, 1955. v+102 pp., illustr. [1956.]

Proceedings

Volume 102

Title page, table of contents, and index. Pp. i–iv, 529–549. February 13, 1956.

Volume 103

Title page, table of contents, and index. Pp. i–v, 633–667. March 12, 1956.

Volume 104

No. 3342. Biology and taxonomy of North American beetles of the subfamily Geotrupinae, with revisions of the genera *Bolbocerosoma*, *Eucanthus*, *Geotrupes*, and *Peltotrupes* (Scarabaeidae), by Henry F. Howden. Pp. 151–319, pls. 1–18. November 28, 1955.

No. 3343. Fruit flies of the genus *Tomoplagia* Coquillett (Diptera, Terphritidae), by Martin L. Aczél. Pp. 321–411, figs. 90–102, pls. 19–26. September 28, 1955.

No. 3344. Scarab beetles of the genus *Psammodius* in the Western Hemisphere, by O. L. Cartwright. Pp. 413–462. August 24, 1955.

No. 3345. A further contribution to the ornithology of northeastern Venezuela, by Herbert Friedmann and Foster D. Smith, Jr. Pp. 463–524, figs. 103–107, pls. 27–30. December 2, 1955.

No. 3346. Modifications of pattern in the aortic arch system of birds and their phylogenetic significance, by Fred H. Glenny. Pp. 525–621, figs. 108–119. December 16, 1955.

No. 3347. Fishes of the family Percophididae from the coasts of eastern United States and the West Indies, with descriptions of four new species, by Isaac Ginsburg. Pp. 623–639, figs. 120–122. October 13, 1955.

No. 3348. Neotropical Miridae, LXV: New genera and species of bugs of the tribe Termatophylini (Hemiptera: Deraeocorinae), by José C. M. Carvalho. Pp. 641–649, fig. 123, pl. 31. October 27, 1955.

VOLUME 105

No. 3349. Notes on shrimps from the Marshall Islands, by Fenner A. Chace, Jr. Pp. 1–22, 8 figs. August 12, 1955.

No. 3350. Lanternflies of the family Issidae of the Lesser Antilles (Homoptera: Fulgoroidea), by R. G. Fennah. Pp. 23–47, 5 figs. November 23, 1955.

No. 3351. An anatomical study of the peregrine megascolecid earthworm *Pheretima hupeiensis* in the eastern United States, by William C. Grant, Jr. Pp. 49–63, 4 figs. October 17, 1955.

No. 3352. Some polyclad flatworms from Polynesia and Micronesia, by Libbie H. Hyman. Pp. 65–82, 5 figs. September 6, 1955.

No. 3353. Biting lice of the genus *Saemundssonia* (Mallophaga: Philopteridae) occurring on terns, by Ronald A. Ward. Pp. 83–100, 1 fig. September 8, 1955.

No. 3354. Three Miocene porpoises from the Calvert Cliffs, Maryland, by Remington Kellogg. Pp. 101–154, 1 fig., 21 pls. December 14, 1955.

No. 3355. A review of the New World flies of the genus *Conops* and allies (Diptera: Conopidae), by Sidney Camras. Pp. 155–187. September 28, 1955.

No. 3356. Populations of the berycoid fish family Polymixiidae, by Ernest A. Lachner. Pp. 189–206, 1 pl. October 21, 1955.

No. 3357. Contributions to the nomenclature, systematics, and morphology of the Octocorallia, by Frederick M. Bayer. Pp. 207–220, 8 pls. December 21, 1955.

No. 3358. Bryozoa of the United States Navy's 1947–1948 Antarctic Expedition, I–IV, by Mary D. Rogick. Pp. 221–317, 35 pls. March 13, 1956.

No. 3359. Type species of the genera and subgenera of parasitic wasps comprising the superfamily Proctotrupoidea (order Hymenoptera), by C. F. W. Muesebeck and Luella M. Walkley. Pp. 319–419. February 16, 1956.

No. 3360. The Spongilla-flies, with special reference to those of the Western Hemisphere (Sisyridae, Neuroptera), by Sophy I. Parfin and Ashley B. Gurney. Pp. 421–529, 24 figs., 3 pls. May 16, 1956.

No. 3361. Marine polychaete worms from Labrador, by Marian H. Pettibone. Pp. 531–584, 1 fig. March 29, 1956.

VOLUME 106

No. 3362. Revision of the milliped genus *Dixioria* (Polydesmida: Xystodesmidae), by Richard L. Hoffman. Pp. 1–19, 4 figs. March 29, 1956.

No. 3363. A revision of the flies of the genus *Rivellia* (Otitidae, Diptera) of America north of México, by Ryoji Namba. Pp. 21–84, 10 figs. June 5, 1956.

BULLETINS

208. The honey-guides, by Herbert Friedmann. vii+292 pp., 6 figs., 25 pls. October 20, 1955.

CONTRIBUTIONS FROM THE U. S. NATIONAL HERBARIUM

VOLUME 32

Part 1. The American species of Aeschynomene, by Velva E. Rudd. iii+172 pp., 10 figs. October 13, 1955.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

ANNUAL REPORT

Seventy-second Annual Report of the Bureau of American Ethnology, 1954–1955. ii+24 pp. 1956.

BULLETIN

Bulletin 163. The Diné: Origin myths of the Navaho Indians, by Aileen O'Bryan. vii+187 pp., 1 pl., 24 figs. June 27, 1956.

PUBLICATIONS OF THE NATIONAL COLLECTION OF FINE ARTS

Contemporary Finnish architecture. (Smithsonian Institution Traveling Exhibition Service catalog.) 20 pp., illustr. [October 1955.]

German drawings. Masterpieces from five centuries. (Smithsonian Institution Traveling Exhibition Service catalog.) 59 pp., illustr. [November 1955.]

Tapestries by Hannah Ryggen. (Smithsonian Institution Traveling Exhibition Service catalog.) 8 pp., illustr. [November 1955.]

Photographs of Venetian villas. (Smithsonian Institution Traveling Exhibition catalog.) 13 pp., illustr. [November 1955.]

Smithsonian Institution Traveling Exhibitions. 1956–1957 catalog. (Smithsonian Institution Traveling Exhibition Service catalog.) [1956.]

Italian arts and crafts. (Smithsonian Institution Traveling Exhibition catalog.) 15 pp., illustr. [February 1956.]

Finnish crafts. Tapio Wirkkala and Rut Bryk. (Smithsonian Institution Traveling Exhibition catalog.) 13 pp., illustr. [April 1956.]

PUBLICATIONS OF THE FREER GALLERY OF ART

Title page and table of contents, Occasional Papers, vol. 2. (Publ. 4223.) [September] 1955.

The Charles Lang Freer Medal (first presentation). Booklet containing a partial bibliography by Prof. Osvald Sirén.

Charles Lang Freer Centennial Exhibition (1856–1956). Booklet listing objects on exhibition in galleries.

First presentation of the Charles Lang Freer Medal. 27 pp., 3 pls. February 25, 1956.

Chinese porcelains from the Ardebil Shrine, by John Alexander Pope. 194 pp., 142 pls., 19 figs. [June] 1956. (Publ. 4231.)

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 in the act of incorporation of the Association. The following reports were issued during the year:

Annual Report of the American Historical Association for the year 1953. Vol. 2. Writings on American History, 1951. 544 pp. 1956.

Annual Report of the American Historical Association for the year 1954. Vol. 1. Proceedings and list of members. 179 pp. 1956.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Fifty-eighth Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, on April 4, 1956.

Respectfully submitted.

PAUL H. OEHSER,
Chief, Editorial and Publications Division.

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report of the Executive Committee of the Board of Regents of the Smithsonian Institution

For the Year Ended June 30, 1956

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, freight, 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, plus accretions, are listed below, together with a statement showing 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 1956	Income 1956
Parent fund (original Smithson bequest, plus accumulated savings)	$729, 190. 53	$43, 739. 96
Subsequent bequests, gifts, and other funds, partly deposited in the U. S. Treasury and partly invested in the consolidated fund:		
Abbott, W. L., special	18, 922. 27	967. 93
Avery, Robert S., and Lydia	64, 167. 58	3, 478. 68
Endowment	448, 899. 22	23, 449. 59
Habel, Dr. S.	500. 00	30. 00
Hachenberg, George P., and Caroline	5, 107. 96	268. 66
Hamilton, James	3, 012. 70	176. 97
Henry, Caroline	1, 536. 06	80. 79
Hodgkins, Thomas G.	154, 474. 02	8, 983. 63
Olmsted, Helen A.	1, 017. 56	18. 44
Porter, Henry Kirke	363, 745. 33	19, 132. 12
Rhees, William Jones	1, 190. 89	67. 02
Sanford, George H.	2, 230. 62	125. 47
Witherspoon, Thomas A.	163, 905. 23	8, 621. 03
Total	1, 228, 709. 43	65, 400. 33
Grand total	1, 957, 899. 96	109, 140. 29

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 1956	Income 1956
Abbott, William L., for investigations in biology	$132,709.55	$6,952.38
Arthur, James, for investigations and study of the sun and annual lecture on same	50,795.15	2,671.68
Bacon, Virginia Purdy, for traveling scholarship to investigate fauna of countries other than the United States	63,632.50	3,346.93
Baird, Lucy H., for creating a memorial to Secretary Baird	30,579.78	1,608.40
Barney, Alice Pike, for collection of paintings and pastels and for encouragement of American artistic endeavor	36,428.22	1,916.04
Barstow, Frederick D., for purchase of animals for Zoological Park	1,269.78	66.72
Canfield Collection, for increase and care of the Canfield collection of minerals	48,577.20	2,555.02
Casey, Thomas L., for maintenance of the Casey collection and promotion of researches relating to Coleoptera	15,919.92	837.37
Chamberlain, Francis Lea, for increase and promotion of Isaac Lea collection of gems and mollusks	35,766.35	1,881.21
Dykes, Charles, for support in financial research	54,687.82	2,876.11
Eickemeyer, Florence Brevoort, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr	13,805.60	726.13
Hillyer, Virgil, for increase and care of Virgil Hillyer collection of lighting objects	8,347.27	439.03
Hitchcock, Albert S., for care of the Hitchcock Agrostological Library	2,004.11	105.43
Hodgkins, 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, to further researches in physical anthropology and publication in connection therewith	47,170.96	2,358.30
Hughes, Bruce, to found Hughes alcove	24,311.23	1,278.73
Loeb, Morris, for furtherance of knowledge in the exact sciences	110,691.94	5,822.10
Long, Annette and Edith C., for upkeep and preservation of Long collection of embroideries, laces, and textiles	689.64	36.27
Maxwell, Mary E., for care and exhibition of Maxwell collection	24,912.29	1,310.34
Myer, Catherine Walden, for purchase of first-class works of art for use and benefit of the National Collection of Fine Arts	25,654.56	1,349.38
Nelson, Edward W., for support of biological studies	21,121.66	987.37
Noyes, Frank B., for use in connection with the collection of dolls placed in the U. S. National Museum through the interest of Mr. and Mrs. Noyes	1,220.25	64.18
Pell, Cornelia Livingston, for maintenance of Alfred Duane Pell collection	9,414.49	495.18
Poore, Lucy T. and George W., for general use of the Institution when principal amounts to $250,000	206,261.18	10,498.81
Rathbun, Richard, for use of division of U. S. National Museum containing Crustacea	13,508.64	710.52
Reid, Addison T., for founding chair in biology, in memory of Asher Tunis	33,983.01	1,857.14
Roebling Collection, for care, improvement, and increase of Roebling collection of minerals	153,284.82	8,062.39
Roebling Solar Research	43,539.32	2,290.07
Rollins, Miriam and William, for investigations in physics and chemistry	119,258.21	6,272.71
Smithsonian employees' retirement	32,571.49	1,744.56
Springer, Frank, for care and increase of the Springer collection and library	22,776.34	1,198.00
Strong, Julia D., for benefit of the National Collection of Fine Arts	12,698.95	667.93
Walcott, Charles D. and Mary Vaux, for development of geological and paleontological studies and publishing results of same	606,908.14	31,980.87
Walcott, Mary Vaux, for publications in botany	73,519.36	3,866.91
Younger, Helen Walcott, held in trust	82,890.00	4,332.46
Zerbee, Frances Brinckle, for endowment of aquaria	1,204.74	63.34
Total	2,262,213.47	119,280.01

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 stocks and securities to the estimated value of $1,958,591.42, as an endowment fund for the operation of the Gallery. The fund now amounts to $7,422,474.98.

SUMMARY OF ENDOWMENTS

Investment endowment for general purposes	$1, 957, 899. 96
Investment endowment for specific purposes other than Freer endowment	2, 262, 213. 47
Total invested endowment other than Freer	4, 220, 113. 43
Freer invested endowment for specific purposes	7, 422, 474. 98
Total invested endowment for all purposes	11, 642, 588. 41

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	$1, 163, 133. 61	
Stocks	1, 982, 829. 93	
Real estate and mortgages	5, 891. 00	
Uninvested capital	68, 258. 89	
		3, 220, 113. 43
Total investments other than Freer endowment		4, 220, 113. 43
Investments of Freer endowment (cost or market value at date acquired):		
Bonds	$4, 242, 034. 31	
Stocks	2, 973, 956. 30	
Uninvested capital	206, 484. 37	
		7, 422, 474. 98
Total investments		11, 642, 588. 41

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1956[1]

Cash balance on hand June 30, 1955		$586, 853. 38
Receipts, other than Freer endowment:		
Income from investments	$247, 422. 84	
Gifts and contributions	646, 732. 82	
Books and publications	49, 433. 13	
Miscellaneous	27, 910. 05	
Employees' payroll withholdings and refund of advances (net)	8, 562. 04	
Proceeds from real estate	45. 00	
Proceeds from sale of securities (net)	224, 658. 71	
Proceeds from sale of cash securities (net)	(98, 798. 14)	
Total receipts other than Freer endowment		1, 105, 966. 45
Receipts from Freer endowment:		
Income from investments		357, 880. 32
Total		2, 050, 700. 15
Disbursements other than Freer endowment:		
Administration	$103, 989. 88	
Publications	32, 349. 47	
Library	1, 210. 42	
Custodian fees and servicing securities	4, 623. 26	
Miscellaneous	2, 941. 63	
Researches and explorations	521, 537. 58	
S. I. Retirement System	2, 323. 32	
Total disbursements other than Freer endowment		668, 975. 56
Disbursements from Freer endowment:		
Salaries	$130, 906. 22	
Purchases for collection	164, 325. 00	
Custodian fees and servicing securities	10, 889. 23	
Miscellaneous	41, 248. 55	
Total disbursements from Freer endowment		347, 369. 00
Total disbursements		1, 016, 344. 56
Cash balance June 30, 1956		1, 034, 355. 59
Total		2, 050, 700. 15

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

ASSETS

Cash:			
United States Treasury current account	$434, 750. 25		
In banks and on hand	599, 605. 34		
	1, 034, 355. 59		
Less uninvested endowment funds	274, 743. 26		
		$759, 612. 33	
Travel and other advances		2, 603. 00	
Cash invested (U. S. Treasury notes)		823, 986. 48	
			$1, 586, 201. 81
Investments—at book value:			
Endowment funds:			
Freer Gallery of Art:			
Stocks and bonds	$7, 215, 990. 61		
Uninvested cash	206, 484. 37		
		7, 422, 474. 98	
Investments at book value other than Freer:			
Stocks and bonds	3, 061, 535. 03		
Uninvested cash	68, 258. 89		
Special deposit in U. S. Treasury at 6 percent interest	1, 000, 000. 00		
Other stocks and bonds	84, 428. 51		
Real estate and mortgages	5, 891. 00		
		4, 220, 113. 43	
			11, 642, 588. 41
			13, 228, 790. 22

UNEXPENDED FUNDS AND ENDOWMENTS

Unexpended funds:		
Income from Freer Gallery of Art endowment		$557, 709. 90
Income from other endowments:		
Restricted	$350, 815. 28	
General	276, 104. 13	
		626, 919. 41
Gifts and grants		401, 572. 50
		1, 586, 201. 81
Endowment funds:		
Freer Gallery of Art	$7, 422, 474. 98	
Other:		
Restricted	2, 262, 213. 47	
General	1, 957, 899. 96	
		11, 642, 588. 41
Total		13, 228, 790. 22

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 $4,759.33.

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 Institution gratefully acknowledges gifts and grants from the following:

American Philosophical Society, gift for hybridization studies of stink bugs.

American Philosophical Society, grant to further research on the color prints of John Baptist Jackson.

Atomic Energy Commission, additional gift for the studies on the regulation of plant growth by radiation.

Atomic Energy Commission, additional gift for mechanism of action of ionizing radiation.

Mr. and Mrs. J. Bruce Bredin, gift to establish "The Bredin Expedition Fund 1955–1956."

Mrs. Agnes Chase, additional gift for copying the index to grass names.

Department of the Army, Chemical Corps, additional gift for research studies to determine the influence of plant regulators.

Entomological Society of America, gift to aid in printing of manuscript entitled "History of Entomology in World War II."

Edward P. Henderson, gift for research on meteorites.

Humble Oil & Refining Co. and California Research Corp., grants-in-aid to the Planktonic Foraminifera Project.

Idaho Power Company, grant for Snake River Archeological Project.

John Simon Guggenheim Memorial Foundation, additional grant for the wax metabolism fund.

Edwin A. Link, additional gift for historical research (marine archeology).

National Academy of Sciences, grant for preparing a manuscript translation of a "Flora of Japan" by Jisaburo Ohwi.

National Academy of Sciences, grant for support of research on U. S. National Museum collection of ascidians.

National Geographic Society, grant to complete the excavations and related work at the archeological site in Jackson County, Ala.

National Science Foundation, grant for taxonomic study of the phanerogams of Colombia.

National Science Foundation, additional grant to make possible the continuation of work of the Canal Zone Biological Area on Barro Colorado Island.

National Science Foundation, grant for the support of research entitled "Monograph of Fresh-water Calanoid Copepods."

National Science Foundation, grant for an optical tracking and scientific analysis program for the U. S. Earth Satellite Program.

National Science Foundation, grant for research on recent Foraminifera from Ifaluk Atoll.

National Science Foundation, grant for study of physical changes in the Indian population of Hacienda Vicos.

National Science Foundation, grant for botanical studies in southeastern Brazil.

National Science Foundation, additional grant for research on "Taxonomy of the Bamboos."

National Science Foundation, grant for publication of manuscript entitled "New Horizons in Astronomy."

Nelson & Goldman Orchard Co., additional gift for the support of biological studies.

Office of Naval Research, gift for research on mammalian hosts and their parasites.

Office of Naval Research, additional gift to perform psychological research studies.

Office of Naval Research, gift to assist work in progress on the preparation of a synoptic catalog of the mosquitoes of the world.

Helen A. Olmsted, bequest, to be added to the Smithsonian Institution endowment fund.

Research Corp., gift to be used in partially defraying the cost of publishing a current edition of the Smithsonian Geographical Tables.

Research Corp., grant for the support of a project entitled "Application of X-ray Techniques to the Study of the Osteology and Relationships of Fishes in Systematic Ichthyology."

The Chicago Zoological Society, San Diego Zoo, and New York Zoological Society, gifts for the Penguin Fund.

Gene M. Stirling, additional gift for the study of the archeology and ethnology of Florida.

The Link Foundation, gift for guided-tour materials and service.

The Museum of Natural History of Houston, gift for improvement of the U. S. National Herbarium collection.

The Rockefeller Foundation, grant for continued research by J. J. Murayama on scolytid and scarabaeid beetles.

United States Air Force, grant for study of atmospheric entry and impact of high-velocity meteorites.

United States Air Force, grant for research directed toward the study of the rate of accretion of interplanetary matter by the earth.

United States Information Agency, additional grant for exhibition "American Primitive Paintings."

Wenner-Gren Foundation and American Philosophical Society, grants to aid archeological research in Shanidar cave, northern Iraq.

Miss Madeline Wilkinson, gift for cleaning and repairing historic dresses or linens.

For support of the Bio-Sciences Information Exchange:

- Atomic Energy Commission
- Department of the Air Force
- Department of the Army
- Department of the Navy
- National Science Foundation
- Public Health Service
- Veterans Administration

Included in the above list of gifts and contributions are reimbursable contracts.

The foregoing report relates only to the private funds of the Institution.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1956:

Salaries and expenses	$4,166,000
National Zoological Park	690,900
Museum of History and Technology	2,288,000

In addition, funds were transferred from other Government agencies for expenditure under the direction of the Smithsonian Institution as follows:

Working funds, transferred from the National Park Service, Interior Department, for archeological investigations in river basins throughout the United States	$92,360

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.

AUDIT

The report of the audit of the Smithsonian private funds follows:

WASHINGTON, D. C. *September 5, 1956.*

THE BOARD OF REGENTS,
SMITHSONIAN INSTITUTION,
Washington 25, D. C.

We have examined the financial statements and schedules, as listed in the accompanying index, 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, 1956. 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, 1956 (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

CLARENCE CANNON
CARYL P. HASKINS
ROBERT B. FLEMING
Executive Committee.

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

Salaries and expenses [illegible]
National Zoological Park [illegible]
Museum of History and Technology [illegible]

In addition, funds were transferred from other Government agencies for expenditure under the direction of the Smithsonian Institution as follows:

Working funds, transferred from the National Park Service, Interior Department, for archeological investigations in river basins throughout the United States [illegible]

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.

AUDIT

The report of the audit of the Smithsonian private funds follows:

[illegible]

The Board of Regents,
Smithsonian Institution,
Washington [illegible], D.C.

We have examined the financial statements and schedules, as listed in the accompanying index, of the Smithsonian Institution [illegible] for the year ended June 30, [illegible]. 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.

[illegible]

In our opinion, [illegible] of the private funds of the Smithsonian Institution at June 30, [illegible] [illegible] in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

[illegible]

Respectfully submitted

[illegible]
[illegible]
[illegible]
[illegible]

GENERAL APPENDIX

to the

SMITHSONIAN REPORT FOR 1956

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 investigation and explorations 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 satisfactory, 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 1956.

Reprints of the various papers in the General Appendix may be obtained, as long as the supply lasts, on request addressed to the Editorial and Publications Division, Smithsonian Institution, Washington 25, D. C.

The Edge of the Sun[1]

By Donald H. Menzel

Director, Harvard College Observatory
Paine Professor of Astronomy, Harvard University

[With 4 plates]

If the title of this lecture, "The Edge of the Sun," perchance suggests to you Rachel Carson's delightful book, "The Edge of the Sea," the resemblance is not purely coincidental. I chose the title deliberately because of the many similarities that exist between the sun and the sea. If any of you should quibble that I use the word "edge" in a different sense than did Miss Carson, to indicate a boundary layer rather than a boundary line, let me refer you to Webster, who approves the double usage.

When I agreed almost nine months ago to give this lecture on the subject of "What's New on the Sun," I had no idea that the sun would be so cooperative. As a result, much of what I would have told you then has since been changed. Even in the several months that have elapsed since the lecture and the preparation of the final manuscript, solar activity has markedly increased. I have included some of the latest illustrations and have employed the information derived from them to help solve our basic problem: "What is the structure of the sun's outer layers and how does solar activity originate?"

Man's interpretation of the sun has been undergoing a gradual evolution for thousands of years. We no longer look to the sun as a deity, nor do we bring offerings to solar temples as a means of soliciting his bounty.

We recognize that the sun is a sphere of hot gas, whose vast output of light and heat comes from atomic energy, released deep in its core. The process of atomic fusion that gives rise to the sun's energy appears to be similar to that employed in our great H bombs: fusion of protons, the nuclei of hydrogen atoms. The energy so released in the sun's interior is equal to that from a billion or so hydrogen bombs exploded every second. Tonight we shall largely concern ourselves with the profound effect that this energy has upon the sun's outer layers, just

[1] The twenty-third James Arthur Lecture, given under the auspices of the Smithsonian Institution April 26, 1956.

before it escapes from the surface and begins its long journey out into the depths of interstellar space.

But if the journey ahead of the escaping radiation is long, its past history is by no means negligible. The radiation takes some 50 million years to worm its way slowly upward from its birthplace close to the sun's center to the outer edge. A snail's pace, indeed, for light, which could traverse that distance in two and a half seconds if an enormous number of atoms did not bar its progress.

Inside the sun, atoms are so closely packed that a speeding packet of light waves can travel only 50-millionths of an inch or so, before it runs head-on into one of the waiting atoms, to be deflected into a new track and run into still another atom a quadrillionth of a second later. In the face of so dense a traffic jam, one wonders how the radiation could ever escape. But the outer layers of the sun are less dense than the inner layers. The radiation inevitably, if slowly, finds a path through the atomic maze, eventually to escape completely. And so the sunlight that warms us today was born in atomic explosions that took place when dinosaurs and other prehistoric animals roamed the earth. These facts enable us to draw one basic conclusion: the sun is highly opaque to its radiation.

Some scientists have speculated that the sun's well-known 11-year cycle, most clearly depicted by the variation in numbers of sunspots, may in some way be due to a periodic fluctuation of heat production deep in the center. A pulsation of the entire sun every 11 years, for example, could change the output of energy. Compression would heat the sun, increase the rate of atomic fusion, and result in the generation of more energy. However, the radiation takes 50,000,000 years to escape and if only 11 years separate each pulse we must find almost 5,000,000 pulses still underneath the surface, separated by only 200 yards or so on the average. A structure something like an onion with alternate layers of warmer and cooler gases might conceivably ensue.

Such a structure could persist, however, only if the radiation flowed directly outward. But we have already noted the roundabout path that the energy must pursue in order to reach the surface. The radiation mills around and around, as if performing a dance whose rules require one to take 999,999 billion steps backward for each million billion steps forward. With such slow progress, the hypothetical onionlike layers completely disappear. The sun's interior must be drably uniform, except for the progressive decrease in temperature and density from core to edge. And if this argument applies to the sun, it also applies to stars in general. Stellar variability, except for the rare extreme when a star suffers complete destruction in a superexplosion, can scarcely be more than skin deep.

We know that energy flows from one place to another by one of three fundamental processes: Conduction through a solid, as when

the spoon in a coffee cup gets hot; convection, the circulation of warm and cool layers of gas; and radiation, the flow of light waves or heat waves through space that may or may not contain matter.

Prior to about 1900, astronomers generally supposed that convection was the major process controlling flow of energy, with heated gas rising and cool gas descending, as in the earth's atmosphere. For convection to occur, however, some very special conditions must be fulfilled.

Imagine a balloon—a weightless balloon—filled with air. I hold one here in my hands, though you cannot see it, of course, because it is invisible. The temperature and pressure are the same as in the surrounding air. If I release the balloon, therefore, it shows no tendency to rise or fall.

But let me lift this balloon a few feet. Air pressure up here is somewhat less than where the balloon was originally. And so the balloon must expand slightly to equalize the external pressure. The invisible, weightless skin of the balloon holds the gas together. As the balloon expands, the air inside it must cool. We now measure the outside temperature to see if it is higher than, equal to, or less than that inside the balloon. If the balloon is colder than its surroundings, the air inside is denser and heavier. The balloon tends to fall back to its original position. If the two temperatures are equal, the balloon, with its weightless skin, tends to stay in its new position. However, if the balloon is hotter than its surroundings, the air inside will be lighter than the air outside. The balloon will tend to rise faster and faster, as long as this condition persists. A true hot-air balloon!

On earth, the air around us is usually full of these rising and falling invisible balloons. Of course I use the word "balloons" in a figurative sense, because the gas really does not possess the "invisible, weightless skin" I postulated. But this absence of an envelope does not significantly change the picture. Volumes of gas will rise or fall, whether they are enclosed or not. The rising masses are the "thermals" used by birds or human pilots of gliders to soar to great heights. The vast sea of air can be very bumpy—as many air travelers realize when a rising or falling blast of air may tip even a large plane.

Although we do not see the thermals in the lower atmosphere, we often can see their upper boundaries, where the rising gas has cooled so much that water vapor begins to condense and form a cloud. As a matter of fact, the condensation process supplies new heat to the rising gas—lights a fire in the balloon, figuratively speaking. And so the gas ascends even more violently than before, like the Chinese "Fire Balloons" that used to climax our Fourth of July celebrations. Clouds, therefore, can be violently turbulent, which is why pilots, especially of small planes, try to avoid them in flight. And you will

note that the atmosphere above the clouds tends to be smooth. No more balloons or thermals. No more "convection," as we term the rising and falling of air. The "balloons" have reached a ceiling where the air above is quiet and stable.

I ask you to bear with me a moment longer, while I discuss the horizontal flow of air masses. The sun heats the earth's atmosphere, as the earth turns on its axis, like a roast on a spit. The heating is greatest near the equator and the gas will rise in that area, allowing the cooler air from the poles to flow in and take its place. The phenomena of weather and atmospheric circulation are very complex. But the basic flow comes from absorbed solar heat, with forces of the earth's rotation playing an important part.

And so, in the vast sea of air, we find not only violent streams of vertical turbulence, but also streams and patterns of horizontal flow. These include tornadoes and hurricanes and the over-all pattern of cyclonic weather.

But what has this sea of terrestrial air to do with the solar atmosphere? Ever since man started to observe the sun, astronomers have employed analogy with the earth's atmosphere as a means of interpreting solar phenomena. Galileo himself, discoverer of sunspots, suggested that the dark areas were clouds of a sort, floating in the sun's atmosphere and carried across the disk by simple rotation. In this view, elementary as it was, Galileo was far nearer the truth than were many of his successors. He at least recognized the atmospheric nature of the phenomena. Lalande, for example, suggested that spots were cold mountain peaks, towering above the luminous surface. And even the great William Herschel, again influenced by analogy and his preconceptions, regarded spots as holes in the fiery, luminous clouds, through which we could glimpse the cool surface beneath.

In 1794 Herschel wrote:

> The sun . . . appears to be nothing else than a very eminent, large, and lurid planet, evidently the first or, in strictness of speaking, the only primary one of our system; all others being secondary to it. Its similarity to the other globes of the solar system with regard to its solidity, its atmosphere, and its diversified surface; the rotation upon its axis, and the fall of heavy bodies, lead us on to suppose that it is also most probably inhabited, like the rest of the planets, by beings whose organs are adapted to the peculiar circumstances of that vast globe.

Peculiar indeed, in the light of modern knowledge! Even in the relatively cool solar atmosphere, the temperature is so high that all chemical substances are vaporized.

But even if Herschel proposed a view that we cannot accept today, he did recognize the importance of circulation in maintaining the physical state of the solar atmosphere. His theory was not idle speculation. He visualized the presence of violent winds and suggested

that the "luminous decompositions" responsible for the light "must unavoidably be attended with great agitations, such as with us might even be called hurricanes." Herschel postulated the existence of "empyreal gas," an unstable substance whose decomposition produced the solar radiation. Excess generation of this substance would lead to instabilities of the sun's atmosphere. The gas would burst violently through the intermediate regions, causing openings and sunspots and generally promoting "maintenance of the general luminous phenomena."

Many years later, John Herschel proposed an alternative theory of sunspots in terms of a general circulation of the solar atmosphere. He knew that terrestrial hurricanes and cylones owe their existence to temperature differences between pole and equator, as I have already noted. He argued that the centrifugal force of rotation would cause the sun to bulge at the equator and thicken the atmosphere. Since Herschel believed that solar radiation originated in the outer layers, his argument indicated an atmosphere hotter at the equator than at the poles. Thus one would expect strong horizontal driving forces, as in the terrestrial atmosphere. The sunspots were to be hurricanes, holes cut by the whirlwind that exposed the cooler layers below.

C. A. Young, of Princeton, noted that any existing temperature difference should in reality occur in the reverse sense. The poles should be hotter than the equator because they are nearer the center of the sun. He pointed out that the effect must be insensible, however, since there is no detectable difference in brightness between the polar and equatorial limbs of the sun. The spots showed no "systematic drift north or south as solar trade-winds would necessarily produce."

Faye and Secchi rejected the horizontal-circulation theory and independently suggested that spots resulted from gases flowing outward under internal pressure. The proponents of this hypothesis withdrew it when they became convinced that the spectrum of superheated gas should show emission lines rather than the absorption spectrum characteristic of spots. The argument is actually fallacious, though it appeared to be sound at the time.

Hale's discovery in 1914 that sunspots possess powerful magnetic fields played an important part in the formulation of our theories. It was immediately apparent that this magnetism must arise from circulating electric currents. And, for some obscure reason, scientists concluded that these currents could come into being only if the matter itself were circulating. In other words, astronomers revived the concept of sunspots as vortices. Practically every book on the sun written since that time and every textbook on astronomy refers to sunspots as "stormy areas," in every sense analogous to terrestrial

cyclones. On earth, a cyclone is a region of low pressure into which the surrounding gases are expanding, subject to adiabatic cooling. Also, cyclones are vortices, which derive their motion from the Coriolis force of the earth's rotation. Thus, astronomers were in effect going back to the "trade-wind" hypothesis for sunspot origin, despite the lack of evidence for differential temperature between pole and equator to serve as a driving mechanism. There was, perhaps, the pious hope that the sun's well-known equatorial acceleration might in some way achieve the desired result.

The vortex hypothesis ran into a good many obstacles and Hale himself was well aware of them. The discovery that sunspot groups in the northern and southern hemispheres switched their polarities from one cycle to the next was a serious complication. On earth, cyclonic motion is counterclockwise in the Northern Hemisphere and clockwise in the Southern. Since the direction of the earth's rotation fixes the sign of the Coriolis force we could not possibly get a reversal of directions in the terrestrial atmosphere. Hence, if the same forces were responsible for the solar vortices, and if the vortex were responsible in turn for the magnetism, why should we expect the reversal? Hale sought to show that the directions of the whirls in the upper atmosphere were invariant, but neither the observations nor the argument were convincing.

Bjkernes proposed an ad hoc model, in which the sun contained four doughnut-shaped vortices below the surface, two in each hemisphere. Each pair of vortices rotated in a different direction and also rotated around each other, the outermost vortex moving toward the equator while the other sank and moved poleward through the hole in the outer doughnut. This picture accounted satisfactorily for the reversal if the direction of vortex rotation determined the polarity.

Application of the relatively new science magnetohydrodynamics casts new light on the nature of highly ionized gases in the presence of a magnetic field. A gas, sufficiently hot so that the electrons have been torn from most of its component atoms, is highly conductive to electricity. The magnetic fields associated with any electric currents that may be present impart to the gas a certain amount of rigidity, as if the material were semisolid. Biermann has pointed out that convection has a hard time getting started in such a gas. The atoms can flow up and down, to a certain extent, parallel to the lines of force. But we cannot expect the violent turbulence ordinarily associated with strong convection. We must, therefore, completely revise our ideas about sunspots. They are not storm areas. They are, in fact, quite the reverse: islands of intense calm floating in the otherwise turbulent sea of the sun's entire convective atmosphere.

I discussed earlier the general nature of convective motion and pointed out, in particular, that the presence of water vapor in the

earth's atmosphere enhances convection because the condensation of water vapor heats the gas, putting back into it the calories that went to cool the air when the water evaporated.

No water exists in the sun's atmosphere, of course. But Unsöld showed some time ago that a completely analogous process takes place there—ionization of hydrogen. Since hydrogen is by far the most abundant constituent of the sun's atmosphere, and since most of this gas is completely ionized at the lower levels, a large bubble, cooling as it rises, would eventually become neutral. As the electrons recombine with their ions, they release a large quantity of energy which can be used for heating the rising gas. The convection can be extreme.

The shining surface of the sun, the part not affected by sunspots, is by no means uniformly bright. It contains many bright flecks on a slightly darker background, spots that look like foam-capped waves on a stormy sea. We have generally referred to this structure as "granulation." The granules are 300 miles or so across on the average, with considerable variation in size. In the neighborhood of sunspots they are much coarser, if indeed the bright structure we can see can properly be called granules. Near the limb of the sun, where we are looking tangentially down to the solar atmosphere and hence see the higher layers, large brightened patches with a veined structure take the place of the relatively simple granulation. These are the so-called faculae.

Astronomers were first inclined to regard this granular pattern as arising in some sort of convection. But this theory gradually gave way to the idea that the white spots were clouds of a solid material, floating in the gas and appearing more luminous because of their higher emissivity, like a gas mantle heated to incandescence. We had to abandon this second hypothesis and revert to the earlier view when we found that the solar temperature was too high to permit the presence of either liquid or solid matter.

Astronomers have long discussed the mode employed by the sun for the escape of energy from the deep interior. Initially, they took for granted that convection was the whole mechanism and the early theories of stellar constitution were devised on that hypothesis. But around the turn of the century, Schuster, K. Schwarzchild, and others showed that radiative processes would dominate, with the atmosphere in stable equilibrium. But they reckoned without knowledge of the effect that hydrogen ionization would have on the equilibrium, and it remained for Unsöld to demonstrate the importance of the hydrogen convective zone in stellar structure. The turbulent convection serves to bring the hotter layers closer to the surface than they would have been in simple radiative equilibrium. We do not know precisely how deep the outer convective layer extends, because small changes in the initial assumptions can lead to great differences far

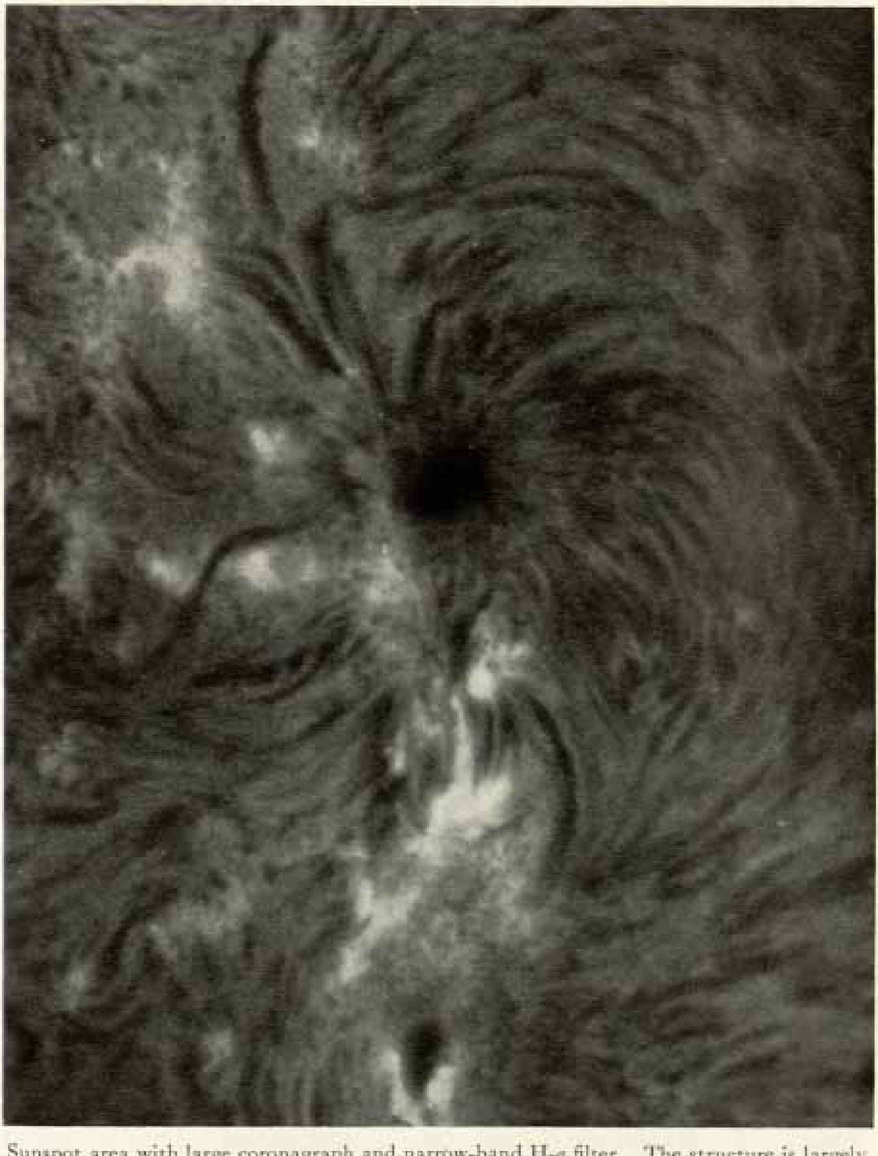
below the solar surface. The turbulent layers may involve as much as the outer 10 percent of the solar radius.

We are now in a position to understand the darkness of the spot relative to the surrounding photosphere. The answer is extremely simple. In a region where magnetism has not inhibited convection, the outer layers are hotter than they would be otherwise. They are, consequently, more luminous than the spots, where convection does not occur. In the region immediately surrounding the spots, the convective layer must rise higher and indeed may even penetrate the photosphere, since rising currents of hot gas must carry outward the extra energy that the cooler spot cannot transport from the solar interior by radiative transfer.

One may speculate what the physical state of the sun would be if a magnetic field strong enough to inhibit convection through the entire solar atmosphere should suddenly come into existence. In the absence of convection, energy transport would have to depend on the less efficient radiative processes. The temperature of the photospheric layer of the sun would cool by at least 2,000 degrees, to a value approximating that of a sunspot. Indeed, under such conditions, we could describe the solar surface as consisting of a single spot. With the effective solar temperature reduced to about two-thirds of its normal value, the total amount of energy radiated, which varies as the fourth power of the temperature, would decline to about 20 percent of its present value.

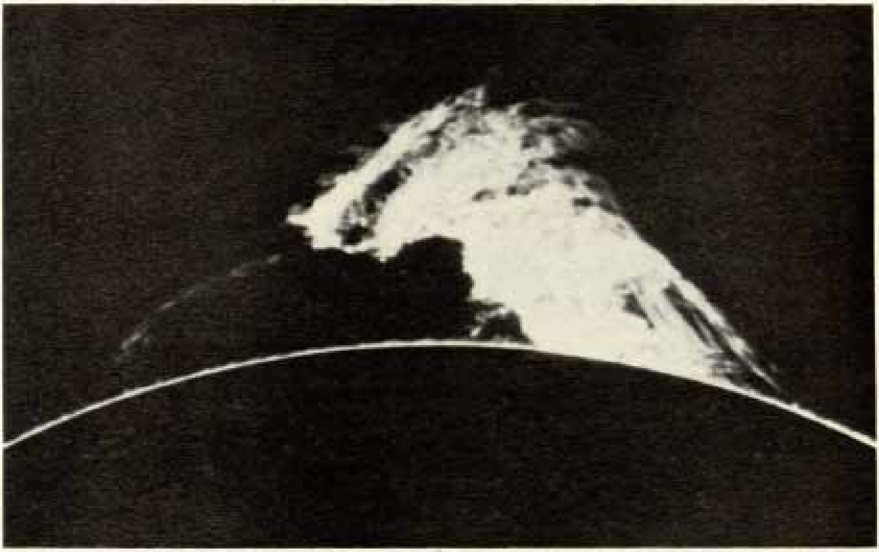
We have previously noted that radiation takes some 50,000,000 years to leak out from the core. By the same argument, a change in the sun's external layers could not have any immediate effect on the solar interior, which would continue to generate energy at its present rate. The accumulated radiation inside the sun would cause it to swell gradually until, some tens of millions of years hence, the increased surface area could compensate for the lowered radiation flux. Even a small expansion, however, would cause marked changes in the rate of energy production and we cannot foretell whether equilibrium will occur or not.

The greatest immediate effect would occur in the sun's outer layers, especially those now in convective equilibrium. Since these layers contain only a relatively small amount of heat we should expect their configuration to change in tens of years rather than in millions. The solar atmosphere would expand and alter the temperature distribution simultaneously to values consistent with the sun's present total output of energy. Although such a model is extreme for the sun, it might apply with some changes to certain types of stars, notably the long-period and Cepheid variables. Possibly no static state will exist and the distended atmosphere will oscillate between maximum and mini-

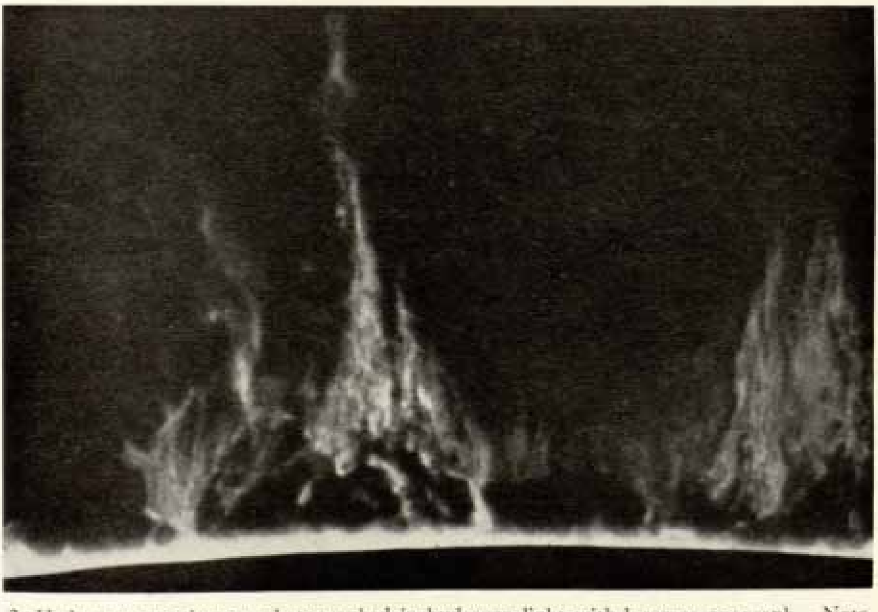


Sunspot area with large coronagraph and narrow-band H-α filter. The structure is largely chromospheric, with prominences. Note the patches of bright hydrogen emission and the long, curved filaments of absorbing hydrogen, probably oriented in part by the magnetic fields of the region. (Sacramento Peak Observatory.)

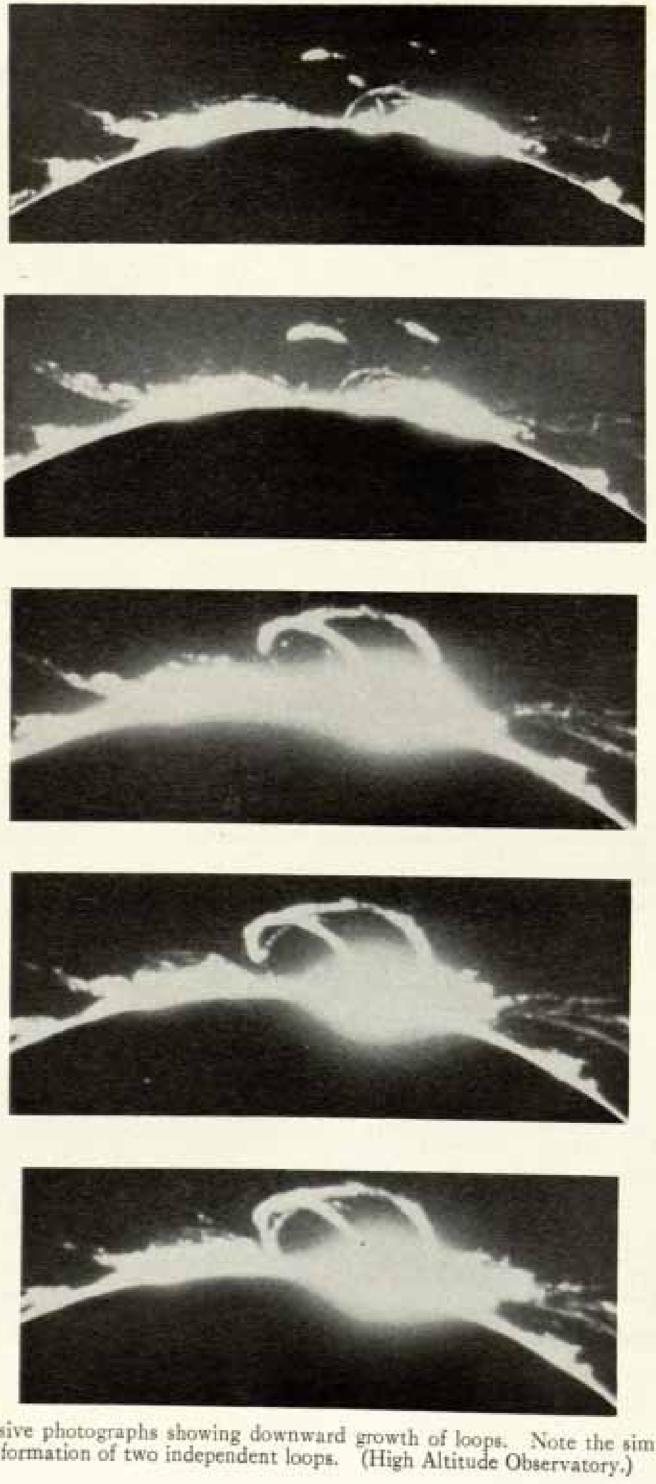
Hydrogen flare near maximum. (Sacramento Peak Observatory.)



1. Typical ascending prominence. The helical structure of the luminous region suggests that electric currents are partly responsible for the formation. (Sacramento Peak Observatory.)



2. Hedgerow prominence, photographed in hydrogen light with large coronagraph. Note detailed filamentary structure. (Sacramento Peak Observatory.)



Five successive photographs showing downward growth of loops. Note the simultaneous formation of two independent loops. (High Altitude Observatory.)

mum positions to make the average flux equal to the rate of energy generation deep in the interior.

In the photospheric and subphotospheric layers, the solar atmosphere may be quite turbulent, though the convective flow is not particularly rapid. The rising hot gas alters the temperature distribution, but kinetic energy of the convective matter does not appreciably affect the atmosphere. At higher levels, however, marked changes occur in the character of the convection. The speed of flow increases as the bubbles expand into regions of lower density, until the gas moves with a speed equal to or even greater than that of sound in the medium. Intense shock waves may then occur. The gas becomes hot as the kinetic energy of the moving clouds gradually dissipates into random motions of individual atoms. This enhancement of convection explains why the chromosphere, the layer immediately overlying the photosphere, is so jagged and rough, consisting of rapidly changing jets and spicules. Motion pictures, taken by Richard Dunn at Sacramento Peak Observatory, clearly demonstrate the violence of activity in these outer layers, and Richard Thomas has studied the heating effect of the jets.

The chromosphere, which until recently could be studied only at the time of total solar eclipse, presented the astronomer with many interesting problems. Of particular significance was the appearance of lines of ionized helium in the spectrum, radiation requiring extremely high excitation. At the same time the intensity of radiation from neutral and ionized metals suggested a somewhat lower temperature. The answer now becomes clear. We actually encounter a wide range of excitation which varies according to the amount of heating provided by the shock wave. The fact that the excitation appears to increase upward is thus consistent with this new view. Astronomers were originally very much concerned to find that the upper chromosphere had temperatures ranging up to 25,000° C. or more when the effective surface temperature of the sun was only 6,000°. Astronomers contributing to these recent advances include Athay, Pecker, Thomas, Zirin, and Menzel.

The concept of a dynamic solar atmosphere now extends to the corona as well as the chromosphere. There are a few unsolved problems, however, chiefly the observed fact that motions of coronal gas appear to be slower than those in neighboring prominences. Apparently the corona derives some of its support from the sun's general magnetic field. To derive such support, material must be shot out from the sun at very high speeds. The observed coronal temperatures, derived from widths of the coronal lines, are at least 1,000,000° and in some regions as high as 5,000,000°.

The idea recently suggested by S. Chapman, that the corona may extend even beyond the earth, is particularly appealing after one

accepts the startling concept that we lie below the edge of the sun. But Chapman goes even further and suggests that the conduction of heat from the solar surface through the corona cannot be neglected and that perhaps our ionosphere derives some of its high temperature from direct thermal contact with the corona through which the earth is moving. Shock waves may even be able to traverse the entire distance between the sun and the corona. On contact with the earth, the wave could distort the earth's magnetic field, producing ionospheric and magnetic storms, as well as certain types of auroral phenomena.

But let us return to the more important "edge" of the sun, defined by the photosphere and chromosphere and other visible appendages of the solar neighborhood. Around sunspots and also around other areas that presumably have intense magnetic fields associated with them, we observe increased activity. We sometimes see matter ejected, usually in the form of surges. In all probability additional surges occur that are invisible to us in the hydrogen radiations we ordinarily employ for observation. The mere fact that we observe more matter falling back toward the solar surface than we do leaving the sun clearly indicates that some of the material must go up invisibly, probably in a stage of high temperature and high excitation.

Several different processes are undoubtedly responsible for the ejection of the material as well as for the form and structure of downfalling masses. As I have already indicated, the hydrogen convective zone, especially with the activity enhanced in the neighborhood of magnetic fields, is a major force. But the electric currents responsible for such fields probably give a marked assist. Although the magnetohydrodynamics of the situation are too complicated for detailed calculation, argument based on simple engineering models reveals that the electromagnetic forces are ample to eject material. The forces acting on the simplest of all configurations, a single loop of current, are well known. The loop tends to expand indefinitely in radius, and the diameter of the current-carrying wire tends to diminish, if the wire should happen to be compressible.

In the solar atmosphere, of course, no solid wires exist. The currents are free to move and change their position. However, as Cowling pointed out long ago, the strength of the currents and the size of the current-carrying elements indicate that magnetic fields will not change rapidly in the solar atmosphere. A sunspot, for example, must have an electric current of 10^{12}–10^{13} amperes circulating about it. We cannot break such a current arbitrarily in less than thousands of years. A magnetic field may be transported from one place to another in the highly conductive volume, but it can scarcely arise spontaneously except in rare instances.

The physical nature of certain forms of prominences presents an interesting puzzle. Downward-moving gas may suddenly become visible

at a certain height and break up into knots or streamers, as it flows toward the solar surface. Such an observation implies that the hot, coronal matter suddenly became cooler or at least denser, so that the hydrogen ions could recombine with the electrons and thus radiate the characteristic spectrum of neutral hydrogen. In the hot, tenuous corona, recombination goes on at a negligible rate.

The so-called loop prominences, which constitute a distinctive class, present a very special problem. Employing motion-picture photography, we have frequently recorded the life history of the loops. Although some variations occur, they generally start as an exceptionally brilliant point well above the solar surface and then grow downward on both sides, often attaining the dazzling brilliance of a solar flare. On occasion, several loops may form and grow almost simultaneously. The total development is generally rapid, of the order of two or three minutes. As the loop fades in brightness, knots or lumps form and tend to flow downward along both sides. Although the loop maintains its shape, the lumps continue to form mysteriously and descend in regular procession. The downward flow may last for an hour or longer. The surprising thing is that we do not see material flowing into the loop.

I have devised an ad hoc explanation of the phenomenon. Suppose that convection, turbulence, or some associated activity has blown into the corona not only material from the rim of a sunspot but also some of the associated electric currents. We expect the pinch effect to operate as previously described, sweeping material in toward the axis of the current. Increased pressure causes ions and electrons to recombine. The simple pinch is unstable, however. As it develops, the central core tends to break into separate lumps, something like a string of sausages. Gravitation probably has little or no effect. The force of the pinch squeezes the material downward toward the sun, where the pinch is weakest. The pinch continues until finally all the current in the region has united, sweeping up the involved ionized gas.

It is significant, I think, that fuzzy loops show up in the hot corona, associated with the sharp loops of the cooler hydrogen emissions.

A magnetic field can also act as a mechanism for ejecting matter under certain conditions. It is well known that any conductor, such as aluminum or copper, introduced into a magnetic field, experiences a resistance. The force originates because the field does not penetrate the conductor, wherein surface currents must be induced. If the piece of metal, so introduced, is later released, it will fly out. In certain regions of the sun's atmosphere, perhaps near the poles or in the borders of spots, where a weak field cannot completely inhibit convection, lumps of ionized gas may become separated from the field, whose

lines of magnetic force will squeeze the mass and eject it into space. I have called this type of action the "watermelon-seed effect," because the ejected lump is something like a slippery watermelon seed held between the fingers and squeezed. Note especially that the imparted velocity may be many times greater than that of the moving fingers. In the case of the sun, the resultant jet may very well be supersonic.

The magnetic fields of the sun must exert a profound effect on the flow of gas through the corona and prominences. In regions of low density and strong field, the material will generally be constrained to move along the lines of force. But in regions where the density is higher, the ionized gas will sweep the lines of force along with it. Thus the contention made by some astronomers that the flow patterns of prominences provide a map of the solar magnetic field is not generally true. Often, as for the loop prominences described above, the flow is along the lines of current rather than of magnetic force.

From time to time we observe, usually near sunspots, areas that shine particularly brilliantly in the light of hydrogen. The physical nature of such eruptions has been the subject of discussion for a long time. Observation shows that the flares usually start as one or more brilliant points of light, growing rapidly to delineate a veined network, which is apparently merely an enhancement of the characteristic reticular structure that existed before the outburst. Although convection may have been responsible for the initial ejection of heated gases, the growth from bright points into linear structures strongly suggests that flares seen against the disk are loop prominences seen at the limb. In fact, the most famous of all flares, which occurred on September 1, 1859, clearly suggests such an association.

Two independent observers, Carrington and Hodgson, simultaneously saw two brilliant points of light appear within an active sunspot group they were sketching. According to the former observer, the spots rapidly developed into the shape of a crescent. These observations were in white light, not in Hα. Hence the flares must have been extremely intense. Their surface brightness, according to estimates, was at least five or six times that of the neighboring photosphere. Within five minutes the outburst had disappeared. There is no doubt in my mind that the "crescents" reported were loop prominences seen from above. However, even though the flare itself represents a relatively stationary phenomenon in the solar atmosphere, extending its growth by propagation along definite paths, observation indicates that some material may be ejected. Dark absorbing clouds, often moving at high speeds, have been seen to accompany flares. It is too early to say, however, whether this represents an effect of the flare as such or is merely an outlying portion of the ejected matter that was later condensed to form the flare. In certain instances we have iden-

tified surges seen at the limb as true flares, so that the flare is by no means restricted to the loop form.

I wish to point out that a new technique is rapidly contributing knowledge about the sun and solar activity: the so-called field of radio astronomy. Time and space do not permit detailed discussion of the phenomenon. However, it is certain that simultaneous optical and radio observations will give important information about solar activity at various levels in the sun's atmosphere, especially since the lower frequencies can escape only from the higher, more tenuous coronal regions. We are still finding out important facts and conclude that the edge of the sun well deserves the attention that scientists are currently devoting to this subject.

The Mystery of Mars

By H. P. Wilkins, F. R. A. S.

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[With 2 plates]

Mars is preeminently the planet of mystery. Because it is farther from the sun than the earth, it takes longer to complete a revolution, and every two years we overtake it, when it shines in the sky as a bright red star. The red color, suggestive of war and carnage, was the reason why the name of Mars, the Roman god of war, was attached to this planet. The red color of Mars contrasts strangely with the pure white of Venus or the silvery luster of Jupiter and is too pronounced for anybody to mistake it.

Although to the unaided eye Mars seems merely a bright star, a good telescope reveals it as a small full moon, that is to say, we can see the face or disk of this little world. We say "little" because Mars is much smaller than the earth, being in fact only 4,200 miles in diameter. A telescope shows certain markings on the disk, and they move in the course of an hour or two, which proves that Mars turns on its axis and has days and nights just as we do, although they are longer. Instead of turning around once every 24 hours as the earth does, Mars requires an extra 37 minutes 22.654 seconds, so that although a smaller world it does not spin round so quickly.

Mars has seasons similar to those of the earth but much longer. They are also more pronounced, because the mean or average distance of Mars is 48.6 millions of miles farther from the sun than that of the earth. From Mars the sun must look smaller, and gives out a proportionally smaller amount of light and heat; we would expect Mars to be a colder world. Mars has an atmosphere, but it is much more rarefied than ours, and it seems safe to say that we would not be able to breathe it because of the deficiency of oxygen, most of which seems to have been absorbed in chemical combination with the surface rocks.

When Mars is comparatively near to us it makes a beautiful picture in a really good telescope. At such times we see a yellowish-red disk,

[1] Chapter 4 of "Mysteries of Space and Time." Reprinted by permission of the publishers, Frederick Muller Ltd., London.

generally with a gleaming white spot at the top and sometimes at the bottom as well, while on the otherwise red background are grayish patches. If the telescope is a very large one, we may also see two specks of light, like small stars, moving rapidly around the planet; these are its two moons or satellites.

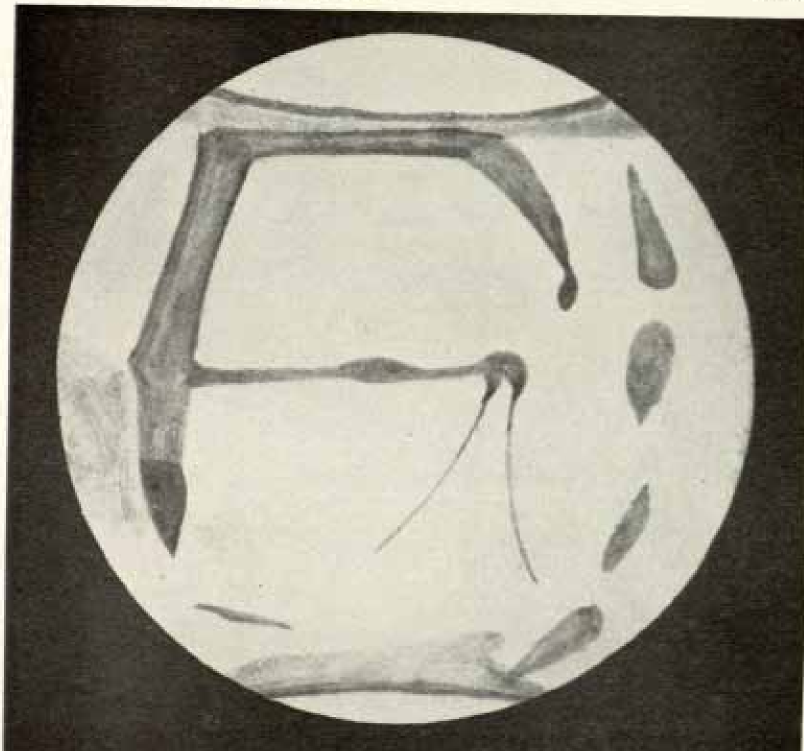
But what makes Mars the most interesting of all the planets is not its appearance as seen at any time with a telescope, but the changes which often take place there. The white spots at the top and the bottom mark the north and south poles of Mars. We know that our polar regions are distinguished for their low temperatures and deposits of ice and snow. Seen from space, from the moon, or from Mars, the earth would have gleaming white spots at the top and at the bottom, just as we see on Mars. It is generally believed that these white patches at the poles of Mars are deposits of ice and snow, but they also partly consist of high cirrus clouds. We know this because in photographs of Mars taken in infrared light, which penetrates to the surface, these patches are smaller than as seen in the telescope or on photographs taken in ultraviolet light, which show only the higher-level features.

Confirmation of the belief that Mars has true polar caps is given by the fact that they are largest in the winter time on Mars, begin to dwindle as spring comes on, and are smallest in summer. The cap at the south pole has even been known to disappear altogether, which never happens with the northern one. This is easily understood because when it is summer in the southern hemisphere Mars is nearest to the sun, and therefore receives the maximum amount of heat. It is, however, strange that while the pole is at the center of the northern cap, the south pole is 180 miles away from the center of the southern cap.

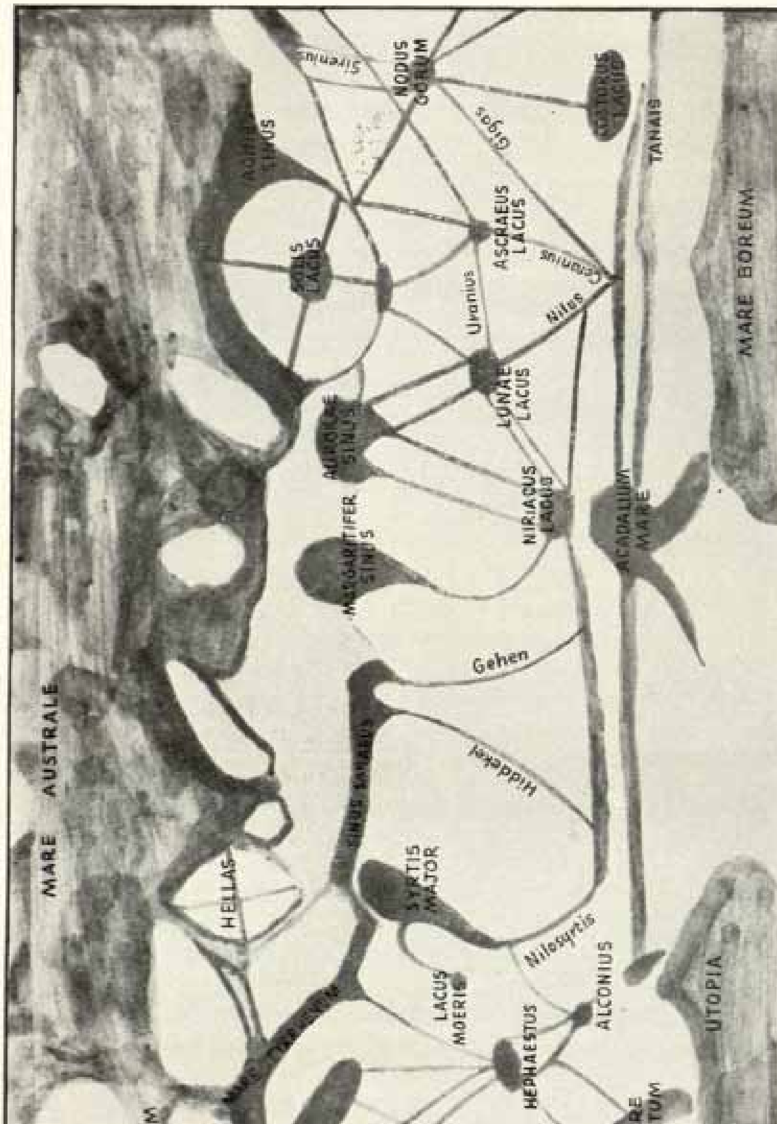
The grayish patches on the disk are permanent features, and for a long time were believed to be seas, because water reflects the sunlight less strongly than the land. It is now known that these patches are not seas, although they may once have been so. They are faint in the winter time, but darken as spring gives way to summer, that is to say, as the polar caps melt and the ice and snow are converted into water. This suggests that water has something to do with the darkening, and the consensus is that the dark areas are tracts of vegetation. What this is, whether the vegetation consists of plants, shrubs, or trees, we cannot say; we only know that it is vegetation of some sort.

These grayish patches are more numerous in the southern than in the northern hemisphere, and encircle the south pole. Many of them run into or join up with each other, but there are isolated patches.

The remaining parts of the disk are uniform yellowish-red and are almost certainly sandy deserts. Indeed Mars appears to be a world



Mars as observed by H. P. Wilkins on June 17, 1954, with the 60-inch Mount Wilson reflector.


MARE AUSTRALE
MARE CHRONIUM
HELLAS
SYRTIS MAJOR
LACUS MOERIS
HEPHAESTUS
ALCONIUS
MARE FRETUM
TRIVIUM CHARONTIS
TITANUM SINUS
Orcus
UTOPIA
MARE BOREUM
TANAIS
ACIDALIUM MARE
NIRIACUS LACUS
MARGARITIFER SINUS
AURORAE SINUS
LUNAE LACUS
ASCRAEUS LACUS
SOLIS LACUS
Gehen
Hiddekel
Nilosyrtis
Nilus
Uranius
Ceraunius
Gigas
Sirenius

Map of Mars.

on which there is very little water, most of it being locked up in the polar caps. But how does the water released by the melting of the polar caps reach the grayish patches, as it to all appearances does?

It was in 1877 that Mars made one of its close approaches to the earth, and modern study of the planet dates from that year. One spectacular discovery was that of its two satellites by Asaph Hall with what was then the largest refracting telescope in the world, of 26 inches in aperture. While this discovery came from America, another came from Italy, where Signor Schiaparelli, using a telescope of 8¾ inches in aperture, found a number of straight and narrow lines which he called canali, the Italian word for channels. This was translated into English as canals, and for the first time the world heard of the famous canals on Mars.

For many years nobody else succeeded in seeing the canals, and they were put down to Schiaparelli's imagination but gradually they were confirmed by other observers with larger telescopes. In 1894 an American amateur, Prof. Percival Lowell, built his own observatory at Flagstaff in Arizona, and equipped it with a fine-quality 24-inch refracting telescope for observing the planets, in particular Mars. Professor Lowell's results were of the highest interest, and some of them were very startling, although scientific men have not accepted them in their entirety.

Professor Lowell believed that Mars is a drying-up world, where every drop of water is precious. The inhabitants were in a sore plight; they had to cultivate crops, and the only water available was that in the polar caps. There was only one thing to do. The inhabitants became one community, and constructed a vast network of channels for the water to be conveyed from the polar caps to the regions where it is needed, which are the patches of vegetation. Since open canals would be wasteful and the loss by evaporation enormous, the canals must be covered, and it would be necessary for the water to be helped, for instance, by pumping, in its world-wide journey. Finally certain dark spots, occasionally found at the spots where one canal crosses another, were considered by Professor Lowell as the centers of civilization, the cities of Mars. Lowell implied that the Martians were engineers, and that the canals were artificial waterways dug by them in an attempt to preserve the race in its fight against the encroaching desert.

This fascinating idea captures the imagination, for if true it means that we see on Mars markings made by an alien but intelligent race. In order to distinguish one spot from another, and to compare drawings made by different observers, names have been given to the various spots, the principal ones being shown on the chart, which is on a cylindrical projection. A glance at the map (pl. 2) will show that zero

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longitude, the Greenwich meridian of Mars, passes through a dark marking shaped like the open beak of a bird. To the left of this is a large, dark and tapering marking, one of the most prominent of the dark patches believed to be vegetation. This is called the SYRTIS MAJOR. From its tip there runs a wide canal, NILUS, which curves round to a dark dot known as COLŒ PALUS. Another canal NEPENTHES, curves from the left side of Syrtis Major, passes a round spot called LACUS MŒRIS and ends in another spot, TRITON LACUS. Although the Syrtis Major is always there, its shape varies from time to time. Sometimes it has a long, pointed tip; at other times, as in 1922, the tip is missing, while white patches have been seen hiding a good deal of the Syrtis for a few weeks. These temporary white patches are certainly clouds, and they are often seen over those parts of Mars on which the sun is just rising, as though they form during the night. The canals from Syrtis also vary a good deal in tint, while Lacus Mœris, which on Lowell's theory would be a Martian city, is sometimes small and faint while at others it is large and dark, presumably according to the amount of water available.

The curved edge of Syrtis Major ends at a small round spot, SYRTIS MINOR, about which is a dark streak called MARE TYRRHENUM. On its left is another but larger patch, MARE CIMMERIUM, to which many canals run. The area to the left of Syrtis Major and north of Tyrrhenum and Cimmerium is desert, a sandy waste, in the center of which is another round and dark spot, called TRIVIUM CHARONTIS. This spot is peculiar because occasionally it becomes two separate spots, which after a time reunite. If Trivium is a Martian city it is situated in a very queer place, right in the middle of the desert. Two canals, one called STYX and the other HADES, connect this desert spot with other canals running up to the north pole, and the water appears to travel along them all the way from the polar cap to Trivium in 12 degrees north latitude.

Still farther to the left, or east, is another dark streak, MARE SIRENUM, on the opposite side of Mars to Syrtis Major, surrounded by desert. East of this is a large light area, in the middle of which is a dark patch from which canals radiate. This spot is sometimes called the "Eye of Mars" because it looks just like an eye; its proper name is LACUS SOLIS, or the "Lake of the Sun." To the south of all these dark areas is a large dusky spot, extending up to the snows around the south pole and called MARE AUSTRALE, or the "Southern Sea." Here and there are a kind of bright islands, such as HELLAS and the THYLES. Between the zero meridian and the Eye of Mars is a pointed dark streak, the MARGARITIFER SINUS or "Pearl Bearing Gulf," and this runs into the track of vegetation known as the MARE ERYTHRÆUM.

From these dark patches canals run across the northern deserts to dark patches grouped around the north pole. Although there are few

of these in the northern hemisphere which, as we have already said, is chiefly desert, one is very prominent and sometimes even more prominent than the Syrtis Major. This dark spot is called the MARE ACIDALIUM, and is connected with the Pearl Bearing Gulf by a wide canal called INDUS. A little to the right, or west, of Acidalium is one of the dark spots in the desert, called LACUS LUNAE or Lake of the Moon. From this spot a wide canal, GANGES, crosses the desert to the patch of vegetation AURORAE SINUS, near the Eye of Mars. The last desert outpost is the LUCUS ASCREUS. Then comes the great desert of AMAZONIA, which extends over 90° of longitude to Trivium Charontis. This desert is crossed by a few canals of which LYCUS, BRONTĒS and OREUS are the largest. Immediately to the west of Trivium is a large white area called ELYSIUM, bordered by canals and with a network of them right up to the pole.

These are the chief permanent markings on Mars, but they are never seen all together. During the winter the polar caps are large, while the canals are then either invisible or can only be traced with difficulty; but as the cap melts, a dark girdle appears around it, probably a temporary polar sea, and then the canals begin to appear. At first only a little bit near the melting snow can be seen, but this gradually gets longer and longer until the whole of the canal is marked out as far as one of the patches of vegetation. Like the canals, these patches are mere shades during the winter, but begin to darken as the canals from the poles fill up, and are very prominent during the summer. With the onset of autumn they change from a dark grayish-green to brown, and then become mere shades in winter.

All this fits in beautifully with Lowell's idea of artificial waterways, but there are other opinions. With his 24-inch telescope Lowell saw and drew the canals as narrow and continuous lines, but another eminent observer, Antoniadi, using a larger telescope, the 33-inch at Meudon, near Paris, declared that these narrow lines were illusions. He said that the reason why Lowell saw and drew them as continuous lines was due solely to his telescope being too small to show their true nature. With the great telescope at Meudon, the canals were seen not to be continuous but made up of a series of dots and dashes, arranged one after the other in straight lines. Whether the canals are continuous or not, whether they are natural or artificial, all observers agree that what we see is not the actual ditch, assuming they are ditches, but the vegetation to either side of them. An American observer, John E. Mellish, declares that with the 40-inch refracting telescope at the Yerkes Observatory, the largest instrument of its type in the world, the canals appeared as cracks, wide and eroded down, comparatively shallow and filled with water. Some of the very wide canals were distinctly seen to be darker in the center, and resembled ditches filled with water and with marshes and vegetation along their

sides. The dark, round spots, which Lowell believed to be cities, oases in the desert, were seen by Mellish as craters, presumably of volcanic origin, and also filled with water.

We have three opinions about these mysterious canals. The first regards them as ditches dug by the Martians and indicative of an advanced civilization, the work of superhuman intelligences. The second does not attempt to decide whether they are natural or artificial, but denies that they are continuous features, declaring them to be series of isolated and apparently quite separate spots. The third regards them as natural features, in fact cracks in the surface and therefore natural waterways.

The regular appearances of the isolated dark spots, Lowell's cities, were also to some extent broken down into collections of separate dots with the Meudon telescope. On the other hand, Mellish regards them as craters, and therefore regular. That there is life of some sort on Mars is now generally admitted, but the question to be answered is whether this consists merely of vegetation, possibly with some elementary animal life, or whether there exist on Mars today, or have existed in the past, creatures somewhat resembling man, beings capable of reasoning and of constructing civil engineering projects on a scale far exceeding anything which man has achieved on the earth.

This question of whether we have brothers in the sky, or at any rate on Mars, is of the utmost importance. If there are intelligent beings on Mars it is not impossible that they may seek to communicate with us, or even to leave their drying-up planet and migrate to our pleasantly watered and warmer world. Is it possible for highly organized beings to exist on Mars?

We already know that the diameter of Mars is 4,200 miles, to which we can add that this globe is not as closely packed as the earth, the density being 3.94 times that of water, while the figure for the earth is 5.52. The small diameter and the low density mean that the mass of Mars, the amount of matter in it, is only slightly more than one-tenth of that of the earth. The surface of Mars, or its area, is not quite three-tenths and the intensity of gravity at its surface is not quite four-tenths (more precisely 0.38) that of our globe.

The low surface gravity is just about sufficient to allow the planet to retain an atmosphere composed of oxygen and nitrogen, with some water vapor. The red color and the spectroscopic evidence that there is little free oxygen in the atmosphere mean that much of the free oxygen the atmosphere probably once possessed has entered into combination with the surface rocks. The amount of water vapor is limited, but still sufficient for the formation of polar caps and occasional morning mists and clouds. The true water-vapor clouds can be distinguished from what appear to be dust or sand storms by their

white color. The yellowish clouds which have attracted the attention of the best observers are thought to be sand storms, in which the sandy surfaces of the deserts are whirled aloft by air currents. There must be winds on Mars; but judging from the manner in which clouds of any kind tend to rise and hang over the same region, without drifting far, it seems that the atmospheric currents are usually ascending or descending, probably associated with temperature variations.

The mean temperature on Mars must be much lower than that on the earth, because the planet is so far from the sun and also on account of its rarefied atmosphere. The best authorities believe that the maximum temperature at noon on the equator is somewhere between 50 and 60 degrees Fahrenheit. From this maximum it must fall rapidly as the poles are approached, and also both in the early morning and the late afternoon for places on the equator. Mars is certainly a cold world, but it is also a dry one; to this it may be added that Mars is a smooth world.

Despite Mars being a small, dry, and cold world, there seems to be some analogy between the conditions on Mars and some of the more arid regions on the earth. A mysterious thing about the red planet is the fact that although it is smaller than the earth but larger than the moon, and thus fits in between them, it is much more smooth than either. The moon clearly tells us that smallness of a planetary globe is no bar to its having a rough and mountainous surface, but on Mars it is doubtful whether there are any mountains higher than the Welsh hills or the highlands of Scotland. Some authorities have set the maximum height much lower, around 2,000 feet, and talk about the featureless horizon on Mars and how, owing to the sharp curvature of its surface, the ground must seem to rise up like a huge convex shield, especially in the desert regions.

The great barrier to increasing our knowledge of Mars is an insurmountable one, namely distance. This, together with the limitations imposed by our atmosphere, renders it certain that the largest telescope man can ever construct will fail to solve the problem of the type of Martian life. It is possible that we will eventually learn more about this alien form of life by radar than by visual or photographic means, unless such means are located somewhere comparatively close to the planet, perhaps on one or either of its moons.

Every time that Mars comes to opposition, and is therefore most favorably situated, enthusiastic and hopeful people "tune in" with powerful radio sets in the hope that they may pick up signals from the Martians. In 1924 and again in 1926 reports appeared in the press of certain unidentified "pips" which might, but almost certainly did not, originate from Mars. Assuming that intelligent beings exist and attempt to contact us, the difficulty here would be to make any-

thing out of the sounds, as it is in the highest degree improbable that they would make use of our terrestrial Morse code!

More nonsense has been written about Mars than about any other planet. The only thing which science has established is the almost certain existence of plant life on Mars, and the possibility that some form of animal life may also exist. Beyond this we cannot go unless the field is thrown open to speculation, when of course there is no limit. There may be people on Mars and they may be anything you like to imagine, but we know nothing about them, and up to the present time nothing has been picked up which suggests that they are attempting to contact us.

It seems reasonable to conclude that if intelligences do exist, they should most earnestly desire to leave their in many ways inhospitable world, and visit ours. Even if they did succeed in the construction of practical spaceships capable of traveling to the earth, our dense atmosphere would prove a serious and possibly fatal barrier. Just as we would be asphyxiated if we attempted to breathe the thin atmosphere of Mars, so the Martians would be drowned by immersion in our dense atmosphere. Only in the higher regions, near the summits of our loftiest mountains, could they hope to survive, at least for several generations and until they became acclimatized to their new environment.

Mystery still surrounds the canals, bound up as they are with the greater mystery of life. As a telescopic object, Mars is often rather disappointing to casual observers. People imagine that we know more than science admits, and expect a large telescope to show the planet like a huge full moon with canals clearly revealed, and possibly even see the canal boats which are imagined as passing to and fro along these waterways. The actual view shows a small and not always round disk of a yellowish-red color, on which the polar caps may be plain enough, as are the darker markings, while the canals generally appear as rather diffused streaks. Should the atmospheric conditions be imperfect, as is usually the case, the view is even more disappointing, as the whole thing is "fuzzy" and unsteady.

The proper place to solve the mystery of Mars is from one or another of his satellites. The nearer to the planet is the larger, and may have a diameter of around 15 miles, while it is so close to the planet (only 3,900 miles from its surface) that it has to scamper around it in 7 hours 39 minutes 26.65 seconds. The outer moon is only 10 or 12 miles in dimeter, and takes 1 day 6 hours 21 minutes 15.68 seconds to complete a revolution at its distance of 12,900 miles from the surface.

The inner moon, PHOBOS, actually makes more than three revolutions around Mars while the planet turns around once, so to the Martians it must seem *to rise in the west* and set in the east. On the other hand the outer moon, DEIMOS, revolves around Mars in a

period which is less than 6 hours longer than that of Mars itself, and to the Martians must seem to move very slowly across the sky. Deimos rises in the east and sets in the west, in the same manner as the sun and the stars. As seen from Mars it would look like a bright star; its disk would be rather difficult to detect with the naked eye.

Both these moons are totally eclipsed at every "full moon," and also they frequently eclipse the sun. The solar eclipses are never total, for even the nearer and larger moon, Phobos, can only appear about a third of the diameter of the sun. There are no total eclipses of the sun for the Martians; they are either partial or annular. The shadow cones which the moons cast from the side turned away from the sun never reach the surface of Mars. There are also eclipses of Deimos by Phobos, but the latter moon moves so quickly that it only eclipses the sun or occults Deimos for a short time, in both cases measured in seconds. As luminaries they must cut a poor show, for the total amount of light they afford during the night is far inferior to that afforded by our single moon.

Owing to their small dimensions and their proximity to Mars, the moons are difficult telescopic objects. The period of visibility is a couple of months either side of the date of opposition, amounting to three or four months at intervals of two years. Even the largest telescopes fail to show any detail on their tiny disks; indeed, it requires considerable attention to make out their disks and to distinguish them from stars.

In 1952 Mars was farther from the earth than in 1954, but higher in the northern sky, and thus better placed for observers in Britain. On May 17 the writer and Patrick Moore, observing together with the writer's 15¼-inch reflector, saw Deimos clearly for more than half an hour, following it until it had drawn so close to Mars as to be lost in the glare. Moore has also caught Phobos with certainty with his 12½-inch reflector, describing it on April 28, 1952, as "unmistakably seen, but excessively faint even with Mars outside the telescopic field; on the very limit of visibility with this instrument, at least to my eyes."

These moons add to the mystery of the red planet. Perhaps they were two of the hundreds of minor planets which revolve around the sun between Mars and Jupiter, captured by Mars during a close approach in the past. They are mere lumps of rock; we are not even sure that they are globes, and it is not impossible that they may have a somewhat irregular shape, as some of the minor planets seem to have. Eros is an example of a small body, about the size of the moons of Mars and perhaps slightly larger, which comes quite near to the earth at certain times and varies greatly in brightness. It has been suggested that this may be caused by Eros being a rough and practically shapeless rocky mass.

Owing to its proximity Phobos cannot be seen from the Martian polar regions, as it is always hidden by the curvature of the surface of Mars. In the equatorial zone it passes overhead, and must look considerably larger when high up in the sky that when near the horizon. A few moments' thought will be sufficient to show that Phobos is considerably nearer when overhead, and therefore looks as big as it possibly can.

If Mars is inhabited by intelligent beings, and if they have telescopes of equal power to ours, it would be easy to find out whether these little moons also are inhabited. The rarefied atmosphere would enable high powers to be used, bringing Phobos within a mile and Deimos to within four miles. However, both moons are certainly barren worlds, being devoid of atmospheres and appreciable surface gravity. They would be admirably suitable for observatories, and may be used as such during the coming era of space travel. What a view of Mars could be obtained from Phobos! Seen from this little world Mars would look over 80 times larger than the moon does to us, and would go through all its phases in less than eight hours.

To ourselves Mars does not always look round, but may appear gibbous, that is to say like the moon three days before or after full. At such times we can see a little bit of the darkened or night side of Mars. Along the line dividing the darkened from the sunlit portion of the planet (the "terminator," to use the correct and technical term), the sun is either rising or setting. This line is generally smooth, but occasionally is irregular owing to the presence of bright projections or spots. When such are seen they can only be viewed for a short time before being carried into the bright or the darkened portion, owing to the rotation of Mars on its axis. Although fiction writers, for example H. G. Wells in his fantasy *The War of the Worlds*, have ascribed these bright spots to flashes from a stupendous gun which was being used by the Martians to project cylinders to the earth, there is no doubt that they are clouds floating in the Martian atmosphere at a considerable distance above the surface and thus catching the sun's rays.

But there are other bright spots, not floating in the atmosphere but on the surface. They appear in the equatorial regions during the summer and autumn on Mars. Usually they lie on or close to the borders of one or more of the patches of vegetation, such as Syrtis Major or Margaritifer Sinus. These white spots develop markedly during the hot season, and, although we are not sure what they are, the plausible suggestion has been made that they may be cultivated areas or, in other words, crops.

Certain canals occasionally show activity of another kind; they become double! What was previously seen as a long, linear marking now has a companion running parallel to it a short distance away. They look exactly like a rail track, and may maintain their parallel

nature for hundreds of miles. They are somewhat rare, and the majority of the canals are always seen as single; moreover, they seem to be confined to the desert regions. The appearance is exactly as though the companion canal were a reserve channel which may be brought into use if the circumstances warrant it. They have been the subject of much discussion; some people regard this double aspect as an illusion, without, however, explaining in a convincing manner how the illusion could arise and why only some of the canals are subject to it.

We have already seen that Antoniadi claimed to have resolved the canals into a series of dots and dashes with the great telescope at Meudon. On the moon there are certain dusky streaks on the slopes of some of the craters which are approximately the same apparent width as those of the Martian canals. By this is meant that they look to us about the same size; in reality, the Martian canals are much larger, and it is only distance which dwarfs them to the size of the lunar streaks.

The writer has carefully examined these streaks with the same great telescope which was used by Antoniadi, and actually used the same eyepieces. In small or comparatively small telescopes the streaks on the crater slopes look just like the canals of Mars, that is to say, simple and uniform lines or bands. But with the giant telescope at Meudon the streaks were clearly resolved into dots and dashes, presenting a perfect analogy to what Antoniadi found on Mars.

It seems to be established that not only the ordinary and single canals but also the double ones are in reality made up of discontinuous fragments. It cannot be a mere accidental arrangement of the dots in a straight line, but must be a real feature of the surface. That is to say, the dots and dashes are either the widest portions of continuous cracks, assuming that the canals are cracks, or they have been deliberately placed in these positions, assuming Lowell's ideas to be true. In either case, we can safely assume that all parts of the cracks or ditches are too narrow for us to see except where the enlargements (the dots and dashes) happen to be. It must be remembered that those astronomers who accept the conclusions of Antoniadi draw the discontinuous fragments as arranged in lines. *Unless there is some underlying linear arrangement, no suggestion of continuous streaks would be recorded.*

Now it is contrary to scientific spirit to assume an artificial origin unless a natural cause is proved inadequate. It is also very difficult to distinguish between natural and artificial structures unless we have a more or less complete knowledge of the regions in question. If the earth could be observed with some supertelescope on the moon or Venus, both natural and artificial features would be seen. The latter

would be such things as towns, cities, and perhaps some of the larger canals. Unless observations were conducted during their actual construction, it would be very difficult to decide whether the Panama and Suez canals were natural or artificial. We know that these canals are partly natural, in the existing lakes, and partly artificial, in the cuttings executed by man; but without this knowledge, an observer on another world could not decide. We are in the same position as the imaginary observer, the canals came into being before telescopes were invented. Although Lowell thought that he detected a few new canals in previously undisturbed parts of the surface, this has not been confirmed by others, and all the canals have an unknown antiquity. Even if Lowell's theory should be proved, it might still be found that the artificial portions are extensions and adaptations of previously existing natural features. The majority if not all of the markings on Mars are natural features; and although they may seem strange to us, owing to their unfamiliarity, they are the logical result of the conditions prevailing on the planet, in exactly the same manner that crater mountains are the natural result of the forces which molded the lunar surface. On any planet the works of its inhabitants must be mere superficial scars in comparison with the operations of Nature—unless the inhabitants deliberately adopt a policy of self-destruction, to which rational beings are naturally averse.

Time enters into the discussion, although it is generally overlooked. The present era is one of life-bearing for the earth, but on Mars might be quite different. For all we can tell, the greatest life-bearing era on Mars may now be long past; on the other hand, it way still lie in the future. The present desertlike appearance of Mars suggests that it is more likely that maximum life existed in the past than that it should still lie in the future. It looks as though the life which still exists on Mars is but a feeble reflection of what once existed. Mars may well prove to be a world in its old age and approaching extinction, for owing to its small size it would run through its stages of planetary evolution more rapidly than the earth.

The favorable opposition of Mars in 1924 was observed by professionals and amateurs alike. At the Jungfrau Observatory, in the Alps, at an altitude of 11,600 feet, Professor Schaerer noted that the canal Tartarus and part of the Mare Cimmerium were cloud covered. According to some press reports, light flashes were also seen, apparently of the same nature as lightning. At the Yerkes Observatory the two moons "shone like chips of star dust." At this opposition the first attempts were made to "listen in to Mars." A 24-valve wireless set was set up in Dulwich Village, and it was stated that strange signals were picked up in the early morning which were very clear and resembled dots in the Morse code, arranged in groups of four and five.

It was stated that these sounds were not Morse and could not be identified as coming from any station on this earth. They continued, intermittently, for about three minutes. Nothing, however, came of this, and it seems probable that the dots were a combination of atmospherics and heterodyning or interference between various stations. In 1924 radio was in its early stages, and these signals almost certainly had a terrestrial origin. Reports of the picking up of similar signals were received from abroad; in America, for example, where it was stated that they alternated between a long wave length of 25,000 meters and a short wave of 75 meters.

At the previous opposition, in 1922, Professor Slipher at Flagstaff had photographed a large white cloud which hung for four days over the edge of the Pearl Bearing Gulf.

A close approach took place in 1909, when Mars was observed by Antoniadi and also by the French observer M. Jarry-Desloges. In this year Syrtis Major had a pointed tip, while among the strange changes noted were those in the canal Phison, which appeared double on September 14 and 16, but single on September 15. It seems possible that it was partly veiled by clouds on the latter date. The Lake of the Sun was elongated in 1909, and a complicated system of canals was seen to radiate from it.

What appeared to be clouds projecting from the surface were seen by Antoniadi on October 10, 11, and 12, 1924, while other clouds were seen over Hellas. In 1924 most of the dark areas were very much darker than usual, which suggests that the proximity of Mars to the sun (it being summer in the southern hemisphere) may have favored the development of vegetation. The polar cap soon showed dark rifts within it, and began to break up into detached pieces which were especially well seen on August 23.

The opposition of 1926 was remarkable in many ways. It was not so close an approach as that of 1924, but the planet was higher up in the sky for northern observers. A special feature of this year was the large number of clouds which were seen to distort the terminator of the planet. Two such clouds were seen to the southwest of Syrtis Major on September 15 by Antoniadi, while on December 15 at least three such clouds were noted to the east of the Lake of the Sun or the Eye of Mars. At times the whole planet seemed to have masses of clouds or mists drifting over it, now hiding this and then that feature on the surface. The canal Nepenthenes and Lacus Moeris, to the left or west of Syrtis Major, were very broad and dark in this year, while the Mare Tyrrhenum was clearly resolved into separate patches which in all probability were more intensive areas of vegetation.

A very large cloud apparently floating at a great height above the surface was seen on March 16, 1929, by the same talented observer,

Antoniadi. Very few of the canals were seen this year, when the planet was farther from the earth than during the previous two oppositions.

A vast *yellow* cloud was seen from August 23 to 27, 1909, by Antoniadi covering much of the surface around the Trivium Charontis, while in December 1911 another such cloud appeared to the south and southeast of Syrtis Major and could be seen changing its shape and size from November 3 to December 23. This cloud stayed for a long time over this part of Mars, in contrast with the majority of such clouds, which usually disappear fairly quickly. It is certain that the yellow and the white clouds differ in their composition, and this has an effect on the length of their visibility.

If we compare the drawings of the earlier observers, made before the canals were recognized as such in 1877, we can still trace, although faintly, some of the principal canals, which proves that these strange features are not of recent development, but are permanent. We can also find traces of clouds and other indications of variations among the dark patches, showing that the weather conditions on Mars have not altered appreciably during the last 100 years.

But in addition to the temporary changes introduced by clouds, we also find others which affect the dark patches, such as changes in their shapes, a growing-out more than usual at this point and a withdrawal at another. These changes are more interesting than those due to mere clouds, as they must mean some alterations in the patches of vegetation themselves. It may be that they arise from the amount of sunshine at the time, coupled with temperature changes, but it is not impossible that some at least are due to the activities of some other form of life—that is to say, to deliberate interference with the growth at the places where the changes are noted. Perhaps the soil is exhausted in these places, with the result that vegetation fails for a time, and it is not impossible that the failing is due to the excessive "reaping" in those areas. It must be remembered that what look to us like small features are in reality objects covering many square miles of the only fertile areas on this otherwise arid planet. It is even possible that the changes are due to the failing of some new kind of vegetation deliberately introduced as an experiment.

The last opposition of Mars took place in 1954,[2] but the planet was too low in the sky for successful observations in Britain. At one time it rose only 10 degrees above the southern horizon, and under such conditions no useful observations could be obtained. The writer was

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[2] Since this was written, Mars came to opposition in 1956. The most striking feature of this opposition was the excessive faintness of the markings. The writer observed at Mendon but only succeeded in detecting a few of the "canals."—H. P. W.

then in the United States, where Mars was at a much greater altitude, in the southern States over 27 degrees, and advantage was taken of the great American telescopes. Among other instruments the planet was observed with the 60-inch reflector at Mount Wilson Observatory and also with the 40-inch refractor at the Yerkes Observatory; the latter instrument is the largest refracting telescope in the world.

As seen from Mount Wilson in early June, the ice cap at the south pole was very large and surrounded by a dark band. There is nothing unusual in this, for the melting cap is *always* seen to be surrounded by a dark band, and the cap was beginning to melt. But what *was* very unusual was the intense blueness of the markings, more especially the so-called "seas" in the southern hemisphere. Before the cap has appreciably contracted these are normally of a grayish hue, and are not pronounced. That this blue color was real was proved by observations with filters of various tints; the blue came through clearly. There was also a lot of cloud in the atmosphere of Mars, as shown on the drawing on plate 1, which was made with the 60-inch Mount Wilson reflector on June 17. That night only two of the canals could be seen, but it was clear that they were continuous streaks and *not* made up of a series of dots and dashes. Later on when Mars was examined with the Yerkes 40-inch refractor, numerous canals were detected, and they all appeared to be uniform streaks strongly suggestive of cracks in the surface, while the oases, several of which were seen, suggested craters, presumably filled up with some dark-colored matter. At Yerkes the blue nature of the markings was again evident, almost vivid when contrasted with the reddish regions. They prompted the remark that perhaps Mars too was experiencing unusual weather. It will be remembered that Britain and Europe had a very wet and unsettled summer in 1954.

With the other and smaller telescopes, such as the 26-inch refractor at the Naval Observatory, Washington, D. C., and the 15½-inch refractor at the Washburn Observatory, Madison, the same general results were obtained. At Yerkes the outer moon of Mars, Deimos, was seen close to the planet itself without requiring any shielding of the planet. Even in the great Yerkes telescope this tiny moon appeared as a point of light and not as a disk. Phobos, the inner moon, was always either behind or in front of the planet on the particular occasions when I was observing with these magnificent instruments. The clouds persisted, and with the Yerkes instrument a large white one was clearly seen projecting beyond the limb of Mars.

There have been other attempted explanations of the dark and permanent markings on Mars. One of the most recent is that of Dr. D. B. McLaughlin, of the University of Michigan, U. S. A. A summary of this new theory was given in the American astronomical journal

Sky and Telescope, vol. 13, No. 11. According to this account Dr. McLaughlin believes that the dark areas are not caused by vegetation, as most astronomers think, but are due to drifts of volcanic ash. The volcanic dust originates in active volcanoes, which are supposed to be at the tips of fan-shaped markings. It is suggested that the general wind circulation of the planet causes the dust and ash to be deposited in the places where we see the dark markings. The green color is ascribed to the reaction of carbon dioxide and the scanty moisture with the ferromagnesian minerals to form chlorite and epidote, which are green in color. The canals Dr. McLaughlin believes to be partly ash and partly volcanic rifts; this idea was, however, suggested long ago by the late Alfred Russel Wallace.

The objection to this theory is the presumed existence of volcanoes on Mars. There may be volcanoes on Mars, but that the ash or dust from them would always be blown by winds to the same points on the planet is a weak point unless we assume that there are certain irregularities in the surface which also enter into the shaping of the dark areas. Also, this theory does not take into account the seasonal changes which affect both the dark areas and the visibility of the canal system.

We have considered the evidence which observations have given as to the presence of water on Mars, even although the indications are that the amount is small. Also, the seasonal changes in the dark markings, their altered colors and the way in which the canals begin to make their appearance as the polar caps melt, the certain if occasional presence of clouds or at least mists on Mars, and the general appearance of this most fascinating planet all combine to suggest that Mars is largely a waterless desert and that the dark areas are really tracks of vegetation that owes its life to what water can be conveyed along the natural waterways or canals. Perhaps the future will show that Lowell, with his imaginative but magnificent idea of their having been dug in the past by a race of intelligent beings in a vain effort to ward off the inevitable drying-up of their world, was right after all; but this is not likely to happen until the first spaceship has touched down on the alien and strange landscape of the red and green planet. Then will come the time when men may settle on the planet; then, perhaps, the name will be changed from that of the god of war to that of the god of peace, and men will live freely in their new environment.

The Story of Cosmic Rays[1]

By W. F. G. Swann

Director, Bartol Research Foundation of The Franklin Institute

[With 2 plates]

The atmosphere is, to an extremely small extent, a conductor of electricity, and we know that such a condition results from the presence of charged atoms called ions, with positive and negative charges. These occur in practically equal numbers. The positive ions are those atoms that have lost a negatively charged particle—an electron—and the negative ions are those that have acquired the negative charges lost by other atoms. As a result of mutual attraction, the negative ions are continually returning their negative charges to atoms that have lost such charges, so that if the continued existence of a "state of ionization" is to be maintained, there must be present some agency that continually detaches electrons from atoms. Such agencies are, in part, the radiations that are emitted by the normal radioactive contamination of the atmosphere. However, such agencies are confined to low altitudes, so that to account for ionization at high altitudes, where, indeed, it is greater than at low altitudes, we must invoke some other agency. This agency is the cosmic radiation which, at first, was assumed to be a single kind of radiation coming into our atmosphere from above.

The simple concept of a single type of radiation entering the atmosphere and being responsible for the phenomena observed had to be modified as time progressed. The situation, as we have it today, is much more complicated. We have been led to believe that there is a "primary radiation" consisting for the most part of positively charged hydrogen atoms, and that the radiation, on entering our atmosphere, bombards the atoms of the atmosphere with the resulting emission of all sorts of other atomic particles which, in their totality, constitute what we *observe* as the cosmic radiation.

ATOMS AND ELEMENTARY PARTICLES

Atoms and their parts.—An atom of matter consists, essentially, of two parts—an inner core, composed of positively charged particles

[1] Reprinted by permission from Sky and Telescope, published at Harvard College Observatory, Cambridge, Mass.

called protons, and uncharged particles called neutrons. Around this core we have a cloud of negative electrons.

Hydrogen, the lightest of the atoms, has in its normal state only one proton in its core or nucleus, and attendant upon this is a single electron. Helium has two protons and two neutrons in its core. Uranium, until recently the heaviest element known, has, in its nucleus, 92 protons. In the case of one kind of radium there are 143 neutrons, while in another kind there are 146 neutrons. It is the number of *protons* that determines the *chemical* nature of the element. Atoms having the same number of protons but different numbers of neutrons are called isotopes of one another.

Subsidiary elementary particles.—Although neutrons, protons, and negative electrons form the only permanent constituents of the atom, other particles come into existence during periods of drastic perturbation such as occur when a primary cosmic ray or one of its descendants strikes an atom of air.

First, we have a particle called the positron, which is the counterpart of the negative electron, having the same mass, but carrying an electric charge equal and opposite to that of the negative electron. Sometimes it is called a positive electron.

Other important particles are the mesotrons. The mesotrons are peculiar in the sense that they have but a finite life and die in due course without the intervention of any external agency.

When the mesotrons were first discovered, it was thought that they were all of one kind, but as knowledge has advanced, it now appears that there are several kinds, which are in part related to one another like child and parent, or brother and sister. When a proton of high energy enters our atmosphere, collisions with the atoms of the air result in the proton's disintegration and the formation of mesotrons which are, as it were, born from its ashes. When a heavy atom enters the atmosphere, its individual protons suffer a similar fate, with the resulting production of mesotrons. The neutrons of the atomic nuclei seem to be preserved from a like fate, but they are not completely immune, because a neutron freed from its home in an atomic nucleus sacrifices its right of permanent existence and dies after a period of about 20 minutes.

On page 249 we shall return to a fuller discussion of the individuals of the mesotron family.

In phenomena of the kind we are discussing, another particle has entered the picture, the neutrino. Its presence has only been inferred, but never observed in the ordinary sense of the word. As is well known, physicists place great faith in the conservation of energy and momentum in atomic processes. However, it appears that in some of these processes, adding up all the contributions of the various particles

to the energy after the occurrence in question gives a sum less than that obtained by adding up the various contributions before the occurrence. And so the concept of the neutrino was invented to play the role of the thief who stole the energy.

Photons.—The term "photon" is used to characterize all of those particles that are associated with wavelike properties. In particular, it comprises ordinary light rays, ultraviolet rays, X-rays, and the so-called gamma rays from radium.

There was a time when these radiations were thought to be of a wave nature, the wave concerned spreading out into space from the place of origin with ever-decreasing intensity.

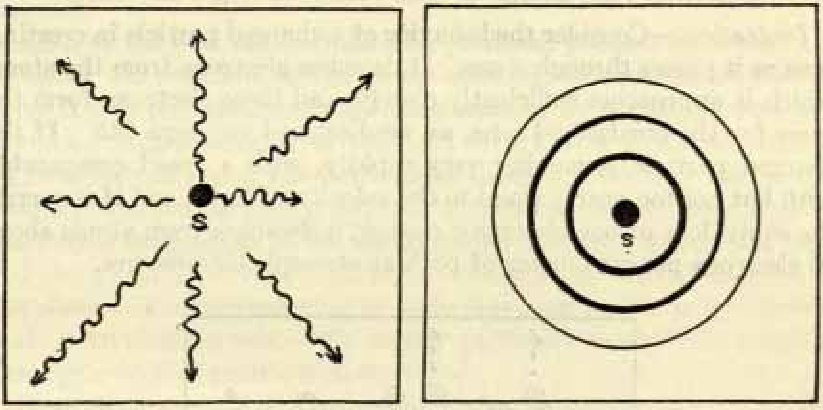


FIGURE 1.—These sketches illustrate the two concepts of the nature of light. At the right, waves diminish in intensity as they spread from a source; at the left, wavelike particles retain their energy as they travel outward.

Early in the present century, radiations of this type began to present a great puzzle to the student of physics. In some respects the radiations acted like waves, as already stated, but in others they acted like particles.

The concept of spreading waves is inevitably bound up with diminution of the wave's intensity with distance from the point of its origin. On the other hand, the radiations we have classed as photons, while exhibiting wavelike characteristics in certain phenomena, masquerade in other instances like bullets shot from a gun. Apart from effects resulting from the resistance of the medium, such a bullet is just as potent after traveling 100 yards as it is after 1 yard. In the case of a battery of such guns firing in all directions from a fort, the chance of getting hit would diminish with the distance from the fort. But if one did get hit, he would be just as dead if hit at half a mile as he would be if hit at 100 feet.

The mathematical physicist has formulated his ideas and theories in such a manner that he is not disturbed by the apparent paradox in

the coexistence of the bulletlike properties and wavelike properties, but he has not succeeded in presenting them in such a form as to give contentment to the layman. Fortunately for our purpose, these matters need not cause us serious trouble. It will suffice for us to think of these radiations, which in the aggregate we have called photons, as particle-like in nature; they differ in energy, however, not by the normal differences of velocity, but by some other characteristics customarily associated with definite frequencies of vibration. In other words, their velocities are all the same (in a vacuum), and their frequency of vibration determines their energy content.

FURTHER PROPERTIES OF THE FUNDAMENTAL PARTICLES

Ionization.—Consider the behavior of a charged particle in creating ions as it passes through a gas. It detaches electrons from the atoms which it approaches sufficiently closely, and these electrons form the basis for the creation of ions, as we discussed on page 245. If the charged particle is moving very rapidly, with a speed comparable with but not too nearly equal to the velocity of light, and if it carries the equivalent of one electronic charge, it detaches from atoms about 30 electrons per centimeter of path at atmospheric pressure.

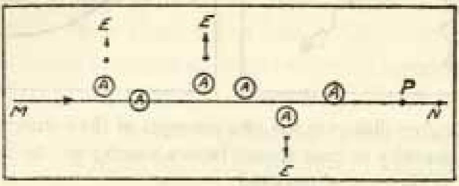


FIGURE 2.—P is a high-energy charged particle pursuing the line of flight MN. It affects atoms along its path and frees the electrons, E.

By this act, the particle loses energy as it progresses through the gas, and the more energy it has lost the more rapidly does it spend that which remains.

Particles moving more nearly with the speed of light, that is, faster than those that begin by detaching about 30 electrons per centimeter of path, are even more active. Thus, the charged particle spends its energy freely when it is very rich (moving nearly with the speed of light) and when it is very poor (near the end of its path). It is most conservative in its expenditures when it is moderately rich.

The ionization produced by a particle per centimeter of its path depends to a first approximation only upon its velocity and its charge. Doubling the charge increases the ionization per centimeter of path by a factor of four.

Pair production.—A phenomenon more drastic than ionization occurs when very rapidly moving charged particles collide with atoms, and associated with it is a phenomenon resulting from the collision of high-energy photons with atoms. The charged particles concerned

in this matter are almost exclusively electrons, for although, in principle, heavier particles can operate in an analogous manner, the effect is so much more prominent in the case of the lighter electron that we can ignore it in the other cases.

Start with a high-energy photon which finds itself directed toward an atom. This photon possesses the characteristic of becoming mathematically irritated when it comes into the vicinity of the atom. Existence as a photon becomes mathematically intolerable, but nature has provided for it the option of changing its state of existence by allowing it to materialize into two oppositely charged electrons; these share the energy of the photon between them, but not necessarily in equal amount.

Each of the pair of electrons thus produced pursues its course, and if either has sufficient energy, when entering the domain of another atom it will jerk that atom in such a manner as to give rise to a new photon. This photon, if of sufficient energy, will repeat the history of its ancestors, giving rise to two more charged particles. The process would go on and on were it not for the fact that each of these progeny has only a small share of the energy of the original photon; and when the energy of a particle falls below about 10 million electron volts, the chance of its reproducing itself in this manner becomes infinitesimal. (An electron volt is the energy gained by an electron in falling through a drop of potential of one volt.)

Once the energy of an electron has fallen below the value necessary to carry on the process of photon emission and pair production, its remaining energy is gradually drained away from it by ionization and it loses the characteristics of a high-energy ray.

In the light of the foregoing, it may be expected that if a high-energy photon or electron enters our atmosphere, or comes into existence in the upper atmosphere as a result of the primary cosmic rays, this electron or photon will initiate the phenomenon of pair production. As we descend into the atmosphere, the number of electrons passing through a unit area will at first increase, attaining finally a maximum, after which it will decrease. This is because there is a birth rate of electrons resulting from the pair production and a death rate resulting from electrons falling to an energy at which they are no longer able to perpetuate the process. Highest in the atmosphere is a region where the birth rate exceeds the death rate; below that the two are equal and the number of rays is a maximum; further descent takes us to regions where the death rate exceeds the birth rate and the number of electrons diminishes.

As we proceed in the study of cosmic rays, we shall find that pair production plays a significant role in the phenomena observed.

Properties of mesotrons.—The need for the existence of a charged particle intermediate in mass between the electron and the proton was

first sensed by the Japanese physicist Yukawa, as a result of efforts to understand the nature of the forces that bind the particles of an atomic nucleus together. From purely theoretical considerations, Yukawa was able to calculate the mass and mean life of the particle in question: about 300 times the mass of the electron and a mean life of the order of $\frac{1}{100}$ of a microsecond (a microsecond is a millionth of a second).

Not long after Yukawa's calculations were made, it was found that the principal constituents that we observe as cosmic rays at sea level are charged particles having a mass of the general order of magnitude of that of Yukawa's predictions, but these particles have a mean life of the order of 100 times that predicted by him.

Of course, the discrepancy of 100 times in the mean life was embarrassing to the logic of the subject, but physicists were happy to have experimental verification of Yukawa's work to the extent of the actual existence of any kind of particle intermediate in mass between the electron and the proton, and having any kind of a finite life expectancy. It was hoped that time would clear up the discrepancy, possibly by modifications of the theory.

Time did, indeed, clear up the discrepancy, but not quite in the way anticipated. The particle found in cosmic rays was not Yukawa's mesotron, but rather a child of that mesotron. Before very long, experiment revealed that there did indeed exist in nature a particle, now called the *pi-mesotron* (π-mesotron), of mass about 300 times the electron's mass and with a mean life of the order of a hundred millionth of a second, as predicted by Yukawa. The pi-mesotrons are usually brought into existence as the result of the bombardment of atomic nuclei by high-energy charged particles such as the primary cosmic rays which enter our atmosphere from outer space. This kind of mesotron can have either a positive or negative charge.

Experiment has further revealed the existence of uncharged mesotrons of mass about 300 electron units; these are also called pi-mesotrons. They are produced by bombardment of atomic nuclei by high-energy particles, and have a life expectancy of the order of 10^{-15} second. A neutral pi-mesotron decays into two photons of high energy—gamma rays.

The child of the pi-mestron is called a *mu-mesotron* (μ-mesotron), and it is the result of the death of a pi-mesotron, which is thought to be accompanied also by the emission of a neutrino. The mu-mesotron plays the most important role in cosmic-ray phenomena. Being a charged particle, it, of course, ionizes like any other charged particle. However, it has a rest mass 210 times as great as that of the electron, and so an energy 210 times that of the electron for the same velocity. Moreover, on account of its large mass, it is relieved of the duty of

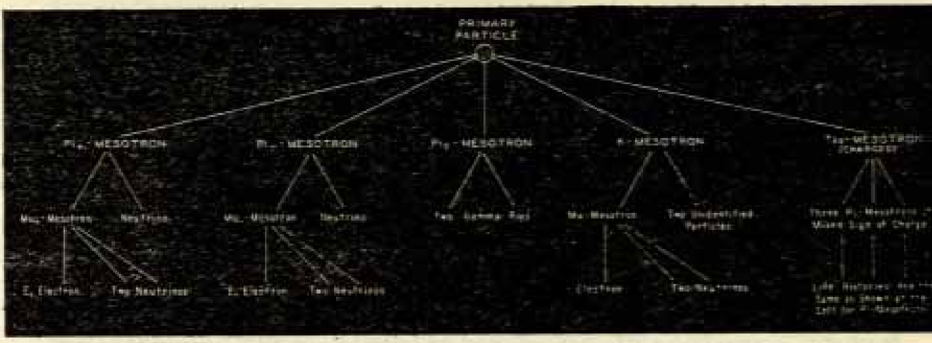


FIGURE 3.—The descendants of a high-energy particle may include those shown here. Any one such primary particle does not, in general, give rise to all the types of mesotrons in the second stage.

pair production and loses energy only by ionization phenomena. As a result of this, the mu-mesotron can travel very much farther through matter than can an electron of the same energy.

The mu-mesotron, when traveling with a velocity small compared with that of light, has an average life of only about 2.3 microseconds. Even if it traveled with the velocity of light and had only this average lifetime, it could not go more than about 700 meters before death overtook it. However, it results that the theory of relativity demands and experiment confirms that the lifetime of the particle shall increase with its energy. As a result of this, many cosmic-ray mesotrons have lives hundreds or thousands of times 2.3 microseconds, so that, so far

ELEMENTARY PARTICLES OF MATTER

Particle	*Mass in electron masses*	*Average lifetime against spontaneous decay*	*Products of spontaneous decay**
Electron	1	Stable	
Proton	1,845	Stable	
Neutron	1,848	18.5 ± 3.6 minutes	Proton and electron
Positron	1	Stable	
Positive mu-mesotron	210	2.3 x 10^{-6} sec.	Electron and two neutrinos
Negative mu-mesotron	210	2.3 x 10^{-6} sec.	Electron and two neutrinos
Positive pi-mesotron	276	About 10^{-8} sec.	Mu-mesotron and neutrino
Negative pi-mesotron	276	About 10^{-8} sec.	Mu-mesotron and neutrino
Neutral pi-mesotron	264	Less than 10^{-13} sec.	Two photons
K-particle	About 1,100	About 10^{-8} sec.	One mu-mesotron and two neutral particles
Tau-particle	977	Greater than 10^{-8} sec.	Three pi-mesotrons
Chi-mesotron†	900–1,500	Greater than 10^{-8} sec.	Pi-mesotron and one neutral particle
Kappa-mesotron†	Less than 1,400	Greater than 10^{-8} sec.	Mu-mesotron
Zeta-particle	537	Greater than 10^{-10} sec.	Two pi-mesotrons
Positive V-particle†	Uncertain	Less than 10^{-8} sec.	Uncertain
Negative V-particle†	Uncertain	Less than 10^{-8} sec.	Uncertain
Neutral V-particle	Uncertain	Less than 10^{-10} sec.	Probably mesotrons and protons
Photon	0	Stable	None
Neutrino	0	Stable	None

*In general, these products are accompanied with release of energy in kinetic form and in amount sufficient to conserve mass.

†It is uncertain how far the positive and negative V-particles are distinct from the chi- and the kappa-particles.

as life is concerned, they could travel right through the atmosphere and to distances far below.

The death of a mu-mesotron is accompanied by the birth of an electron—positive or negative—and two neutrinos.

Finally, in the realm of cosmic-ray particles there have appeared the *K-mesotron*, of around 1,100 electron mass units, and another heavy particle, the *tau-mesotron* (τ-mesotron) of about 900 electron mass units. The tau-mesotron is unstable and is believed to decay into three pi-mesotrons.

It is of interest to observe that even the neutron, when in free space, is unstable and has a life expectancy of only about 18½ minutes, after which it changes to a proton by ejecting an electron in the mysterious process of dividing nothing into two halves, throwing out the negative half (a negative electron) and retaining the positive half (a proton).

Of the various mesotrons, only the mu-mesotron plays a significant part in the phenomena observed in cosmic rays. However, from the standpoint of what one may call cosmic-ray genealogy, a recognition and understanding of the other particles is necessary.

COSMIC RAYS IN THE ATMOSPHERE

The primary cosmic radiation.—The primary cosmic rays appear to contain samples of every kind of nonradioactive atom in the universe. The chief constituent is the proton, the nucleus of the hydrogen atom. The percentages of the elements vary according to different observers, but from representative data they are in the ratio of 4,000 particles of hydrogen to 1,000 of helium, to 35 of carbon, nitrogen, and oxygen, to 10 of all nuclei with atomic numbers greater than 10.

There can be no mesotrons in the primary radiation, for the mean life of the mu-mesotron, the longest-lived of the mesotron family, is only 2.3 microseconds when the particle is at rest, and even with energies as great as 100 billion electron volts, the mean life is only $\frac{2}{1000}$ of a second. There is no place from which the mesotrons could have come, for the nearest body that could reasonably be a candidate for supplying them is the sun, and a particle traveling with the velocity of light itself would take more than 8 minutes to reach us from the sun.

Lifetime considerations rule out even neutrons as possible components of the primary radiation, since neutrons have a mean life of the order of 18.5 minutes. The sun is the only body from which they could reach us, and if they came from the sun in appreciable amount, there would be a much larger change in their intensity from day to night than experiment reveals. Unlike charged particles, whose paths

can be bent by the earth's magnetic field, neutrons could not reach the side of the earth opposite their point of origin.

The production of mesotrons.—When the protons of the primary radiation enter our atmosphere, they very rapidly disintegrate into mesotrons, as the result of collisions with the nuclei of atoms. The protons disappear so rapidly by this process that only about a third of them remain at an altitude where the pressure is $\frac{1}{10}$ of an atmosphere.

Even in the case of the heavier atoms contained in cosmic rays, it is the protons in their nuclei that are responsible for giving birth to mesotrons; and since mesotrons are the most important constituent of the rays that we observe at lower altitudes, a helium atom, containing two protons, is twice as effective in producing mesotrons as is a single proton. An atom like iron, with 26 protons in its nucleus, is 26 times as effective as is the proton itself. If iron atoms, for example, were only 1 percent as numerous as free protons, they would nevertheless contribute about one-third as many mesotrons as do the free protons. Thus, despite the relatively small percentage of atoms of high atomic weight, it turns out that 50 percent of the mesotrons produced in the atmosphere come from primaries that are heavier than protons.

When a proton, either free or in combination in a nucleus, enters the atmosphere and collides with the nucleus of an atom of air, it is probable that, in the first instance, pi-mesotrons are produced, as shown in the genealogical chart on page 251. A slowly moving pi-mesotron with a mean life of 10^{-8} second would travel only a meter or so before disintegrating to form a mu-mesotron. A slow mu-mesotron, with a mean life of the order of 2.3 microseconds, would go less than 700 meters before disintegrating into an electron.

Mesotrons of higher energy live longer and penetrate farther, so that a mesotron of 10 billion electron volts would live for about $\frac{2}{10000}$ of a second and in that time could travel 60 kilometers. Thus, from mean-life considerations alone it would have no difficulty in penetrating the whole atmosphere. As a matter of fact, only about 1.3 billion volts of its energy are necessary to allow for all the ionization it would cause on such a journey, so that neither ionization loss of energy nor mean-life considerations would prevent such a mesotron from reaching the earth's surface. Indeed, some of the mesotrons are produced with such high energies that they can penetrate far more than the thickness of the earth's atmosphere, and cosmic-ray intensity has a measurable value at depths below the earth's surface comparable with 250 meters of water.

Starting in the outer regions of the atmosphere, we have only the primaries. These decrease rapidly with descent, by the production of mesotrons, so that the mesotron intensity rises as we descend into the atmosphere until, at a depth of about $\frac{1}{10}$ of the whole atmosphere,

the rate of production of mesotrons balances the rate of decay and there is a maximum in the mesotron intensity. Below this point, the disappearance of mesotrons (as a result of mean-life considerations enhanced by energy loss) exceeds the rate of formation, and the mesotron intensity declines and continues to decline with further descent. The high-energy mesotrons penetrate far, while the low-energy mesotrons, either by decay or by coming to rest as a result of energy loss, travel only shorter distances.

The production of electrons.—How does the number of electrons change with height? Near the extreme upper limits of the atmosphere cosmic-ray electrons are very few, because the mesotrons that breed them have not yet been produced by the primaries in sufficient number. The mu-mesotrons that are produced with low energy in the first tenth of the atmosphere die very near the places where they are born, giving rise to electrons. Higher-energy mesotrons, which can travel farther, do not die as rapidly and therefore do not produce electrons as copiously as do the low-energy mesotrons. Therefore, many more electrons will be formed in the higher regions of the atmosphere than in the lower.

Each electron that is produced, however, goes through the process of pair production (discussed earlier, on pp. 248–249) and gives rise to progeny which increase in numbers as we descend from the point where the original parents were formed. The increase continues until it becomes balanced by the loss of electrons, when the ionization that they produce reduces their energy below the point at which the electrons can reproduce themselves. Thus, each electron formed has its own little genealogical history involving rise in progeny to a maximum with descent, followed by a decline in numbers with further descent. A combination of the life histories of all the parent electrons produced near the top of the atmosphere thus results in a rise of the electron intensity as we descend, a maximum being reached at a depth corresponding to about $\frac{1}{10}$ of the atmosphere, after which the electron intensity diminishes rapidly with further descent.

The situation is such that practically none of the parent electrons produced in the higher regions of the atmosphere can succeed in having any progeny at the earth's surface. In fact, a parent electron would have to have an energy of some 10 trillion electron volts in the outer regions of the atmosphere to have a single offspring at the earth's surface!

Such electrons as we find in the lower atmosphere come partly from the relatively rare deaths of fast-moving mesotrons and from the deaths of mesotrons that have been slowed down by ionization energy losses. Another source of electrons is closely related to ionization itself: If a mesotron passes sufficiently near an electron in an atom,

it may hurl that electron out with an energy very high compared with the normal energy given to electrons by mesotrons in ordinary ionization. Electrons shot out of atoms with high energy in this manner are referred to as *knock-on electrons*, and they contribute appreciably to the electron component of the radiation measured, particularly at low altitudes.

Neutrons.—It is of importance to observe that disintegration of the protons in a primary incident atom leaves free neutrons, which should therefore be fairly plentiful in the places where proton disintegration occurs. Experiment, indeed, reveals the fact that neutrons do exist in the atmosphere, and their intensity mounts very rapidly as high altitudes are approached. It is not at present known whether the neutrons in high-energy atoms disintegrate on collision as protons do, but even if such is the case, we may expect to find some neutrons that have escaped destruction of this kind by becoming reduced in energy in the collision process to the point at which they no longer invite destruction by such a process.

Extensive showers.—The phenomena above are the main contributions to what we measure as the cosmic radiation. However, there are other comparatively rare but very interesting phenomena. In extensive showers, some of the rays observed at sea level arrive so close together in time, in spite of wide separation in their places of arrival, as to suggest that they have a common origin, probably in one very high-energy primary particle. P. Auger, who has studied these matters intensively, states that such showers of rays may correspond to more than a million particles arriving simultaneously over an area of 25 acres. If we should imagine these particles to originate through pair production from a single high-energy electron, it would be necessary to assume for that electron an energy between 10^{15} and 10^{16} electron volts. Taking all losses into consideration, as high as 10^{18} electron volts for the parent particle has been estimated as necessary to account for some of the phenomena observed.

Nuclear disintegration caused by cosmic rays.—Another matter of great interest in nuclear physics, although possibly of subsidiary interest to cosmic-ray students, is nuclear disintegration produced by the rays. The neutrons in the upper atmosphere doubtless play a significant role in promoting such nuclear disintegrations.

It has been customary to classify the events observed according to the number of prongs which emanate from the centers of collision of the rays with the nuclei of the atmospheric atoms, as seen in sensitive films. Study of these tracks, their angular spread, their ranges in matter, combined with the fundamental principles of the conservation of energy and momentum during collision, serve to enhance our knowledge in that most mysterious realm of nuclear theory that involves the nature of nuclear forces.

THE EFFECT OF TERRESTRIAL, SOLAR, AND GALACTIC MAGNETIC FIELDS

The primary cosmic rays appear to come toward our earth uniformly from all directions, or nearly so. The earth is a huge magnet, with a magnetic field of small intensity but large extent, so that the paths of charged particles approaching the earth are bent. Consideration of the influence of the magnetic field leads to the following conclusion: Particles of the same charge and momentum (relativistic mass times velocity) are indistinguishable as regards the effect of the magnetic field upon them.

While the student of cosmic rays usually speaks of particles in terms of their momenta, the kinetic energy is a quantity more familiar to the layman. It is, however, less simply related to the bending effect in a magnetic field. Thus, for a given energy, heavy particles are bent less in their paths than are light particles.

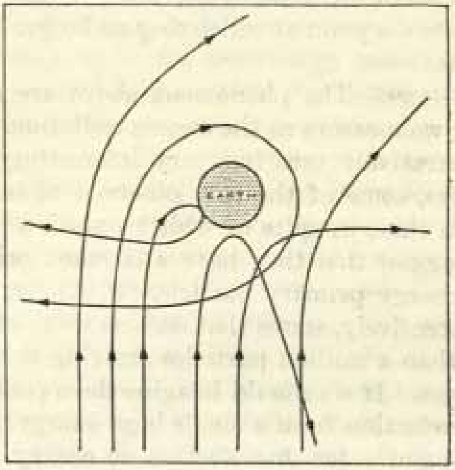


FIGURE 4.—Paths of primary cosmic rays (in this case protons with 15 billion electron volts energy) as they are deflected by the earth's magnetic field. The paths are drawn in the plane of the earth's magnetic equator, with the north pole upward from the paper.

Any charged particle, such as a proton, has to have a certain minimum energy before it can reach the earth's vicinity at all without being bent back into space by the magnetic field. That minimum energy amounts to 14 billion electron volts for a proton entering vertically at the magnetic equator. It gets less and less as we proceed toward the magnetic poles until, theoretically, at the poles themselves particles with infinitesimal energy could reach the outer bounds of the atmosphere.

At any given geomagnetic latitude (we shall henceforth call this simply *latitude*), the minimum energy for entry of positive particles into the atmosphere varies as the direction of entry varies. It is greatest for the east and least for the west, the value for the vertical being intermediate in amount.

There was a time when a strong belief existed that the primary particles were photons and not charged particles at all. J. C. Clay's discovery of the variation of cosmic-ray intensity with latitude, a discovery confirmed by a series of worldwide measurements by A. H. Compton and his associates, first led to the conclusion that there were at least some charged particles in the primary radiation. Later, as the matter was more deeply studied in connection with intensities from different directions, it appeared that there was no room for anything else but charged particles and, further, that the particles were positively charged.

Of course, the latitude effect is greatly complicated by the fact that our observations are made in the atmosphere itself. Suppose that observations could be made at an altitude so high that a negligible amount of air existed above. Then we might expect that the intensity of the radiation would mount continually as we passed from the magnetic equator to the magnetic pole and included in our measurements more and more of the less energetic radiation that can reach the atmosphere at higher latitudes. But if we should observe at a depth in the atmosphere, and even if we could be sure that we were measuring only the primary cosmic rays, we should expect that the increase of intensity with latitude would continue only until a latitude was reached at which the low-energy rays, deflected away by the magnetic field below that latitude, would still be unable to reach us because they were stopped by the atmosphere.

From this viewpoint the variation with latitude of, let us say, the vertical intensity of the primary cosmic rays might take the form shown in the accompanying simple diagram (fig. 5). The curve *ABC* would hold at very high altitudes; *ABD* would apply at a place where there is an appreciable amount of the atmosphere above; *AEF*, where

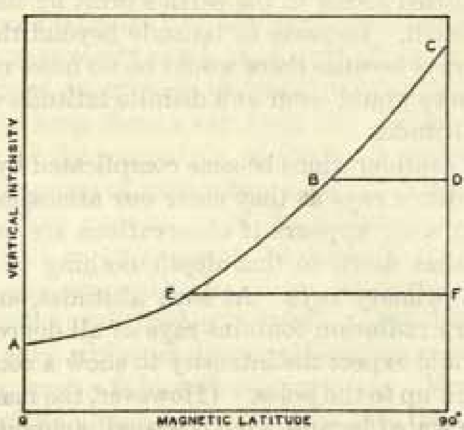


FIGURE 5.—The effect of absorption by the atmosphere on the intensity of cosmic rays at various latitudes.

there is more of the atmosphere above, and so on. We might thus expect that the knee of the latitude curve—the place where the horizontal portion starts—would occur at a latitude which was greater the greater the altitude.

Now the simplicity of the foregoing picture is disturbed by the fact that the knee does not seem to vary with latitude as the altitude is varied, but seems to occur around 50° latitude for all altitudes. This led to the view that the origin of the knee was not to be explained by the absorption of low-energy rays by the atmosphere, but by something outside the atmosphere, something that creates, for the energy spectrum, a lower limit of energy which is nevertheless sufficiently great to permit penetration of the whole atmosphere. Under such conditions, the intensity-versus-latitude curve would show, at all altitudes, a knee corresponding to this energy.

To solve this paradox, it was suggested that the knee of the latitude curve owed its origin to the sun's magnetic field. The bending of the paths of the rays near the earth, that is, within a few earth radii, is caused mainly by the earth's magnetic field, which is here considerably stronger than the field of the sun. At greater distances from the earth, however, the sun's magnetic field could predominate.

Consider a sphere containing the earth's orbit and centered at the sun. Then, neglecting the influence of the earth's magnetic field, we can ask what energy a cosmic ray of assigned type must have to enter that sphere at all in the vicinity of the earth's orbit, which orbit lies roughly in the plane of the sun's magnetic equator. No rays of energy less than this amount could reach the earth's orbit at all. If this energy is enough to penetrate the atmosphere, we would expect, as found, that the cosmic rays falling upon the earth would increase in intensity with increase of latitude from the equator only to the point at which all the rays permitted access to the earth's orbit by the sun had been received by the earth. Increase of latitude beyond this point would yield no further rays because there would be no more rays. The knee of the latitude curve would occur at a definite latitude which would be the same for all altitudes.

The foregoing considerations become complicated by what happens to the primary cosmic rays as they enter our atmosphere. However, a fairly clean-cut story appears if observations are made so high in the atmosphere that down to that depth nothing in particular has happened to the primary rays. At such altitudes, and for the case where the primary radiation contains rays of all degrees of smallness in energy, we should expect the intensity to show a continual increase with latitude right up to the poles. (However, the matter is not quite as simple as here stated because even the small amount of atmosphere above the apparatus at high altitudes, and indeed the absorbing mate-

rial in the apparatus itself, places a lower limit on the energy of the rays that can be observed.)

If the intensity of the magnetic field of the sun at its magnetic pole is known, we can calculate its value at the earth's orbit, and we can calculate the energy below which no rays are to be found striking the earth's atmosphere. We can then compute the corresponding latitude on the earth at which further increase of latitude would yield no additional rays, as these would have energies lower than those permitted by the sun to be present.

The magnitude of the sun's magnetic field has been debated for a long time, and particularly within recent years. Optical measurements of the Zeeman effect led, about 40 years ago, to the conclusion that the sun had a field of about 50 gauss at its pole. If the sun acted like an ordinary magnet, the corresponding field in the earth's vicinity would prevent protons reaching us if they had less energy than 3 billion electron volts, which is the energy for entry through the earth's magnetic field at the latitude of 50° geomagnetic. Consequently, on this basis, we should expect that even at the outer limits of the atmosphere there would be no increase of intensity with latitude from 50° to the pole.

However, recent experiments by M. A. Pomerantz, under the auspices of the Bartol Research Foundation, the Office of Naval Research, and the National Geographic Society, have shown that over the range of latitude from 52° to 69° there is an increase of 46 percent in the vertical primary cosmic radiation intensity. Also, this radiation is composed of rays of such small energies that they could not possibly have come to us from outer space through the sun's magnetic field if it had more than 6 percent of the strength originally assumed from the Zeeman effect.

This argument should be accepted with reservation. There is increasing evidence that some primary rays may come to us from the sun itself, and such rays might reach us in spite of the sun's magnetic field because their short journey to us would not permit enough bending in their paths to keep them away from us. At the present time, the whole question of the magnitude of the sun's magnetic field and its bearing upon the primary cosmic rays calls for further elucidation.

Astronomers have come to doubt the existence of a solar magnetic field as high as 25 or 50 gauss at the poles of the sun. Indeed, G. Thiessen, who was originally one of the strongest supporters of the earlier value for the sun's field, concluded in 1949 that a strict analysis of the original data, while not denying the existence of the larger field, does not support such a field with any certainty. Moreover, his recent careful observations by improved methods, and those of others, using the new solar magnetograph, have led to a solar value of only about one gauss, and in the opposite direction to that formerly found.

On the other hand, observations of the solar field at one time do not necessarily guarantee its value at another. This warning is important, for some stars are known with certainty to possess variable magnetic fields. H. W. Babcock found in 1948 that the star HD 125248 has a magnetic field of 6,000 gauss at its pole, a field that reverses itself to a comparable value of opposite sign in a period of about 10 days. In Sky and Telescope for March 1950, Otto Struve presented a detailed discussion of "Stars as Magnets."

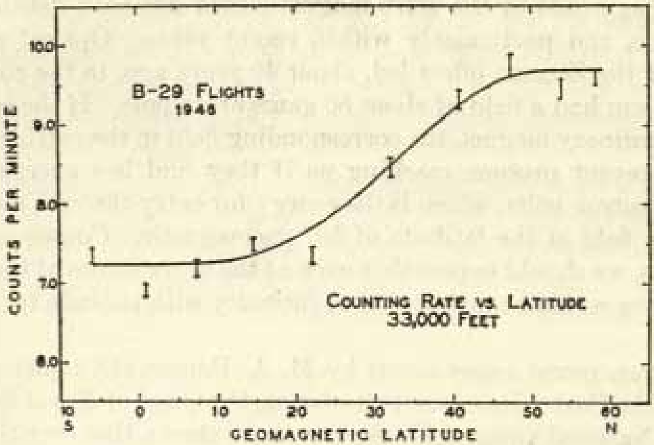


FIGURE 6.—How cosmic-ray intensity varies with latitude is shown by these measurements made under the author's direction in 1946 with airborne Geiger counter trains. As the number of counts per minute varies, each measured intensity has a statistical uncertainty, indicated by the length of the vertical line representing it. Note the leveling off of the curve at about 50° latitude.

Finally, in connection with cosmic magnetic fields, it has been suggested that the great galaxies of space may be the seats of magnetic fields. The magnetic fields in question are extremely small, of the order of 10^{-5} gauss, but their great extent makes them potent influences on the paths of the cosmic rays within the galaxy. Theoretical considerations show that a charged particle coming to the boundaries of such a region would be turned back into the galaxy as though the latter were provided with a reflecting wall, and similar considerations operate to prevent any cosmic ray that is outside the galaxy from entering it. Thus, on such an assumption, the cosmic rays within the galaxy would remain imprisoned within it forever or until destruction through collision with atoms or with other material in the galaxy, such as the stars, terminated their existence.

THE ORIGIN OF THE PRIMARY COSMIC RADIATION

Early students of the primary cosmic radiation pictured it as distributed with equal intensity over the whole of galactic and intergalactic space. Such an idea is attended with considerable difficulty.

Thus, R. D. Richtmyer and E. Teller have pointed out that on such a view the total energy carried by all cosmic-ray particles is much more than all the energy ever emitted by stars, together with their kinetic energy. In fact, it would be an energy less by only a few orders of magnitude than the total energy ($E=mc^2$) represented by all the matter in the universe.

Difficulties also arise as to how the supply of cosmic-ray particles can be maintained, since it is necessary to allow for a continual loss as a result of their collisions with atoms in space.

Such considerations have led to the general concept of an extensive magnetic field confining cosmic radiation to a definite region, a galaxy for example, as just mentioned above. Such a theory removes the necessity of extending the rays to the whole of intergalactic space, and avoids the enormous amount of energy that such extension would impute to cosmic rays in the universe as a whole.

There are three general possibilities to account for the enormous energies of the rays themselves, from 10^{10} to as high as 10^{17} electron volts:

1. The particles may receive energy by relatively small forces acting over great distances.

2. They may receive energy in single acts associated with enormous forces.

3. The particles, with their energies, might be considered to have been born with the universe, their properties depending upon the circumstances associated with that event.

The third possibility, first propounded by the Canon Lemaitre, cannot very well be proved or disproved. At the time of the supposed origin of the universe, conditions may have been so drastically different from what they are now that in our ignorance we may assume almost anything to form a basis for the origin of the high energies.

The second category is deemed unlikely because we now know that the cosmic radiation contains particles much heavier than protons. Quantum theory demands that a process that could give them their energy in a single act would disintegrate them.

The first category, therefore, presents the natural field for explanation in terms of our present knowledge. This category may be divided into two classes, in one of which the energies are acquired little by little by processes that are primarily mechanical, while in the second the forces are primarily electrical. Of course, mechanical forces are usually electromagnetic in the last analysis, but it is convenient to distinguish between processes that are very clearly the result of electromagnetic forces and those in which any electromagnetic feature is involved in more subtle form.

Mechanical methods.—Thus, in the mechanical realm we have effects of the pressure of light. For instance, L. Spitzer, Jr., has considered

the acceleration of small particles under the influence of radiation pressure in the tremendous energy outburst of a supernova. He calculates that such particles can receive from a supernova outburst from 0.01 to 1.0 billion electron volts per nucleon (proton or neutron) of each particle, within an interval of a few hours to a few weeks.

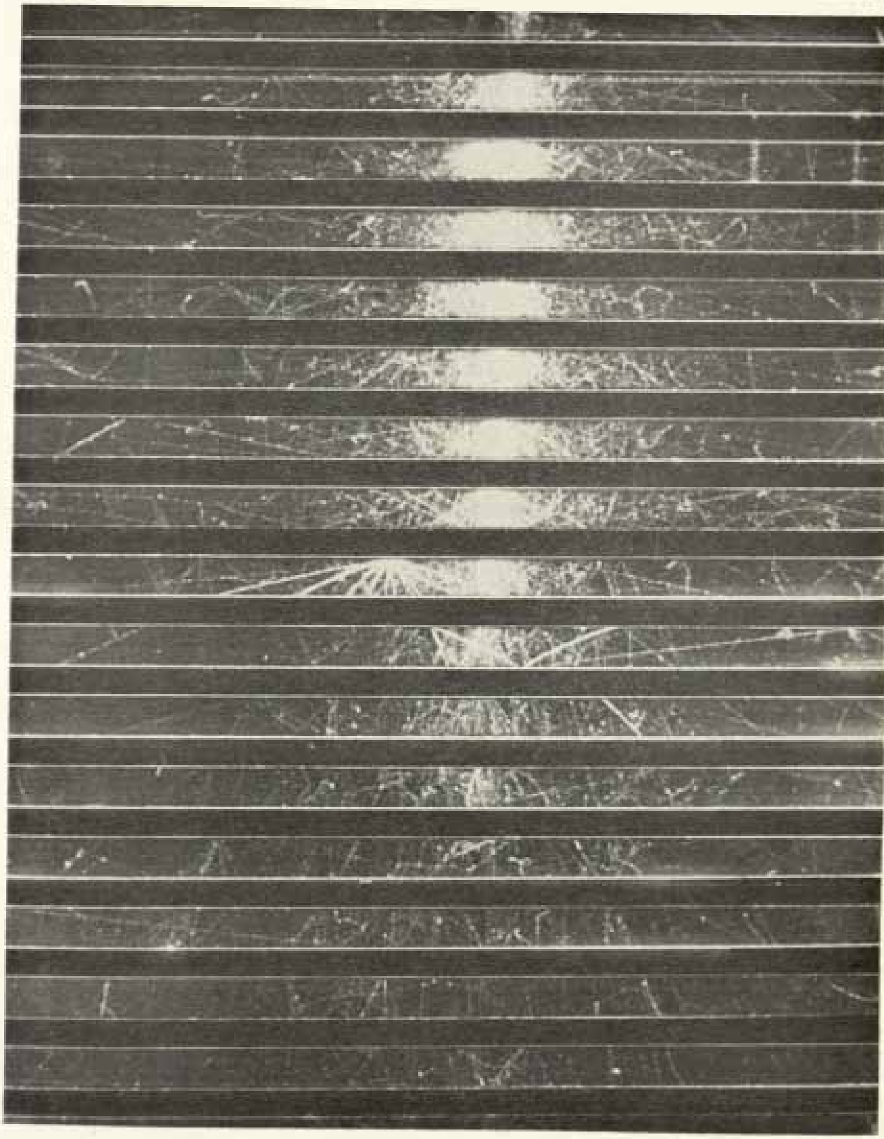
It is also postulated that the particles are held within the galaxy by an extensive magnetic field. As a result of collisions with atomic nuclei in the galaxy, the particles which have escaped collisions with stellar bodies break up ultimately into nucleons. The neutrons soon change to protons because of their finite life expectancy, and the protons are lost finally by encounters with atomic nuclei or by striking large bodies like the earth. An equilibrium condition is set up in which the number of high-energy nucleons contributed to the galaxy per unit time is equal to the number lost by the aforesaid processes. By this means, a cosmic-ray intensity between 0.0001 and 0.01 of the measured intensity is predicted, depending upon assumptions as to the frequency of nuclear collisions in the galaxy.

E. Fermi, in 1949, suggested an intriguing mechanism which may be pictured in elementary fashion by thinking of a room containing gas molecules and many hard steel spheres flying about and rebounding from one another and from the walls of the room. It will be convenient to eliminate gravity temporarily during our meditations.

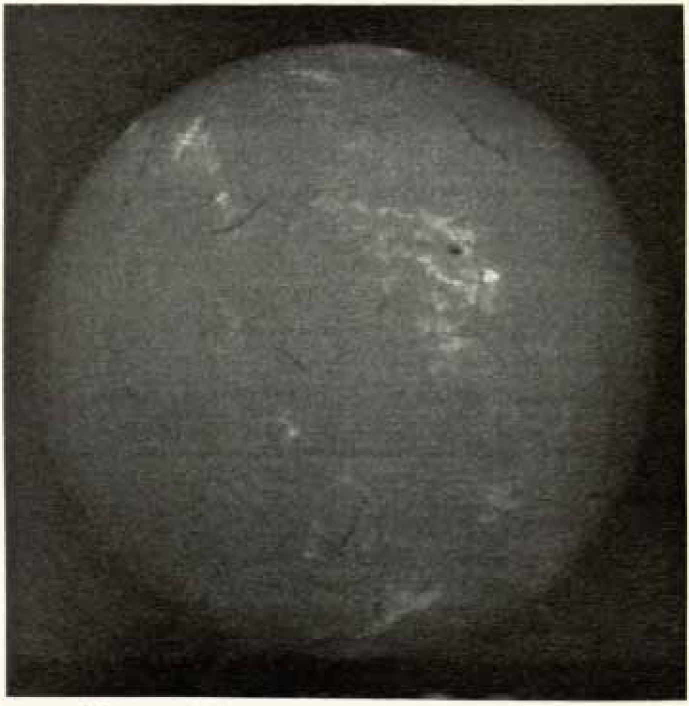
According to well-understood principles of thermodynamics, the spheres will, in the last analysis, lose their energies to the gas molecules and will finally come to a state of equilibrium in which the average translational energy of each sphere will be the same as that of a gas molecule. If the spheres are sizable, let us say 10 centimeters in radius, their average velocity will then be very small compared with that of the molecules. If, however, the spheres and the walls of the room are perfectly elastic, and if the spheres have considerable velocities initially, it will be a very long time before they get to this final state of equilibrium.

Meanwhile, the spheres will seek another quasi-stationary equilibrium in which they have a velocity distribution among themselves which is like that of the gas molecules, but with an average kinetic energy of each sphere enormous compared with that of one of the molecules. This kinetic energy will be approximately equal to the total original energy of the spheres divided by their number. In other words, the spheres will have a kind of macroscopic temperature of enormous amount which diminishes extremely slowly to the final temperature representative of the true equilibrium of both spheres and gas molecules.

The quasi-equilibrium of the spheres is not an accidental phenomenon, but is an inevitable consequence of the laws of dynamics as applied to the collisions between the spheres.



A cosmic-ray cascade of 10 billion electron volts.



$H\alpha$ spectroheliogram showing solar flare, April 26, 1946.

Suppose now that we imagine the molecules to be reduced in number so that the chances of molecules colliding with one another are very much less than their chances of colliding with the spheres. The molecules may become "ambitious" and seek, through their collisions, to accommodate themselves to the kinetic energy of the spheres, acquiring velocities much greater than those of the spheres. This ambition, though at first sight fantastic, is not indeed illogical under the specialized conditions we have assumed—dynamical laws require it.

In the Fermi mechanism our steel spheres are replaced by bounded magnetic fields, associated with moving masses of gas in the galaxies. A magnetic field of this kind is representative of a hard elastic body, because an electric particle entering it is turned back to the region from which it came, without any loss of energy as measured in the frame of reference in which the magnetic field is at rest.

However, there are certain difficulties in the Fermi mechanism. A fast-moving charged particle loses energy by ionizing the other atoms in its path; and while the density of matter in space is very small, the loss of energy by this process more than offsets the Fermi gain for low energies, where the ionization probability is greater. Only when a particle has attained the lower range of cosmic-ray energies is the Fermi mechanism capable of taking hold to increase further the energy of the particle. In this matter, heavy particles are at a disadvantage with respect to light particles. Thus, the Fermi mechanism requires a kind of injector process to get it started, such as the suggestion of Spitzer already cited.

Then, since the average energy gained by the mechanism is only about 10 electron volts per collision, and since each particle would have only about one collision per year, about 60 million years would be necessary for a particle to acquire cosmic-ray energy. During this period, it would have opportunities for collision with the nucleus of some particle in the surrounding space, and such a collision, as we know from the evidence presented by protons entering our atmosphere, would result in destruction of the particle and its conversion into mesotrons, which disappear because of their finite life.

As our quantitative knowledge becomes more complete, the strength of the evidence against the Fermi mechanism increases also, one of the most potent difficulties arising from the time necessary for the particle to acquire cosmic-ray energies and the chance of its destruction during that time.

Electromagnetic methods.—The science of electricity and magnetism suggests many processes by which cosmic-ray energies can be realized. Phenomena and quantities that are of negligible importance in experiments on a laboratory scale can grow to very fundamental

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significance in the scale of the cosmos. We can only briefly sketch some of the suggestions that have been made in this connection.

First, we could view the planets or other cosmic bodies as electrically charged to very high potentials, so that charged particles coming to them from space could acquire great energies in reaching them. It is with some comfort that one finds a fairly general method of dismissing this naive suggestion. While interstellar space contains only about one atom per cubic centimeter, there is reason to think that it is a comparatively good conductor of electricity for small electric fields. A large portion of interstellar atoms is ionized by ultraviolet starlight, and the mean free path of the ions is large because of the low density. Therefore, on a simple view of the matter, the electrical conductivity of interstellar space should be comparable with that of a completely ionized gas at atmospheric pressure and should amount, in fact, to two percent of the conductivity of copper. Under such conditions, any electrostatically charged body in the galaxy would become rapidly discharged.

A rotating, magnetized, conducting sphere experiences electrodynamic forces resulting from the rotation of its substance in its own magnetic field. Such a rotating sphere develops a potential difference between its axis and its equator. A star the size of our sun, possessing a magnetic field like that attributed to the sun until recently, would acquire a potential difference of about three billion electron volts when rotating in a nonconducting medium. For a magnetic star, such as was cited by H. W. Babcock, with a field of some 6,000 gauss at the pole and twice the sun's radius, the potential difference would be of the order of a thousand billion volts for the same angular velocity.

These potential differences would not be completely annulled by the electrical conductivity of interstellar space since they would be continually rejuvenated by the rotation of the star. They would be modified depending upon the ratio of the conductivity of space to the conductivity of the star itself. Under suitable conditions, such a rotating star could shoot out from one of its poles charged particles which at great distances would show cosmic-ray energies.

Recognizing the existence of violent magnetic disturbances on stars, akin to the growth of sunspots with their accompanying magnetic fields, the writer, some 20 years ago, suggested that such phenomena might result in cosmic-ray energies. The mechanism is quite analogous to that of an ordinary electrical transformer, where we have a changing magnetic field threading through a wire circuit and inducing therein an electromotive force which drives the current through the circuit. The actual circuit itself is not necessary for the realization of the electromotive forces, and if there be charged par-

ticles in the vicinity of the changing magnetic field, they will be whirled around by the electromagnetic forces even though they do not form part of a material circuit. It seems that cosmic-ray energies can readily be acquired by processes of this kind.

Recently, the foregoing mechanism has been extended to galaxies, where magnetic fields of the order of 7×10^{-6} gauss are recognized as existing. On the supposition that these magnetic fields have grown from zero, it appears that a charged particle that had zero energy when the field was zero would acquire energy continually, and could attain an energy greater than 10^{19} electron volts by the time the field had risen to 7×10^{-6} gauss. The complete story of the possibilities in this matter involves the lifetime of a cosmic ray, and the conditions pertaining to the case where the magnetic field has already attained a finite value at the time the particle, as a result of becoming charged, starts to acquire energy.

It is also known that if an electrical conductor in a magnetic field is removed from the field, the conductor will tend to carry the magnetic field with it. What really happens is that the change of magnetic flux that would occur in the conductor, if it simply left the magnetic field behind, introduces electromotive forces and so current. This forms a new magnetic field which just replaces the loss of magnetic flux that would otherwise have resulted from the departure of the conductor from the original field. A. Unsöld has called attention to the fact that, in those huge solar cataclysms in which a mass of matter is seen to be hurled from one portion of the sun's surface and to fall back upon another, we have a condition favorable for changing magnetic fields. If such a mass of matter is conducting and starts from a place where there is a magnetic field, it will pursue its course in the cataclysm, carrying the magnetic field with it until it eventally splashes once more into the sun, resulting in the annihilation or the dispersal of the magnetic field that it carried. The rapid change in magnetic flux through the regions of space in which the cataclysm occurs provides for the birth of electrical forces that can give cosmic-ray energies to charged particles.

Another method of accelerating charged particles has been suggested by D. H. Menzel and W. W. Salisbury and has been further developed by E. M. McMillan. It depends upon energy that is electromagnetic in nature, but with very low frequencies of only a few cycles per second and existing only in the extreme outer portion of the solar corona. Such low-frequency waves may arise from large magnetic disturbances initiated by solar flares and propagated through the corona. Sparsely distributed ions in the space around the sun (and other flare-type stars) might be accelerated to cosmic-ray energies if a mechanism of this kind actually exists.

But if the general cosmic radiation originates in stellar flares, why does it come nearly uniformly from all directions? This difficulty attends any theory that involves the stars as the origin of cosmic rays. Therefore, it has become customary to postulate an extensive magnetic field extending throughout the whole galaxy. This field is supposed to be weak but sufficiently extensive to curl up the paths of the cosmic-ray particles in such fashion as to prevent their escape from the galaxy, and at the same time to provide, as the result of successive reflections at the boundaries of the galaxy, for a condition in which an observer on our earth, for example, receives rays with approximately equal intensity from all directions.

If cosmic rays are purely stellar in origin, however, we might expect cosmic radiation from the sun to outweigh that from the other stars by something like the extent to which sunlight exceeds starlight. This is not the case, and radio noise from the stars in general seems to outweigh that from our sun; therefore, Unsöld is driven to assume that the sun is not typical in these matters and that the cosmic-ray activity of many stars may be very much larger than that of the sun.

An alternative not inconsistent with the possibilities is to attribute practically the whole observed cosmic radiation to the sun itself. For this, the magnetic field of the space around the sun would have to confine cosmic rays to the general vicinity of the solar system, with boundary reflections producing the observed near-uniformity from all directions. It is a fact that unusual solar activity is accompanied by variations in measured cosmic radiation. Thus, for example, in July of 1946 an exceptionally large flare developed on the sun, and during this period a change of as much as 20 percent in cosmic-ray intensity was observed by stations of the Carnegie Institution of Washington distributed in various localities.

Abundances of the elements.—Suppose that, regardless of the methods of origin and places of origin of the rays, different substances contributed to the rays in proportion to the amounts of the substances present. If the rays came directly to us from their places of origin, the proportions of atoms of different kinds in the primary rays should reflect the abundances of the different kinds of atoms in the universe.

If, however, the rays are confined by the boundaries of a magnetic field co-extensive with the galaxy, like fish kept in a gigantic pool, they will increase in numbers without limit. But each fish will die eventually, and a state of equilibrium will finally be reached in which the density of fish is such that the number that die per year will equal the number thrown into the pool. For a given rate of supply to the pool, the ultimate density will be greater, the greater the life of the fish. If fish of different kinds have different lives, their ultimate relative numbers will reflect their relative lifetimes as well as the rate at which they are thrown into the pool.

Death occurs to a cosmic ray when, in its wanderings through the galaxy, it strikes another atomic particle and disintegrates into mesotrons, and these in due course decay into electrons and neutrinos. The chances of collision are small; a cosmic ray may travel for many millions of years without hitting another atomic nucleus and dying. However, a larger atom will collide more frequency than a smaller one, and so lifetime considerations will tend to favor the lighter particles.

From the researches of astronomers, physicists, and chemists, we have found the observed relative abundances to be:

Element	*Cosmic rays*	*Sun, stars, interstellar matter*
H	100,000	100,000
He	25,000	10,000
C, N, O	900	130
Heavier elements	10	15

This table does not favor the light elements in relation to heavy ones, although carbon, nitrogen, and oxygen appear to be relatively more abundant in cosmic rays than in the universe as a whole. However, the mechanisms of acceleration may act more strongly on one atom than on another, and there is, after all, very little reason to suppose that the atoms of different elements have an equal chance of receiving cosmic-ray energies.

Nevertheless, one cannot doubt the importance of obtaining further more definite knowledge of the relative abundances of elements in the primary cosmic rays, and of the relative energies acquired by the different kinds of particles. From data of this kind, combined with further studies of such phenomena in the cosmos as a whole, we may hope some day to understand in greater detail all the processes involved in the life histories of these rays from the time of their creation from ordinary matter to their entry into our atmosphere.

Death occurs to a cosmic-ray when, in its wanderings through the galaxy, it strikes another atomic particle and disintegrates into everything, and these in due course decay into electrons and neutrinos. The chances of collision are small; a cosmic ray may travel for many millions of years without hitting another atomic nucleus and dying. However, a larger atom will collide more frequently than a smaller one, and so lifetime considerations will tend to favor the lighter particles.

From the researches of astronomers, physicists, and chemists, we have found the observed relative abundances to be:

	[illegible]	[illegible]
H	100,000	100,000
He	11,000	20,000
C, N, O	600	150
Heavier elements	10	25

This table does not favor the light elements in relation to heavy ones, although carbon, nitrogen, and oxygen appear to be relatively more abundant in cosmic rays than in the universe as a whole. However, the mechanism of acceleration may act more strongly on one atom than on another, and there is, after all, very little reason to suppose that the atoms of different elements have an equal chance of receiving cosmic-ray energies.

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Atmospheric Pollution in Growing Communities[1]

By François N. Frenkiel

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An urban community consists of an agglomeration of houses, commercial and industrial buildings, parks, churches, and various locations in which human activities are performed. Most of these activities require the use of such air-polluting sources as motor vehicles, railroads, house heating, refuse disposals, factories, and powerplants. Like a living being, a living community breathes the surrounding air and discharges the polluted air into the atmosphere. The very life of an urban area must, therefore, be accompanied by atmospheric pollution. In some cases, unfavorable meteorological conditions provoke an accumulation of pollutants; in others the density of polluting sources or their ineffective control are responsible for increasing contaminations. When, however, the meteorological conditions become unfavorable, in an area with a particularly high density of polluting sources, the air contamination may become very serious.

In an urban area the pollutants emitted into the atmosphere by such sources as industry, municipal and household incinerators, house heating, motor vehicles, railroads, and the inhabitants themselves include solid particles, liquid droplets, vapors, and gases. Some of the heavier particles fall out rapidly to the ground near the pollution sources, and the lighter ones deposit at some distance. However, a large amount of the pollutants move through the community before they are dispersed into the surrounding areas. Sometimes a temperature inversion confines the pollutants to lower levels of the atmosphere, or a mountain chain restricts their dispersion out of the com-

[1] This article is based on a paper presented at the annual meeting of the Air Pollution Control Association in Detroit, Michigan, May 22–26, 1955, and published in the Scientific Monthly, April 1956, pp. 194–203. It is used by permission of the editor of that journal. The present paper includes changes and additions made during the author's part-time association with the David Taylor Model Basin. A large part of the studies described were supported by the Bureau of Ordnance, Department of the Navy, under contract NOrd 7386.

munity. After a certain time, they spread out into the rural areas, reaching other communities, another State, or even another country. The nature of some pollutants may change by chemical or physical processes that take place during their dispersion. These processes may be due to meteorological causes such as snow, rain, and fog or to solar radiation and interactions with aerosols of natural origin, including salt nuclei, volcano dust, pollen, or such gases as ozone and nitrogen oxides. Various pollutants may interact among themselves,

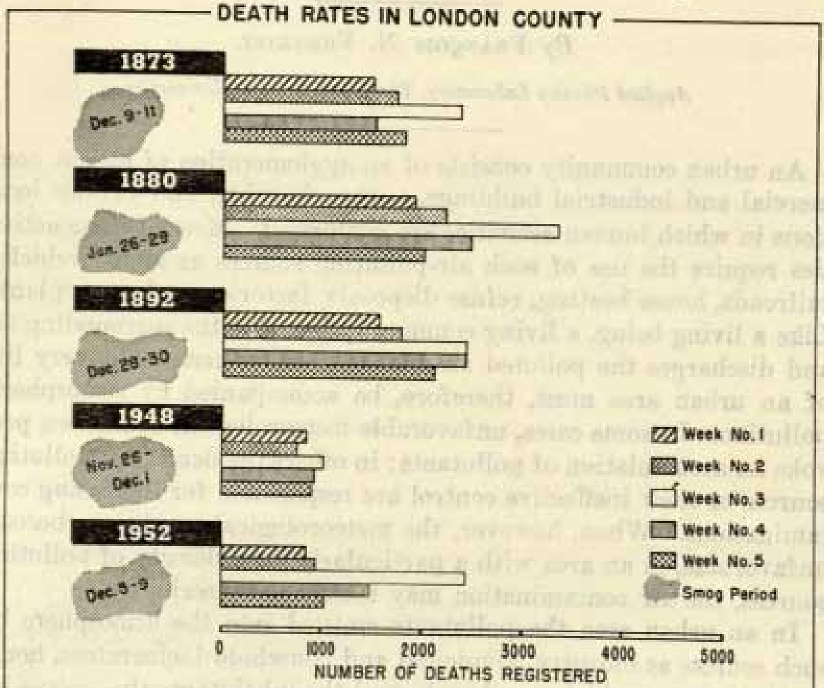

Figure 1.—Death rates in London County. Weekly death rates during several winter-season smog periods are compared with the weekly rates preceding and following the week of the smog period.

disintegrate, or otherwise change during their dispersion. Except for those pollutants that change into normal constituents of the atmosphere, the dispersing aerosols and gases come, after a certain time, into contact with the surface of the earth. Most of the solid particulates reach the land or the sea as a fallout; other pollutants may be washed down by the rain or may simply hit the ground when they are spreading in the atmosphere.

Atmospheric pollution starts with the *production* of pollutants—often as undesirable or incidental consequences of various industrial processes. An airborne cycle (fig. 5) for the pollutants begins with the *emission* of pollutants; emission is followed by *transfer* through

the atmosphere, and the cycle is completed by the *contact* of pollutants with people, livestock, vegetation, or any other objects. This contact may result in the elimination of the pollutants from the atmosphere, or it may be followed by the repetition of a similar cycle. The final stage of atmospheric pollution is its possible *damage* to health and property.

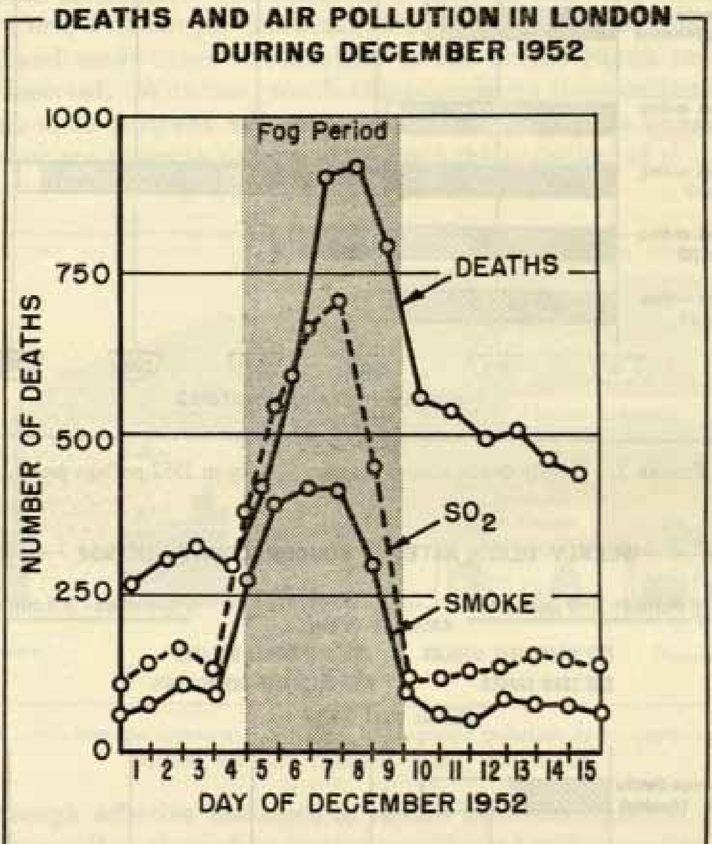

FIGURE 2.—Deaths and air pollution in London County during December 1952. Daily mortality rates are compared with the concentrations of smoke and of sulfur dioxide (SO_2).

Although the physiological effects of air contamination are not very well known, it has been determined that each year atmospheric pollution is responsible for the death of a large number of people. It is estimated [1,2][2] that the intense smog of December 1952 in London, England, which contained large concentrations of sulfur dioxide, killed at least 4,000 people (see figs. 1–4). For the last two years the concentration of ozone during smoggy days in the streets of Los

[2] Figures in brackets indicate references at end of text.

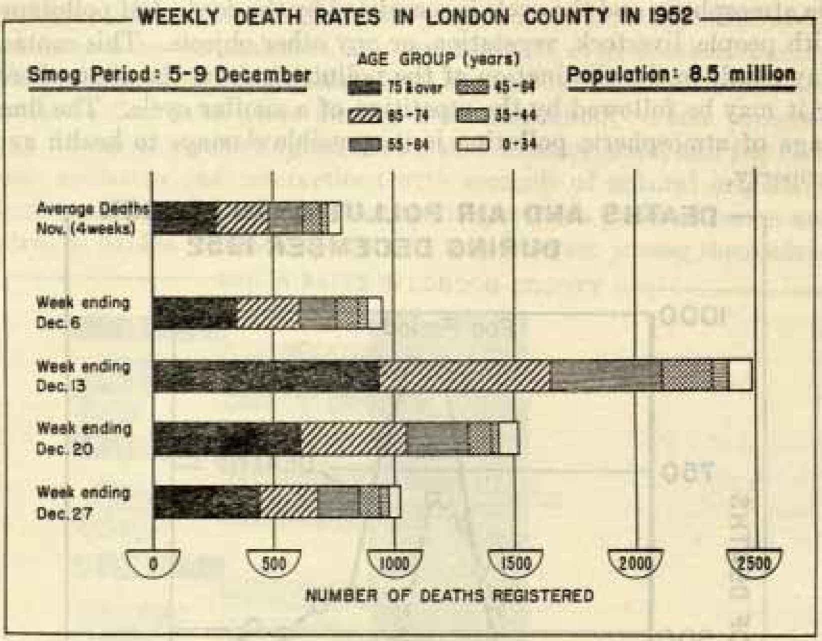

FIGURE 3.—Weekly death rates in London County in 1952 per age group.

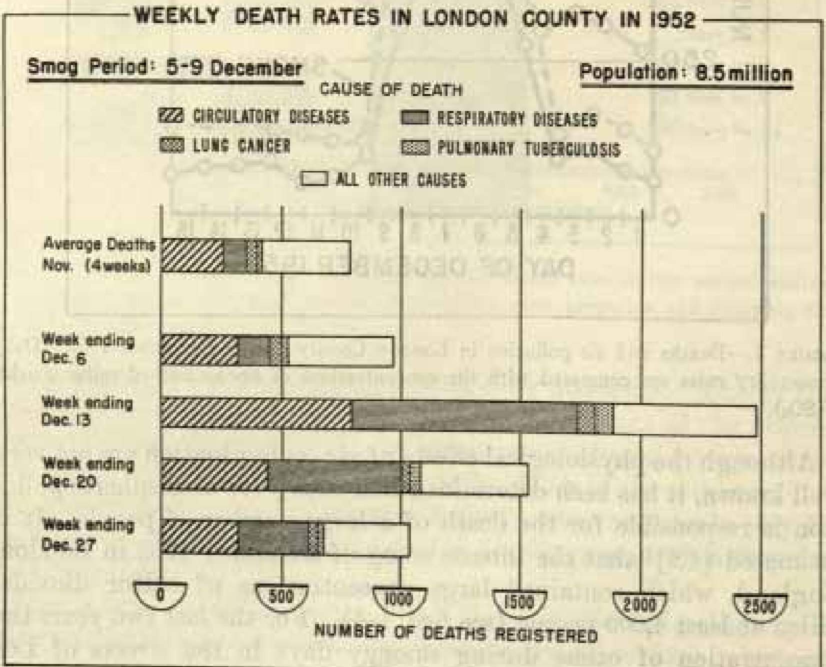

FIGURE 4.—Weekly death rates in London County in 1952 per cause of death.

Angeles County, Calif., was often larger than the safe concentration levels recommended by industrial hygienists as the maximum acceptable concentration for adult workmen in the factories. In many urban areas over the world, atmospheric pollution deteriorates buildings and materials, damages plants and crops, reduces visibility, and increases morbidity. The nuisance of periodic outbursts of smog in New York, Pittsburgh, Cincinnati, Detroit, Los Angeles, San Francisco, and many other communities in the United States has often been reported. With the growth of a community these outbursts will become more frequent and more damaging unless some appropriate measures are taken to control or to limit the pollution of the atmosphere.

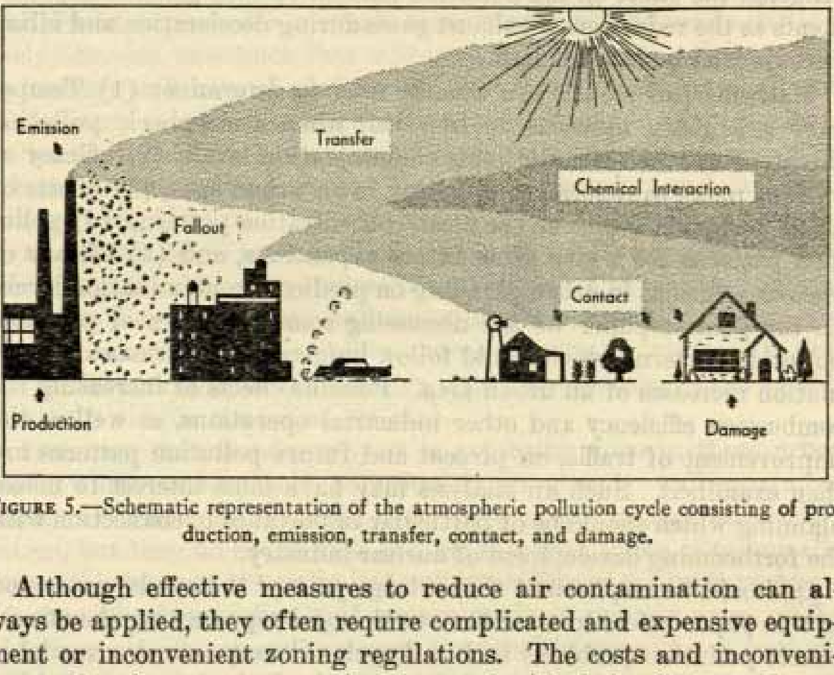

FIGURE 5.—Schematic representation of the atmospheric pollution cycle consisting of production, emission, transfer, contact, and damage.

Although effective measures to reduce air contamination can always be applied, they often require complicated and expensive equipment or inconvenient zoning regulations. The costs and inconveniences of such measures must be compared with their effects on the reduction of present or future air contamination of the community. These measures, whether corrective or preventive, must necessarily represent a compromise between the costs and inconveniences of pollution control measures and the desire for clean air in the community.

Mathematical methods can be used to study several aspects of atmospheric pollution in an industrial area. One of the objects of such studies is to determine the probable pollution patterns and the relative contributions of each pollution source to the mean concentration at each location. As an example of the results that can be obtained with a mathematical model of atmospheric pollution, we shall use Los

Angeles County, for which extensive data on the meteorological conditions and the distribution of pollution sources are available, and which is a good proving ground for atmospheric pollution studies. A theoretical analysis determines the contributions of pollutants dispersed from the following five general sources: (1) Motorcars, (2) oil and gas heating, (3) refuse incinerators, (4) petroleum industry, and (5) other industries. The expected effects of various improvements in the operation of incinerators, cars, and industry can then be evaluated using mathematical models with appropriate characteristics representing these improvements. The effect of a partial reduction in the production of certain pollutants by industry is calculated. Since motorcar exhausts contribute largely to the air contamination in Los Angeles, the effect on the pollution pattern of such general improvements as the reduction of exhaust gases during deceleration and idling periods can also be evaluated.

Mathematical models can then be used to determine: (1) Temporary emergency measures to be taken when atmospheric pollution threatens to reach the allowable contamination levels, (2) efficacy of various plans to reduce the pollution in an urban area, (3) effects of a new pollution source on the mean concentration patterns, (4) pollution patterns for a city after future expansions, and (5) efficacy of various solutions in urban planning on predicted contamination levels. In the present paper we are discussing some estimates of probable pollution patterns which would follow industrial expansions and population increases of an urban area. Possible effects of increasing the combustion efficiency and other industrial operations, as well as the improvement of traffic, on present and future pollution patterns are then examined. Such an analysis may have some interest to urban planning which should be of particular importance in connection with the forthcoming development of nuclear industry.

It should be emphasized that a large part of the results presented in this paper refers to a mathematical model representing the atmospheric pollution problems in Los Angeles County. Such a model is necessarily a simplification of the real physical phenomena taking place in the atmosphere. Although most of the data on the relative contributions of each pollution source are based on published reports in which these contributions are estimated, the mathematical model cannot reproduce exactly the real situation.

ATMOSPHERIC POLLUTION CONTROL

Production, emission, transfer, contact, and damage—this is the story of atmospheric pollution. At each of these stages the reduction of the danger of contamination can be attempted, and in most cases scientific and technological methods for this purpose already exist [3].

Those methods consist essentially of one or more of the following: (1) Improvement of chemical or physical processes with consequent reduction of the quantity of pollutants produced; (2) collection of pollutants at their sources; (3) transformation of noxious pollutants into inoffensive ones; and (4) improvement of the methods for evacuating pollutants into the atmosphere. When these methods are sufficient to eliminate the inconveniences and dangers of contamination and are still economically acceptable, then the atmospheric pollution problem can be easily solved. Often, however, under certain meteorological conditions, there still remains too much pollution even after all these methods have been applied.

The question then arises: What other methods can be used to reduce further the atmospheric contamination? An obvious answer is that one should improve the methods already existing and, more particularly, develop new ones that will give better results. Science and technology will have to play an important role in such development. As in many other technical problems, scientific work on atmospheric pollution depends on basic research in various fields of science. That a better understanding of those problems is necessary and that basic research will be helpful should be self-evident. But what is important to know now is: What can we do about atmospheric pollution with the help of the knowledge presently available? Can we, for instance, eliminate the emission of pollutants into the atmosphere from the various industrial plants or other sources of pollution without altering the useful operation of the industry or of those sources? The answer is a very simple one: Yes, we can.

You may then wonder why it is not being done in those urban areas where atmospheric pollution is an already well-recognized nuisance. There are no doubt many reasons for the lack of effective action, but they do not include the one that says action is technically impossible because of our limited understanding of the basic problems of atmospheric pollution. If we are ready to pay the price of the necessary equipment and to accept the possibly complicated methods of pollution abatement, we can reduce the contamination to any desired degree. The expenses and inconveniences required to achieve these results should be measured by the importance that is placed on the need for the reduction of atmospheric pollution.

How important is the reduction of atmospheric pollution at present? There is still need for much research to provide a quantitative determination of the dangers, inconveniences, and costs of atmospheric contamination. Nevertheless, it is a recognized fact that several urban areas produce too much pollution already and that a further increase in the contamination of their atmosphere may become very dangerous under certain meteorological conditions. Urban areas

must therefore face the problem of reducing the degree of contamination without at the same time seriously affecting many of those human activities that are responsible for the contamination and which, as much as the clean air, are necessary to the population.

Zoning of an urban area for the purpose of eliminating or limiting atmospheric pollution has been considered in several instances. The usual purpose of zoning in urban planning is the regulation of residential building. However, the principles and methods used in such zoning cannot be applied directly to atmospheric pollution zoning. In the regulation of residential building, one is concerned with zoning the *use of the land;* in the regulation of atmospheric pollution, one should be concerned with zoning the *use of the atmosphere* above the land. In the present article, I shall refer to such *air zoning* and I shall examine how it can be achieved.

An urban area usually includes residential and industrial buildings. Both the industrial and residential parts of the area contain sources of pollution. In a residential area, those sources may include house chimneys, motorcar exhausts, household incinerators, and others. In the industrial area, we may have smokestacks, oil refineries, steel mills, and other sources of industrial pollution. We should differentiate between two general areas of contact of pollutants with the ground. The first is the area near the source of pollution itself, and the second is the area at a considerable distance from the source. Most of the industrial sources emit very large amounts of pollutants but often discharge them through tall stacks and avoid the high concentrations of pollution at ground level. Therefore a large part of the industrial pollutants comes in contact with the ground at considerable distances from the industry that produces them. In residential buildings, automobiles, and house incinerators, the most important area of contact of pollutants with the ground is near the source of pollution itself.

The problem of air zoning is to limit the amount of atmospheric pollution tolerable at various locations in the area. In a populated community such limitation may be based on health requirements, nuisance level, visibility, or the pollution deposits on buildings, cars, and other objects. In rural areas it is necessary that atmospheric contamination be reduced to such an extent that it will not poison the soil, damage crops and vegetation, or injure livestock.

ATMOSPHERIC DISPERSION OF POLLUTANTS

The most obvious dangers of contamination are limited in some areas to the periods of time when the meteorological conditions are very unfavorable to the dispersion of the pollutants. Since not much can as yet be done about the weather, consideration is often given to shutting down sources of pollution when such unfavorable conditions

prevail. If such extreme measures should be necessary, it would be essential to reduce them to a minimum. It may indeed often be sufficient to reduce only partially the operation of the sources of pollution and to apply this measure only to some of the sources. It will also be important to predict the unfavorable atmospheric conditions in advance to avoid the application of such measures after the damage has started. What then is the most important information about the atmospheric conditions required for such a prediction? It appears to concern primarily the following factors: The velocity of the wind that carries the pollutants, the characteristics of the turbulence that disperses them, and the nature of the temperature inversions that confine them to the lower levels of the atmosphere. With the exception of precipitation, these are the most important atmospheric factors with which we should be directly concerned.

One of the most common illustrations of turbulent diffusion, which is directly related to atmospheric-pollution problems, is the dispersion of smoke emitted from a stack. The dispersion of the smoke plume is caused by two principal factors: (1) The general air motion that

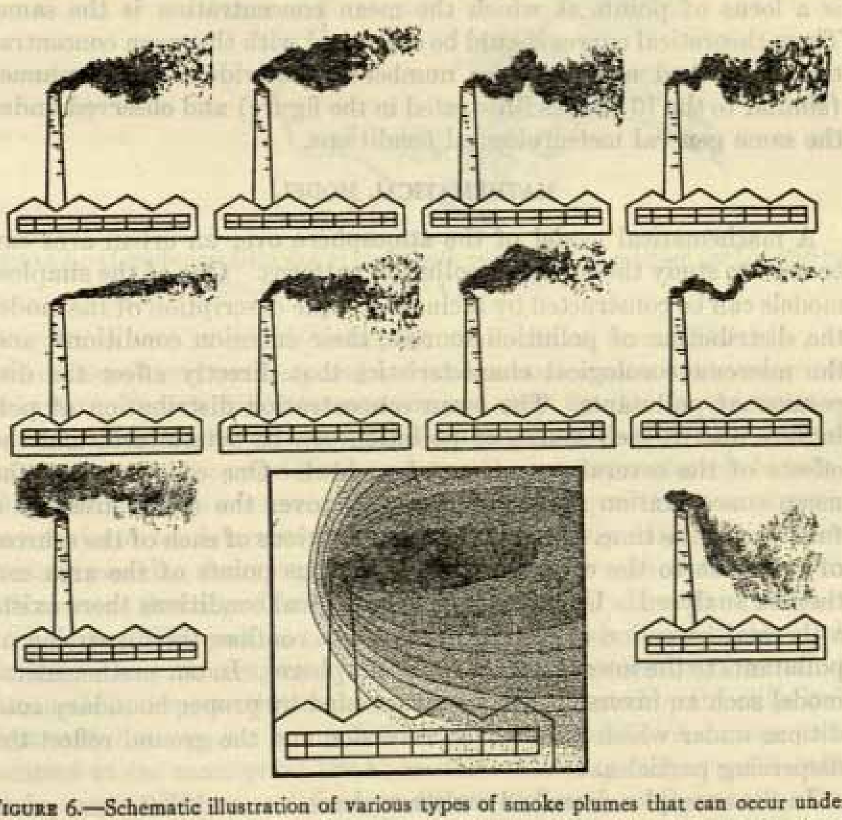

FIGURE 6.—Schematic illustration of various types of smoke plumes that can occur under the same meteorological conditions. Mean concentration for an average smoke plume in the framed figure can be compared with theoretical results.

carries the smoke downstream, and (2) the turbulent velocity fluctuations that disperse it in all directions. Figure 6 illustrates some shapes of smoke plumes under the same atmospheric conditions. The nature of atmospheric turbulence makes impossible a correct prediction of any of the individual examples of smoke plumes. One can, however, describe mathematically an average smoke plume and relate the mean concentrations of smoke at each point of this plume to the statistical characteristics of turbulence and to the mean wind velocity. The equations of turbulent diffusion for a continuous point source, which may be used to represent the emission from a smokestack, can be written explicitly under some simplifying assumptions, particularly when the mean wind velocity remains constant and the mass and size of the dispersing particles can be neglected [4].

The theoretical equations give the mean concentration distribution of dispersing particles as a function of the statistical characteristics of turbulence and of the mean wind velocity. These equations can be used to determine isoconcentration curves similar to those represented in figure 6 in the framed illustration. Each of these curves is a locus of points at which the mean concentration is the same. These theoretical curves should be compared with the mean concentrations measured using a large number of individual smoke plumes (similar to the 10 plumes illustrated in the figure) and observed under the same general meteorological conditions.

MATHEMATICAL MODEL

A mathematical model of the atmosphere over an urban area can be used to study the probable pollution patterns. One of the simplest models can be constructed by including in the description of the model the distribution of pollution sources, their emission conditions, and the micrometeorological characteristics that directly affect the dispersion of pollutants. The mean concentration distribution of pollutants due to each source of pollution can be determined, and the effects of the several sources can be added. One can then find the mean concentration pattern of pollution over the urban areas as a function of the time. The relative contributions of each of the sources of pollution to the contamination at various points of the area can then be analyzed. Under some meteorological conditions there exists a thermal inversion above the ground that confines the dispersion of pollutants to the lower levels of the atmosphere. In our mathematical model such an inversion will be represented by proper boundary conditions under which the thermal inversion and the ground reflect the dispersing particles.

In the examples described earlier we have assumed that there exists a well-defined mean wind velocity that is approximately constant in

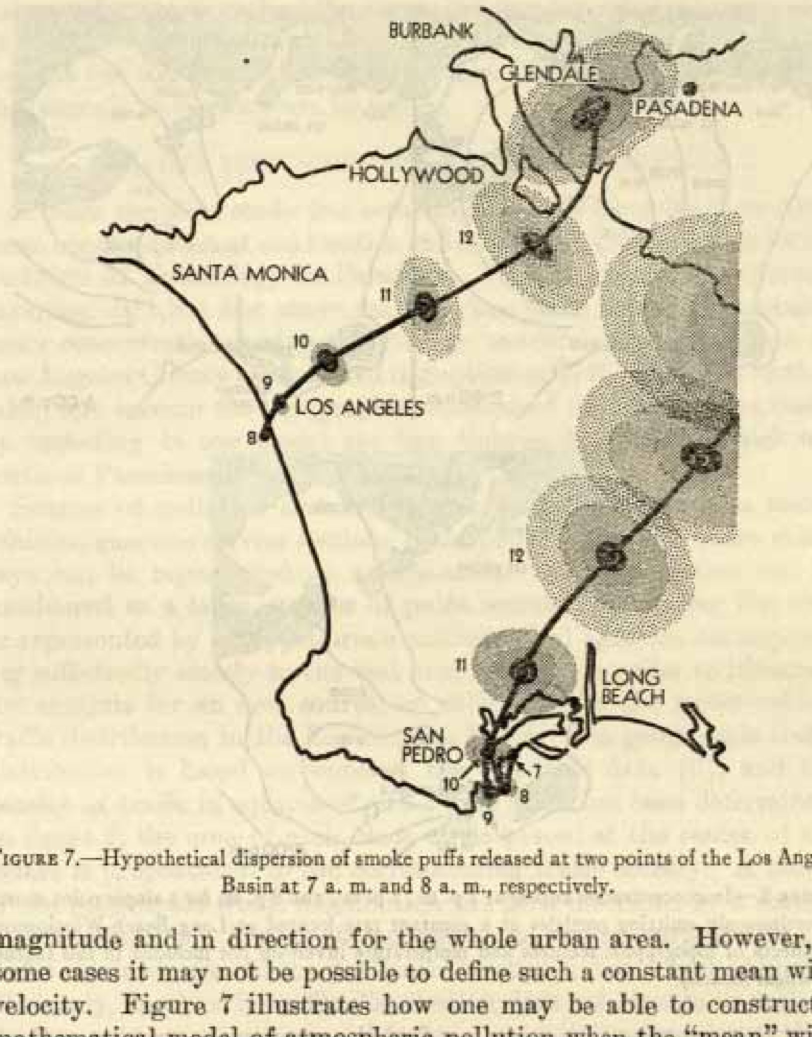

FIGURE 7.—Hypothetical dispersion of smoke puffs released at two points of the Los Angeles Basin at 7 a. m. and 8 a. m., respectively.

magnitude and in direction for the whole urban area. However, in some cases it may not be possible to define such a constant mean wind velocity. Figure 7 illustrates how one may be able to construct a mathematical model of atmospheric pollution when the "mean" wind velocity cannot be considered as being the same for the whole area. On this figure an outline of Los Angeles County is illustrated with two trajectories determined from measured hourly wind streamlines. Let us consider, for instance, the point marked with the number 7. We assume that a puff of smoke has been emitted above this location at 7 a. m. The puff is carried downstream with the general wind velocity along the trajectory. At the same time, the turbulent wind fluctuations disperse the smoke puff to sizes illustrated by the elliptical figures for successive hours following the emission. A smoke puff emitted at the same point but at another time may follow a different trajectory and have a different rate of dispersion. By adding the effects of a large number of similar smoke puffs emitted at the same

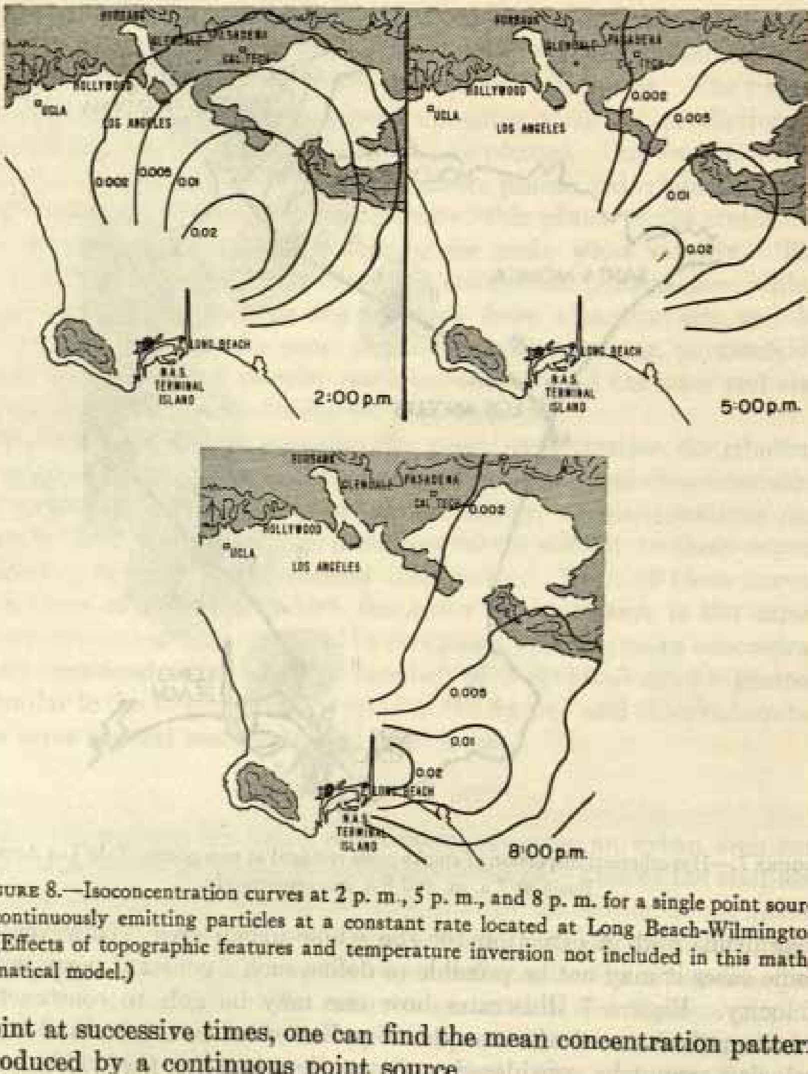

FIGURE 8.—Isoconcentration curves at 2 p. m., 5 p. m., and 8 p. m. for a single point source continuously emitting particles at a constant rate located at Long Beach-Wilmington. (Effects of topographic features and temperature inversion not included in this mathematical model.)

point at successive times, one can find the mean concentration pattern produced by a continuous point source.

Such a study has been made for Los Angeles County. The main difficulty in the analysis was the lack of appropriate micrometeorological measurements for the Los Angeles Basin. Although some very valuable data on hourly flow patterns are available [5], data on turbulent fluctuations are not sufficient. It was therefore necessary to make several assumptions concerning the characteristics of turbulence. Figure 8 represents some results of this analysis. The point source is located in the Long Beach-Wilmington area; it is assumed that it emits pollutants at a constant rate. The mean concentration distributions at 2, 5, and 8 p. m. have been determined, and the corresponding isoconcentration curves are traced on the figure. The

values referring to each of the curves indicate the relative magnitudes of the mean concentration In this analysis we have not taken into account the topographic situation of Los Angeles and have assumed that there is no temperature inversion.

RELATIVE RESPONSIBILITIES OF POLLUTION SOURCES

A more complete study has been made to determine the theoretical mean concentration at one location in Los Angeles County—California Institute of Technology in Pasadena. We have assumed a thermal inversion at 1,500 feet above sea level and have found the probable mean concentrations using the average meteorological conditions in Los Angeles County as measured in September 1947. We have further taken into account the topographic situation of the Los Angeles Basin by including in our model the San Gabriel Mountains, which are north of Pasadena.

Sources of pollution distributed over a large area such as motor vehicles, gasoline service stations, home incinerators, and house chimneys can be represented as area sources. An area source can be considered as a large number of point sources spread over the area or represented by an appropriate mathematical equation corresponding sufficiently closely to the real area source. In order to illustrate the analysis for an area source, we shall consider the motor-vehicle traffic distribution in the Los Angeles Basin. The geographic traffic distribution is based on some of the available data [6], and the density of traffic in squares of size 4 by 4 miles has been determined. In figure 9, the area of each black circle placed at the center of the square is proportional to the corresponding traffic density. A model of the geographic traffic distribution has been described by a mathematical equation. Figure 10 represents the hourly variation of the traffic volume measured at a particular location in Los Angeles County. Obviously, the hourly traffic distribution does not change in each of the squares in the same way; however, we shall assume that it does for our model, because more complete data on the traffic variations were not obtainable.

Using similar methods, it is possible to include in our mathematical model of Los Angeles County several other sources of pollution and to consider their relative contributions to the mean concentration at each locality in the area. We have considered four classes of pollution sources, namely: (1) Motorcars, (2) oil and gas heating, (3) refuse incinerators, and (4) industry. In what follows, I shall try to illustrate what kind of data can be found on these relative contributions of various sources of pollution. We shall first add to our mathematical model an area source representing the pollution from refuse incinerators. Not having available information on

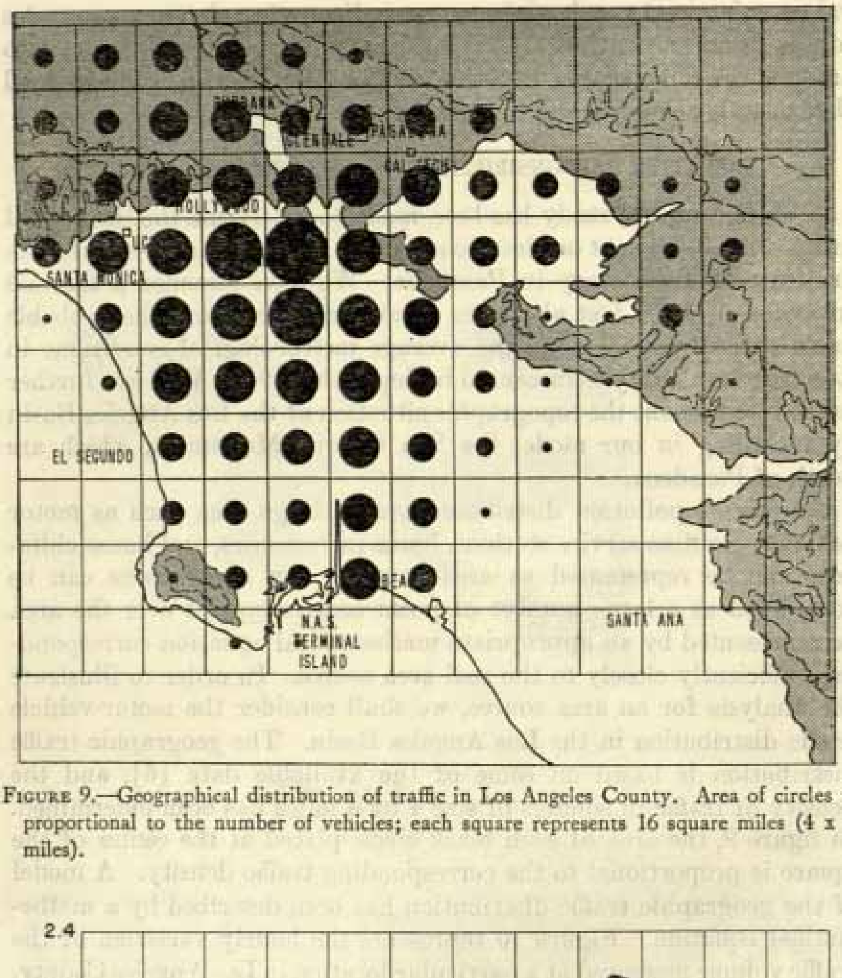

FIGURE 9.—Geographical distribution of traffic in Los Angeles County. Area of circles is proportional to the number of vehicles; each square represents 16 square miles (4 x 4 miles).

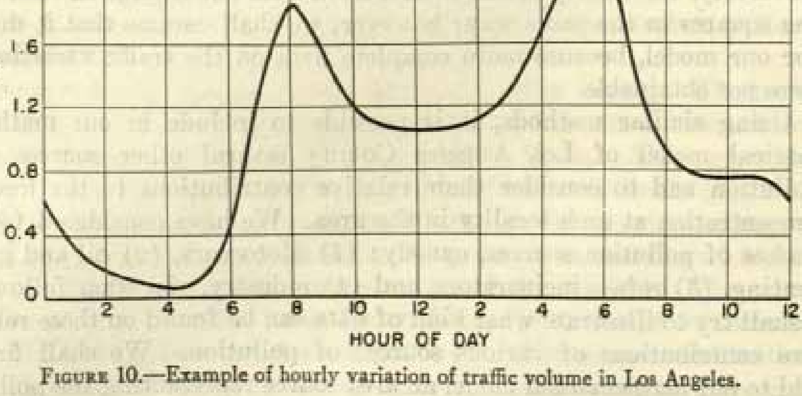

FIGURE 10.—Example of hourly variation of traffic volume in Los Angeles.

their geographic distribution in the area, we have used the same distribution as we did for the motorcar traffic, which is approximately comparable to the distribution of population. We have further assumed that the incinerators are operated between 6 and 10 a. m. with an hourly variation presenting a maximum at 8 a. m. Finally, we have considered the case when the relative amounts of pollutants emitted in our mathematical model during a period of 48 hours by the four sources—motorcars, oil and gas heating, incinerators, and industry—are 52, 6, 16, and 26 percent, respectively. These percentages were derived from data referring to the emission of "important"

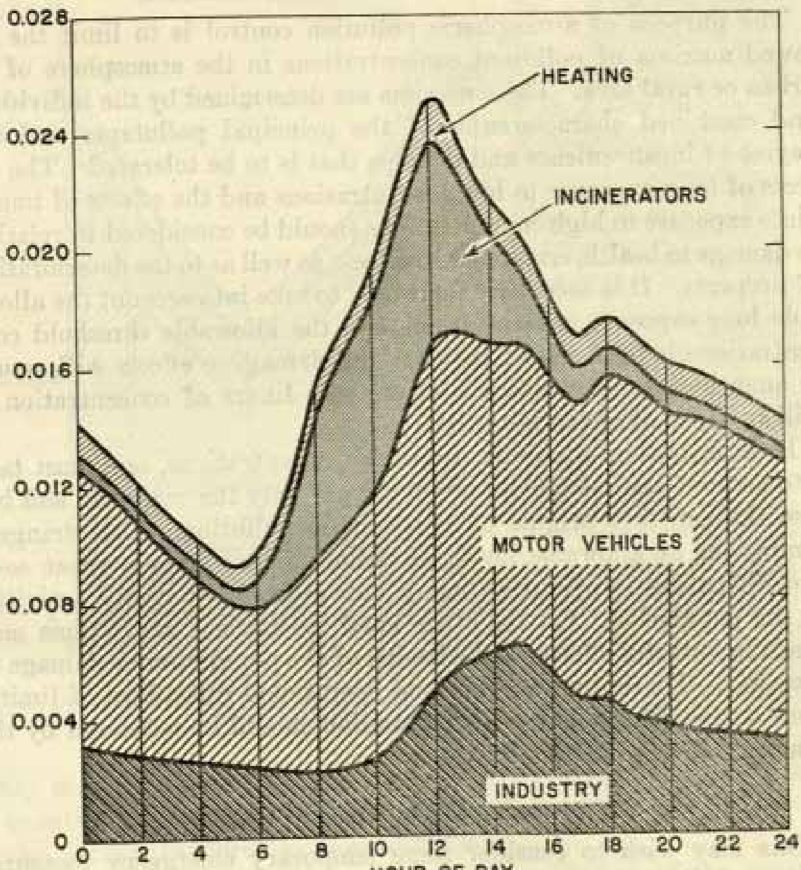

FIGURE 11.—Relative contributions of the selected four principal sources to the mean concentration at the California Institute of Technology. The data refer to a mathematical model of Los Angeles County in which the topographic features and inversion are taken into account. For this hypothetical model the relative proportion of the "important" pollutants (including acids, organics, and nitrogen dioxide) emitted by the four principal sources are based on the 1954 data for Los Angeles County [7]. The meteorological conditions are based in large part on data for the month of September [5].

pollutants as evaluated for 1954 [7]. Figure 11 represents the relative contributions of each of the four sources to the mean concentration at California Institute of Technology as functions of the hour of the day. It should be emphasized that these results cannot be directly compared with measured mean concentrations at the institute. In this example we have not, indeed, taken into account the chemical reactions of the various pollutants that may occur before they reach the point of measurement. We shall refer later to some chemical reactions and include their effect in the model of atmospheric pollution.

ALLOWABLE POLLUTANT CONCENTRATIONS

The purpose of atmospheric pollution control is to limit the allowed maxima of pollutant concentrations in the atmosphere of an urban or rural area. These maxima are determined by the individual and combined characteristics of the principal pollutants and the degree of inconvenience and damage that is to be tolerated. The effects of long exposure to low concentrations and the effects of immediate exposure to high concentrations should be considered in relation to damage to health, crops, and livestock, as well as to the deterioration of property. It is necessary, therefore, to take into account the allowable long-exposure concentrations and the allowable threshold concentrations beyond which harmful and damaging effects will result. A quantitative determination of the safe limits of concentration is still an object of research studies.

In determining allowable threshold concentrations, one must take into account several factors involving not only the receiving end but also the emitting origins of atmospheric pollution. Too stringent limitations of allowable levels of pollution may impose great costs and difficulties in operating many indispensable or useful activities of the population. On the other hand, insufficient restrictions may result in harmful effects on the health of the population or damage to property. Therefore, the costs and operational difficulties of limitations on the allowable levels of pollution should be measured by the beneficial effects of such reductions.

TEMPORARY EMERGENCY MEASURES

One may wish to consider some temporary emergency measures that would limit or modify the operation of the sources of pollution and reduce the contamination. One could, for instance, consider changing the hours of operation of the incinerators to shift their contributions to pollution to other hours (see fig. 12). The contribution of motorcars can be modified by changing, for the emergency period, the traffic pattern or traffic regulations. As a result, idling and deceleration periods, during which the motorcars emit large amounts

of pollutants, would be reduced and the over-all time of operation of motorcars would be shortened. The industrial pollutants may be reduced, for the emergency period, by changing the hours of operation of some of the industrial sources of pollution. The emergency measures could, for instance, attempt to distribute the pollution concentration more uniformly over the 24-hour period to keep it below a chosen value for the allowable threshold concentration at any hour.

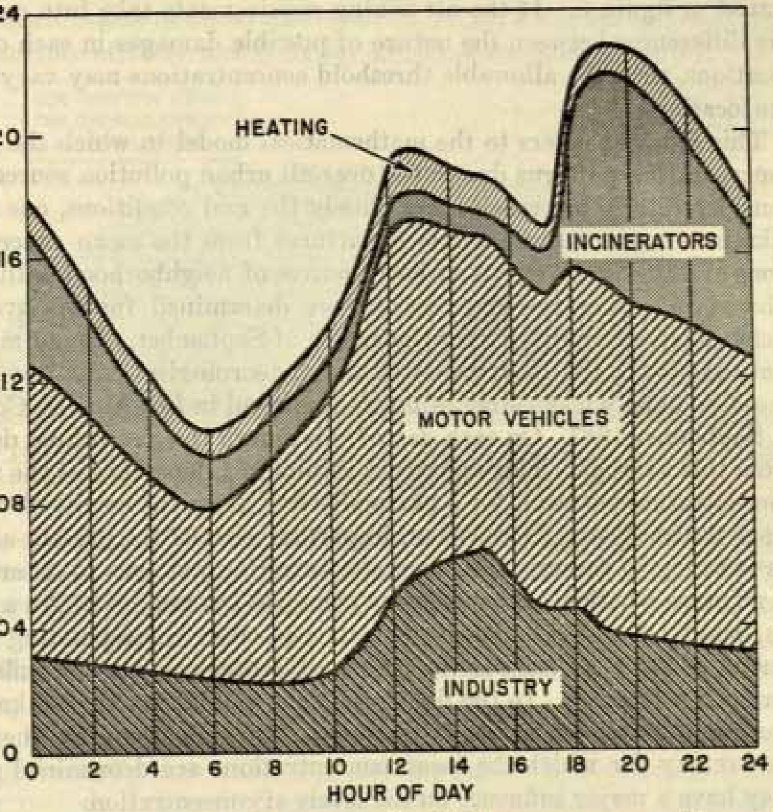

FIGURE 12.—Similar to preceding figure except that the incinerators are assumed to operate between 4 p. m. and 8 p. m. instead of between 6 a. m. and 10 a. m.

They must of course be applied in time to be effective; this requires a quantitative prediction of the mean concentrations to be expected under various meteorological conditions.

The emergency measures modifying the operation of the various pollution sources may not always be sufficient, and the stoppage of some of these sources may have to be considered. The effects of the modification in the operation or of the complete stoppage of the sources of pollution can be analyzed not only as far as the four general sources of pollution (motorcars, oil and gas heating, incinerators, and industry) are concerned, but also with reference to in-

dividual sources or groups of sources. In our present example, we have considered the concentration of pollutants referred to in figures 11 and 12. It may be necessary to examine the pollution levels for other pollutants as well. A similar analysis would, of course, have to be made for other locations in the urban area or in the surrounding rural areas. A complete analysis will therefore require finding the pollution patterns over Los Angeles County, similar to those illustrated in figure 8. If the air-zoning requirements take into account the differences between the nature of possible damages in each of the locations, then the allowable threshold concentrations may vary with the location.

This analysis refers to the mathematical model in which the mean concentration patterns due to the over-all urban pollution sources are considered. To approach more closely the real conditions, one must take into account the possible departures from the mean concentrations and the added effects of local sources of neighborhood pollution. The mean concentration patterns were determined for the average meteorological conditions for the month of September. In our mathematical model, the description of the meteorological conditions was based on hourly mean streamlines as measured in Los Angeles County in September 1947. On each day of this month the streamlines depart from this average. This departure results in a departure of the mean concentration patterns, for a particular day, from the results obtained from the analysis. However an important part of the present analysis is to try to forecast the mean concentration patterns to determine in advance whether any emergency measures are required. An analysis based on general meteorological conditions corresponding to a period of the year, such as the month of September, may be sufficient for such a forecast. In the final result one would, however, take into account the characteristics of the temperature inversion for the particular day for which the mean concentrations are determined since they have a major influence on the levels of concentration.

LOCAL SOURCES OF NEIGHBORHOOD POLLUTION

Let us now consider a residential neighborhood with its own sources of pollution that may include automobiles, indoor heating, home incinerators, and so forth. Figure 13 illustrates a small neighborhood with two houses and one incinerator. We should differentiate between the contamination from the over-all sources of urban pollution and the contamination from the local incinerator. The over-all sources of urban pollution include, for instance, the numerous industrial sources represented in our mathematical model. If our residential neighborhood is located near the California Institute of Technology, then the mean concentration originating from the over-all sources of

urban pollution is represented by curves similar to those in figures 11 and 12. For the present discussion, let us use the curves in figure 11 and consider what should be the expected mean concentration of pollutants, say, at 12 M. From the scale used in the figure, we find a mean concentration of 0.0251 at 12 M. While the relative amounts of pollutants emitted in the urban area by motorcars, oil and gas heating, incinerators, and industry are, respectively, 52, 6, 16, and 26 percent, the contributions of these three sources to the mean concentration at the institute at 12 M. are 47, 6, 27, and 20 percent, respectively.

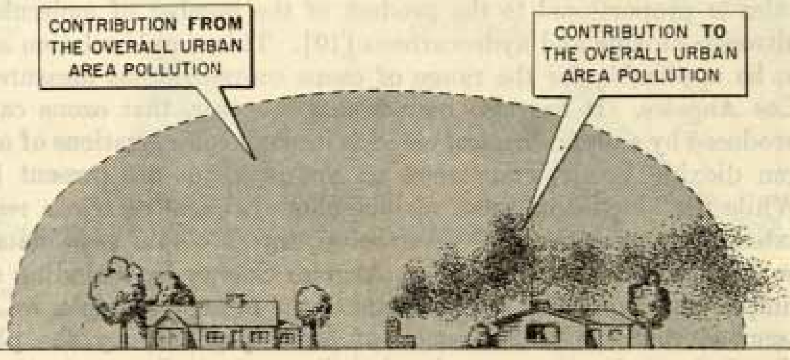

FIGURE 13.—Illustration of a residential area with the pollution from its own sources and from the over-all urban pollution sources.

The operation of the local incinerator will of course contribute to the over-all pollution. However, before they lose their identity by mixing with pollutants from many other surrounding sources, the pollutants originating from the local incinerator may largely increase the pollution in the neighborhood. A similar problem to the one concerning a local incinerator may occur in industrial or commercial areas. For instance, at a busy crossroad a large number of cars may have to stop periodically for traffic signals; during their deceleration and idling periods they emit large quantities of pollutants. Each such crossroad may in itself be considered as a local source of pollution that contributes largely to the contamination of the neighborhood. There will be many other similar cases where one may have to differentiate between the *over-all sources of urban pollution* and the *local sources of neighborhood pollution.* In the study of air zoning, the effects of both classes of sources must be taken into account.

PHOTOCHEMICAL OZONE PRODUCTION IN A POLLUTED ATMOSPHERE

The study of the relative contribution of various pollution sources to the contamination described before ignores the chemical reactions that modify the nature of pollutants. We shall now try to include in this model an example of some such reactions. A very important photochemical reaction taking place in the atmosphere of Los Angeles

County (as well as in other polluted areas) results in the production of ozone. It has been shown by A. J. Haagen-Smit [8] that a mixture of nitrogen dioxide and of certain hydrocarbons in air yields ozone when submitted to the effect of sunlight. This ozone formation is limited to a range of concentrations of nitrogen dioxide and hydrocarbons in air of the order of parts per million in volume. The chemical kinetics of the reactions leading to ozone production are not yet well known although some possible reactions have been considered [9]. Some experiments seem to show that the number of ozone molecules is proportional to the product of the number of molecules of nitrogen dioxide and hydrocarbons [10]. This simple relation seems to be applicable for the range of ozone concentrations measured in Los Angeles. It has also been found, however, that ozone can be produced by a photochemical reaction in small concentrations of nitrogen dioxide in air, even when no hydrocarbons are present [11]. While the kinetics of these various photochemical reactions require extensive studies, we can, nevertheless, try to obtain some data for our mathematical model of Los Angeles County by including some simple reactions. For the purposes of the present example, we have assumed that the concentration of ozone produced by the photochemical reactions is proportional to the product of concentrations of nitrogen dioxide and of hydrocarbons. We have also assumed that four hours of sunlight irradiation are necessary to complete the reaction. Figure 14 shows some of the results obtained under these conditions. Figure 14a illustrates the combined effect of all sources of pollution including (1) incinerators, (2) gas and oil heating, (3) petroleum industry, (4) cars, (5) industries other than petroleum. Figures 14b to 14f refer to the cases when all sources of pollution are active except, respectively, one of each of the five sources listed above. The dash-line curves on figures 14b to 14f (corresponding to the curve of fig. 14a) give the combined effect of all sources for comparison. As far as our mathematical model is concerned, it appears that the exclusion of incinerators (fig. 14b) from the pollution sources will not reduce very much the ozone concentration. We should call attention again to our figure 13 and emphasize that in our mathematical model we are referring to the contribution from the over-all urban area pollution. This over-all contribution from the incinerators is not very significant as far as the ozone contamination at the California Institute of Technology is concerned. However, the additional contribution of each incinerator to the pollution of its immediate neighborhood may be much more significant. One must also recall that the contribution of incinerators to the contamination by pollutants other than ozone may be much more important. Figures 11 and 12 illustrate, for instance, the importance of this contribution.

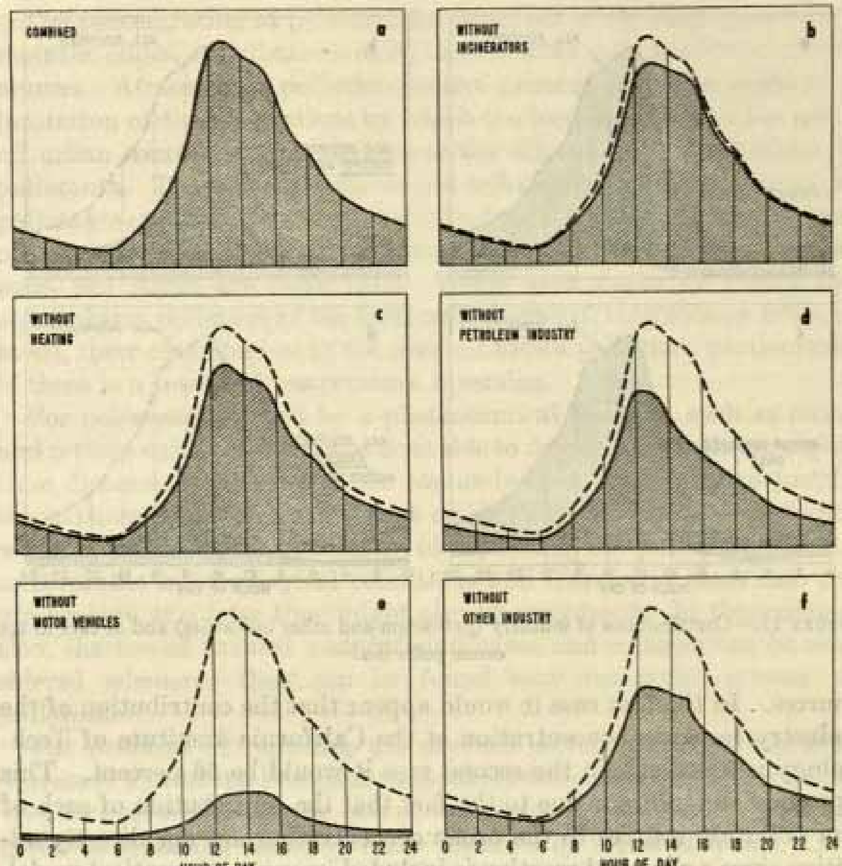

FIGURE 14.—Relative contributions of various pollution sources to the mean concentration of ozone at the California Institute of Technology. These results refer to a hypothetical model of atmospheric pollution in Los Angeles County.

A comparison of the results which the mathematical model yields for cars and industry is given in figure 15. In this figure we have combined the contributions of the petroleum industry with the other industries. Figure 15a shows the ozone concentration for the case when *only* the industrial sources are in operation, while figure 15b refers to the case when all the sources *except* the industry are in operation. These two figures show how difficult it may sometimes be to assign relative responsibilities to the various pollution sources for their contamination. Let us consider, for instance, the concentration values at noon. Figure 15a indicates that if *only* the industry is in operation, the 12 M. concentration is about 9 percent of the value obtained when *all* the sources are combined (dash-line curve). However, figure 15b shows that all of the other sources *except* the industry will produce a concentration of about 44 percent of the value for the combined

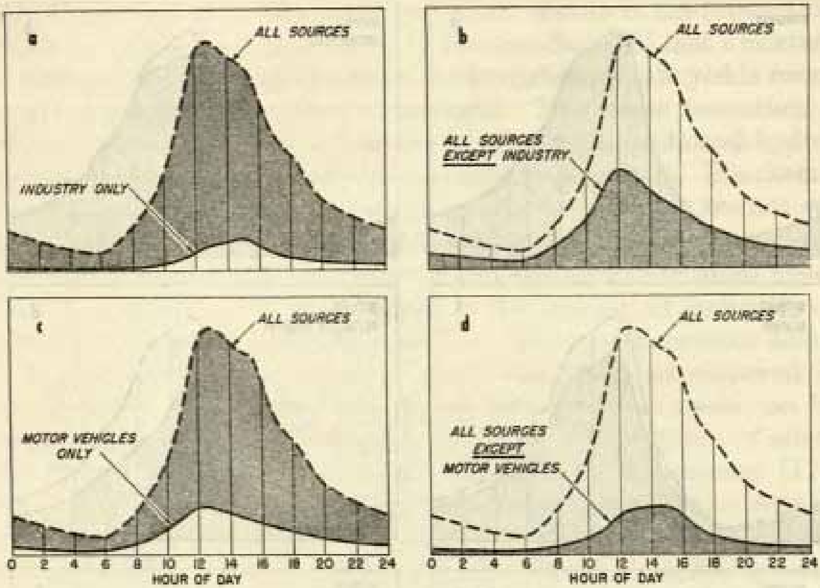

FIGURE 15.—Contributions of industry (petroleum and other industries) and of cars to the ozone pollution.

sources. In the first case it would appear that the contribution of the industry to ozone concentration at the California Institute of Technology is 9 percent, in the second case it would be 56 percent. This apparent difference is due to the fact that the contribution of each of the pollution sources to the ozone concentration are not directly additive since a chemical reaction is included in our mathematical model. In the case of figures 11 and 12 no such reaction was included and the total concentration of "important" pollutants was equal to the sum of the contributions from each of the sources. This is not necessarily true when a chemical reaction is playing a part in the atmospheric pollution. Figures 15c and 15d represent similar results for the concentratins obtained for cars only and for all sources except cars.

REDUCTION OF POLLUTION FROM EXISTING SOURCES

To avoid using temporary emergency measures too often, the possibility of permanently correcting an unsatisfactory pollution situation might be studied and the effect of the local sources of neighborhood pollution in each locality should first be examined. In the case illustrated in figure 13, the contribution of the incinerator operation to the pollution level would be evaluated. From this evaluation it can be determined whether the contribution of the local sources of pollution to the neighborhood pollution is too large; where necessary, remedies can be applied. This may correct many local situations where the main responsibility for the pollution lies with the local sources.

The concentration of pollutant for a section of an urban area represents the added contributions of its local sources and the over-all urban sources. Atmospheric pollution control principles may be based on a limitation of the proportions by which the local sources and the over-all urban sources may contribute to the allowable concentrations of pollutants. These limitations do not refer directly to the amount of pollutants emitted into the atmosphere, but to the mean concentrations of pollutant. To avoid contamination near the ground in an industrial zone, tall stacks are often used. While such stacks do reduce the atmospheric pollution of the local neighborhood, they change little, if at all, their contribution to the over-all urban pollution, particularly if there is a low-level temperature inversion.

For pollutants formed by a photochemical reaction, such as ozone and certain oxidants, it may be desirable to determine whether a night-time dispersion will reduce the contamination sufficiently to justify the expense of special equipment or the inconveniences of different working hours. The possibility of collecting the pollutants during unfavorable meteorological conditions and dispersing them into the atmosphere at a later time might also be considered. In this connection, the use of natural underground caves and caverns can be considered whenever they can be found near industrial sources of pollution.

The problem of reducing the over-all pollution from such area sources as motorcars, incinerators, house heating, and so forth, requires very serious study. In the case of incinerators, consideration is often given to replacing them by other methods of refuse disposal. The possible reduction of pollutants should be evaluated by taking into account the contamination for which an alternative method may be directly or indirectly responsible. As far as motorcar pollution is concerned, several abatement methods are considered. They include the use of devices that would modify the exhaust gases into inoffensive pollutants, the use of special fuel, and modification of engines. Serious consideration should be given to a general analysis of traffic patterns. An extensive use of expressways and roads without traffic lights would greatly reduce the contribution of motorcars to over-all urban pollution. In many urban areas the effect of an increase in public transportation, including the building of subways, on the pollution pattern might be examined. An analysis of the driving habits of the population and the conditions of the car engines could determine whether proper improvements would reduce the fuel consumption. In an urban area with hundreds of thousands of automobiles, a small improvement for each car should not be neglected. The effects of such undesirable habits as excessively long warm-up periods, rapid decelerations, and parking with idling engines could be evaluated.

In a study of various pollution control methods, it is important to determine if their effects are sufficiently significant to justify their expenses and inconveniences. Let us, for instance, consider the methods which consist in a reduction of the quantity of pollutants emitted at the sources. Our mathematical model can be helpful in such an estimate. Referring to the contribution of the industry to ozone concentration, we have already determined the contamination level when all industrial sources are eliminated from our mathematical model (see fig. 15b). Such an elimination would either require a complete stop to all industrial operations or complicated and expensive equipment to avoid production or emission of ozone-forming pollutants. It is doubtful that such extreme solutions would be practical and it is difficult to imagine a situation in which they might be necessary, al-

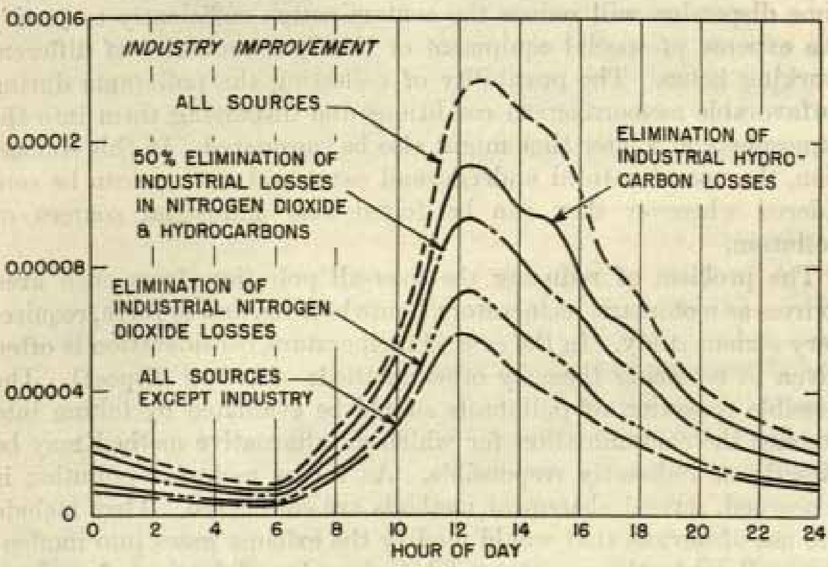

FIGURE 16.—Effects of general improvements of industry operation on the ozone pollution.

though during an emergency, an industrial area not prepared to control air pollution by more reasonable methods may be forced to stop the operation of all its industrial sources. Such a situation should be avoided by studying in advance the effects of a partial reduction of the quantity of pollutants emitted into the atmosphere. In the ozone formation of our mathematical model, nitrogen dioxide and hydrocarbons both play an important role. Figure 16 illustrates the effects of each of these pollutants on the ozone concentration. It appears that the elimination of nitrogen dioxide from industrial pollutants would have a much larger effect than the elimination of hydrocarbons. This conclusion refers, of course, to the location of the California Institute of Technology and the result may be different for another location. If we can evaluate the expenses in investment and operation

required to eliminate either nitrogen dioxide or hydrocarbons, then we will be able to compare each of these control methods with their effects. Most probably a practical solution will be unable to eliminate entirely either nitrogen dioxide or hydrocarbons. We should, therefore, also try to examine the effects of partial reductions for each of these pollutants (an example is represented by one of the curves on fig. 16).

The contribution of motor-vehicle exhausts to the production of ozone appears to be very large and deserves an extensive study. We will give here only some results obtained by an analysis similar to the one made for the industrial sources. It is known that the exhausts contain relatively large quantities of hydrocarbons during idling and deceleration periods. Some thought is given to either reducing those periods or using methods to intercept hydrocarbons. Figure 17 rep-

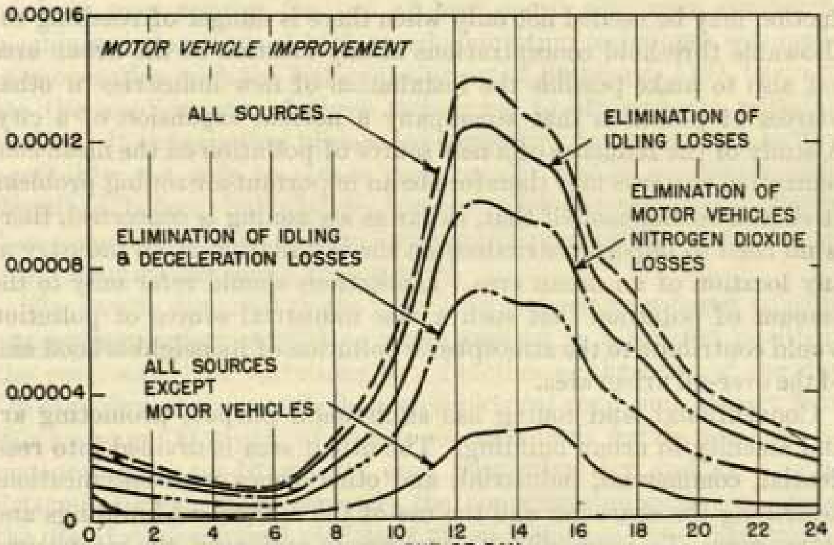

FIGURE 17.—Effects of general improvements of motor-vehicle operation or construction on the ozone pollution.

resents some results obtained for our model, using available data on the nature of the exhaust gases during various periods of motor vehicle operation [12]. It appears that a complete elimination of idling and deceleration periods would reduce the ozone concentration to about half of its value obtained with all the combined pollution sources. This result assumes that the methods used for such a reduction do not themselves add ozone-producing pollutants. One must, for instance, consider whether burning hydrocarbons in the exhaust gases does not produce too large quantities of nitrogen dioxide. Figure 17 shows that a complete elimination of nitrogen dioxide from the exhaust gases would have a smaller effect than the elimination of

idling and deceleration effects (largely due to hydrocarbon losses). It seems, however, that many of the more recent motor-vehicle engines, with an increased compression ratio, produce relatively larger proportions of nitrogen dioxide. The relative importance of nitrogen dioxide effects as compared to hydrocarbon effects may, therefore, be quite different in the future.

This discussion is presented here to indicate a method for an analysis and does not give final results, which require the use of much more extensive data than it was possible to use in our extremely simplified model of atmospheric pollution.

AIR ZONING FOR NEW POLLUTION SOURCES

All these studies are closely connected with air zoning problems for an existing urban area. Their purpose is to reduce the pollution of both the over-all urban area and the local neighborhood. Such a reduction may be needed not only when there is danger of reaching the allowable threshold concentrations at any location of the urban area but also to make possible the installation of new industries or other sources of pollution that accompany a normal expansion of a city. A study of the influence of a new source of pollution on the mean concentration patterns may therefore be an important air zoning problem. It should be emphasized that, as far as air zoning is concerned, there is no need to impose restrictions on the installation of an industry at any location of an urban area. Limitations should refer only to the amount of pollution that such a new industrial source of pollution would contribute to the atmospheric pollution of its neighborhood and of the over-all urban area.

Conventional land zoning has as its main purpose promoting art and amenity in urban building. The urban area is divided into residential, commercial, industrial, and other zones with specifications describing the character and the use of the authorized buildings and enterprises. To accomplish its purposes in each zone, the means used by land zoning are to apply certain restrictions to the buildings in the same zone. Air zoning proposes to limit the contamination of the urban atmosphere, and would specify the allowable levels of concentration for the atmosphere of each zone. However, building restrictions for each zone must take into account the contributions of the whole urban area to the contamination of its atmosphere. The necessary restrictions will therefore depend on the meteorological conditions of the urban area and result in different requirements for the same classes of zones, according to their location in the area. When building restrictions are considered, one must of course determine some specifications that would apply for all weather conditions. Such restrictions could be based on an analysis of the me-

teorological conditions for various periods of the year, using data for several years. One must keep in mind, however, that there will always be a certain probability of exceptional meteorological conditions that would produce an abnormally high contamination. The probability of such an occurrence can be reduced to any desirable degree by appropriate zoning regulations. It should be noted that it is not necessarily advisable to base the building restrictions on the most unfavorable meteorological conditions. Temporary emergency measures when such conditions prevail could be employed and in consequence the restrictions could be relaxed.

OPERATIONAL USE OF HIGH-SPEED COMPUTING

The examples of mathematical models of atmospheric pollution used in this paper were made sufficiently simple to avoid too extensive numerical computations. A more complete and more correct analysis may require the use of high-speed electronic computing machines. Some use of high-speed computing techniques was made, in cooperation with the National Bureau of Standards [13], to evaluate the applications of these techniques to atmospheric pollution studies. It appears that high-speed computing techniques can be used profitably, not only to obtain very rapidly results similar to those described before, but also to forecast probable pollution patterns fast enough to be able to take appropriate precautions when dangerous contamination levels are expected.

The results discussed in the preceding sections were based on average meteorological conditions corresponding to a selected month of the year, and their variations as a function of the hour of the day. On each day of the month the meteorological conditions depart from this average. One can, of course, use as a basis for the analysis the meteorological conditions for each particular day and as a result determine much more correctly the concentration patterns. Since the use of mathematical models of atmospheric pollution requires extensive numerical computations, such an analysis will be practical only if high-speed computing techniques are used. A method of civil defense against radioactive pollution involving the use of high-speed computers was suggested some years ago [14]. Similar methods show promise of success in problems of peacetime air pollution of urban areas and can be used not only to analyze data on atmospheric pollution and urban planning but also on an operational basis in the control of atmospheric pollution.

In an area to be protected from pollutants we place a net of instruments measuring the directions and the magnitudes of the mean wind velocities, the character of the turbulence, and other meteorological information such as, for instance, the characteristics of the temperature

inversion. If the expected degree of contamination is determined before dangerous concentrations are reached, then the operational expenses of many methods of pollution abatement as well as the investment in special control equipment could be greatly reduced. Evacuation into the atmosphere is indeed one of the best and most economical methods of disposing of pollutants. If we are able to determine the periods of time when such evacuation can be made without danger, then during those periods the use of the special equipment or special fuel will not be necessary. It is therefore important to determine the unfavorable conditions much more correctly than a human forecaster is able to do, since any action to reduce the emission of pollutants during the unfavorable time will be expensive. The meteorologist would alert the computing center whenever there seemed to be a possibility of unfavorable meteorological conditions. The computing center would then take over the problem of continuously following the mean wind velocity pattern, the turbulence characteristics, and the temperature inversion in the area. From these data the concentration of pollutants which may be reached over the area will be computed. At some chosen points of the area the concentration in contaminants will be measured and the results relayed to the computing center to improve the precision of the computation. The high-speed computation will determine what the expected concentration distributions will be if the operation of the sources of pollution continues without change. If, at any point in the protected area, the occurrence of a dangerous concentration is predicted, action would have to be taken to reduce the emission of pollutants. It will be possible to determine which individual sources contribute most to the dangerous concentrations, since the computation is done by adding the effects of the various sources. One will then find what the effects of shutting-down or reducing the production of pollutants at some of these individual sources will be on the predicted concentrations. As a result it may be sufficient to take such action at only some of the sources of pollution and limit the expense and inconvenience to a minimum.

URBAN PLANNING

A growing urban area must expect an increase of atmospheric pollution unless a greater effort in its abatement measures balances the effects of additional sources of pollution. As an example, we shall use again Los Angeles County (or rather the mathematical model representing the County) and forecast the mean concentration at the California Institute of Technology for 1960 and 1980. This forecast will be based on data concerning the future increase in population, fuel consumption, and so forth. To simplify this computation, we shall use the same mathematical model of Los Angeles County as we

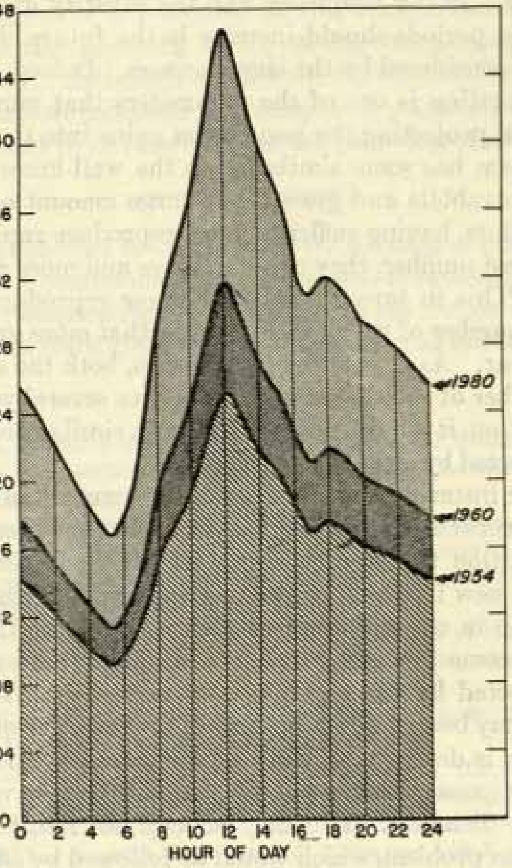

FIGURE 18.—Estimates of hourly variation of mean concentration at the California Institute of Technology for 1960 and 1980, for the "important" pollutants, compared with the 1954 values taken from figure 12. (Based on estimates of population and industrial growth and assuming no major change in their geographic distribution in Los Angeles County and no improvement in the pollution control methods.)

have used before. The result illustrated in figure 18 is determined for the mean concentration of the most "important" pollutants. In this figure, the curve for 1954 is the same as the one already shown on figure 11; the results for 1960 and 1980 assume that the abatement methods have the same efficiency as those for 1954. If we assume that the allowable threshold concentration is, say 0.020, then the mean concentration for 1960 will be larger than this allowable threshold value between 8 a. m. and 8 p. m., and in 1980 from 7 a. m. to 3 a. m. of the next day, as against the period of 10 a. m. to 3 p. m. for 1954. In our mathematical model, these results correspond to the same meteorological conditions for each of the three cases. Obviously, the probable number of days when the meteorological conditions will be favorable for high concentrations of pollution in 1960 and 1980 will be larger

than in 1954. If the frequency and the severity of above-allowable concentration periods should increase in the future city, then it must be carefully considered by the city planners. Indeed, in that case, the pollution situation is one of the parameters that must be taken into account when projecting the population gains into the future.

The problem has some similarity to the well-known interrelationship between rabbits and grass. If a large amount of grass is available, the rabbits, having sufficient food, reproduce rapidly. But, with their increased number, they consume more and more grass and finally lack food. This in turn results in a lower reproduction rate and a drop in the number of rabbits. Following that more grass grows, more rabbits appear. As a result of this process, both the amount of grass and the number of rabbits may fluctuate over several years. In atmospheric pollution, it is quite possible to have a similar problem, although it will be affected by more than two factors.

Let us, for instance, consider the development of an urban area surrounded by rural areas and let us assume that the area has at present enough pollution to cause concern. If for some reason this urban area attracts new inhabitants and new industries, then this will result in an increase in atmospheric pollution. Following this increase, the area may become less attractive to new inhabitants and the rate of growth expected by the city planners may drop. In addition, the rural areas may become so contaminated that a larger quantity of crops and livestock is destroyed. Much of the necessary food, the quantity of which increases with the population, will then have to be brought from greater distances. This may or may not result in an increased transportation problem, which would be followed by added pollutants. It will, in any case, increase the living costs, which again will affect the attractiveness of the urban area to new inhabitants. On the other hand, some discouraged farmers may decide to give up their farms to an industrial or residential expansion that, together with the possible growth of surrounding cities, will increase the pollution of the urban area.

To these various effects, one must also add those that will have an influence on the population that still remains in the expanding urban area. The increased health hazard and the higher probability of lethal concentrations of pollution may have disastrous consequences. Such disasters may not necessarily result in a reduction of the population by death, but they may cause some of the inhabitants to leave the urban area. Although we have not included all the parameters that have an influence on the population growth, it should be obvious that this process is more complicated than the one concerning rabbits and the grass. It may, however, be followed in a similar way by a fluctuation of both the number of inhabitants and the level of contamination over

a number of years. This discussion may or may not apply to Los Angeles County, but it is presented at this time to indicate the need for including in city planning an air-zoning and atmospheric-pollution control study. Although one should expect that the future will bring many practical solutions to atmospheric pollution control, such expectations cannot be included in a serious planning of urban development.

ACKNOWLEDGMENTS

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Hurricanes

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[With 1 plate]

INTRODUCTION

Hurricanes have been very forcibly brought to the attention of a large portion of the population of the United States during the past few years. Hurricanes Carol and Edna successively battered the New England coast in 1954 within a 2-week period. There had not been a hurricane to affect this area seriously since 1944, and many of the local residents believed that they were well outside the main hurricane belt. The situation became worse one month later when Hazel brought gale-force winds to the New England area and almost total destruction to certain portions of the North and South Carolina beaches.

Hazel was the most severe storm to hit the Cape Fear area of North Carolina during this century, but in 1955 within the 6-week period from August 12 to September 19 three more hurricanes, Connie, Diane, and Ione, entered the North Carolina coast. This made four hurricanes that penetrated the North Carolina coast within a distance of about 100 miles within one 11-month period. Although Hazel was the most destructive of these four storms in North Carolina, the floods caused by the rains of Connie, Diane, and Ione were record-breaking for much of eastern North Carolina.

As though to show her impartiality, nature sent two violent hurricanes and one lesser tropical storm into the Tampico, Mexico, area during the 1955 season. These hurricanes were Hilda and Janet and tropical storm Gladys. The first two also laid waste much of the Yucatán, Mexico, area.

Although the concentration of hurricane activity in North Carolina and the Tampico area during this period was unusual, it has been matched in other years at other places. In 1916–17, Mobile, Ala., was afflicted with three hurricanes, with wind speeds in that city of 107, 128, and 98 m.p.h., respectively. One of these also caused ocean

tides to rise 11.6 feet above normal. In 1947–48, Miami, Fla., was battered by four hurricanes.

Hurricane Janet of 1955 was one of the greatest recorded in meteorological history. Dunn, Davis, and Moore [7] [1] list the lowest reliable sea-level land barometer readings of record in the world as follows:

Location	*Date*	*Inches*
Lower Matecumbee Key, Fla.	Sept. 2, 1935	26.35
Basilan, P. I.	Sept. 25, 1905	26.85
Cossack, Australia	Jan. 7, 1881	27.00
Chetumal, Mexico	Sept. 28, 1955	27.00

When Janet passed over Chetumal the winds were measured at 175 m.p.h. before the anemometer collapsed. The wind continued to increase, and the maximum speed was estimated in excess of 200 m.p.h. Thus, Janet had the second lowest barometer reading ever observed in the Western Hemisphere and had winds estimated in excess of 200 m.p.h.

From the meteorological viewpoint, the 1954 and 1955 seasons offer several items of special interest: (1) The great acceleration in speed of forward movement by Carol, Edna, and Hazel; (2) the lack of acceleration of hurricane Ione after reaching the latitude at which hurricanes Carol, Edna, and Hazel had accelerated so rapidly; (3) Hazel's and Carol's maintenance of great intensity after moving into northern latitudes and after traveling over land; (4) recognition that the flood resulting from hurricane rains is the number two killer and destroyer among the hurricane forces, ranking next to the storm surge (the storm surge as used here refers to the rise of the ocean surface that usually precedes and accompanies a hurricane's passage across the coastline), and ahead of the hurricane winds as a destructive force; and (5) the shift in hurricane tracks from the United States Gulf coast and Florida areas to the North Carolina-New England area.

After the 1954 and 1955 seasons, people in the northern States abandoned their former custom of labeling most hurricanes as Florida hurricanes, regardless of where they originated. Figure 1 presents the tracks of all tropical storms and hurricanes for 1947, at which time most of the storms were concentrated in the area extending from South Carolina to Texas. Tracks of most of the important storms of the 1954 and 1955 seasons are given in figure 2, and these illustrate why hurricanes are no longer automatically labeled as Florida hurricanes. During 1954 and 1955 not a single tropical storm of hurri-

[1] Numbers in brackets indicate authorities cited in the list of references at end of text.

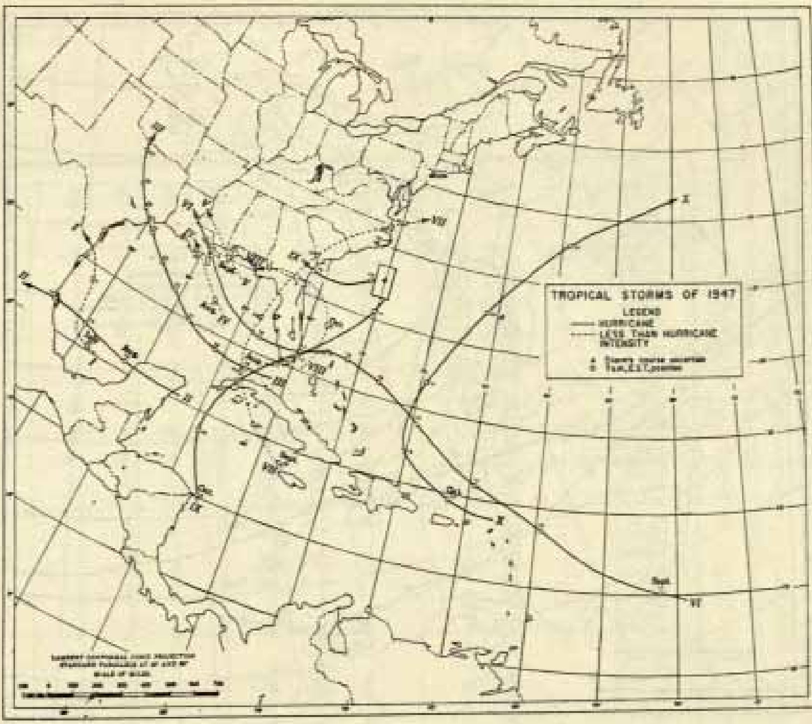


FIGURE 1.—Tracks of hurricanes and tropical storms of 1947.

cane intensity entered the United States coast from Texas, around Florida, through Georgia, but, as mentioned earlier, six storms ravaged the United States coast from North Carolina to New England. This radical shift in pattern can be illustrated by comparing figure 1 with figure 2.

Such radical differences in paths as those indicated have caused speculation as to the possibility that the area of hurricane incidence has shifted from southern United States to northeastern United States. To investigate this point, research has been performed by the Office of Climatology of the United States Weather Bureau. In figure 3, the occurrence of tropical storms within the various coastal sections is shown chronologically. The graphs in this figure show that more storms have affected northeastern United States and the North Carolina area the past two years than at various times since 1887. There have been long periods when storms did not affect New England, for instance, but there have been other periods when hurricane frequency in northeastern United States was even greater than it was during 1954 and 1955. It is evident, therefore, that the recent shift in tracks does not necessarily indicate a semipermanent relocation of the hurricane alley.

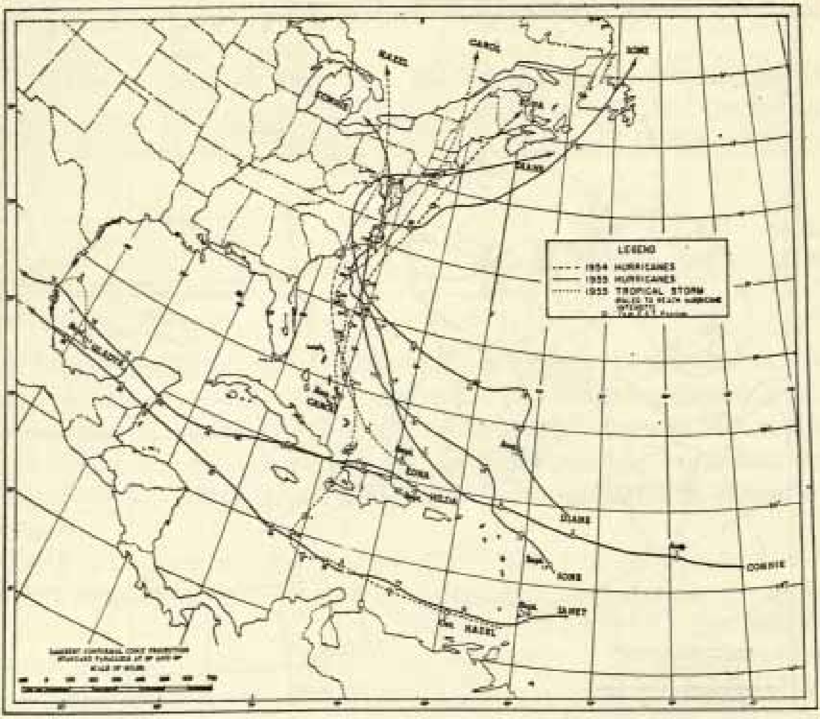


Figure 2.—Tracks of most of the important hurricanes and one tropical storm of the 1954 and 1955 seasons.

The type of damage caused by a hurricane varies with the characteristic of the storm and the nature of the terrain affected, and results mainly from (1) high winds, (2) floods resulting from the heavy rains that are typical of most hurricanes, and (3) inundations caused by the storm surge. When hurricane Janet crossed Swan Island in 1955, all trees were blown down, and nearly every house on the island was either destroyed or severely damaged; but not a person was killed. Hurricane Diane caused very little wind damage, but the floods that were triggered by the rains killed many people and caused property damage estimated at about 1 billion dollars. The amount of damage caused by the hurricane winds is largely dependent on the type of building code enforced in the ravaged cities. The damage from floods is usually much greater in mountainous areas than on flat terrain. When a foot of water falls on relatively flat land, the people are inconvenienced but few are drowned. The same amount of water falling over a range of mountains may start a flood that will drown people 150 miles or more away where perhaps there had been no rain. The inundations caused by the storm surge are greatly dependent upon the slope of the Continental Shelf and the elevation near

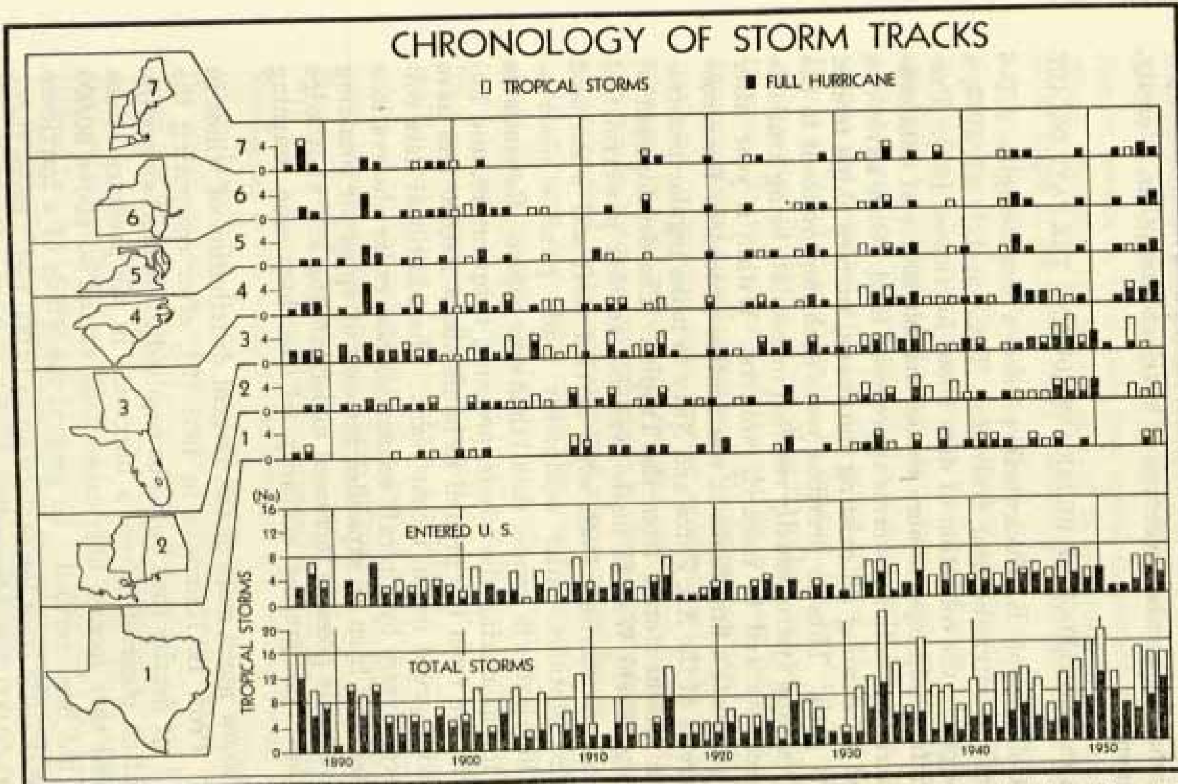


FIGURE 3.—Chronology of tropical storms and hurricanes. The time scale extends from 1887 on the left to 1955 on the right. The solid portion of each bar represents the number of storms that reached hurricane intensity. The seven upper bar graphs depict the occurrences of hurricanes and lesser tropical storms in the seven coastal regions shown by the small maps. A storm affecting one or more of these areas is graphed in each area. A storm is called of hurricane intensity if sometime during its life it had winds above 75 m. p. h. regardless of the speed of maximum winds when the storm passed through the specified area. The bar graph at the bottom represents the total occurrence of storms, by years, over the Atlantic, Caribbean, and Gulf of Mexico—those that remained at sea as well as those striking land.

the coast. Thus, the forecasting problem varies for different areas as well as for different storms affecting the same area.

In this paper we shall discuss some of the things we have learned about hurricanes in the past few years, the various forecasting problems connected with storms, the research needs, and the ultimate potential for making accurate forecasts of hurricane inception, intensity, and movement.

ADVANCES IN KNOWLEDGE OF HURRICANES DURING THE PAST DECADE

When Col. Joseph B. Duckworth piloted a single-engine AT-6 aircraft into a hurricane near Galveston, Tex., on July 27, 1943, a new era began in the collection of data about hurricanes [22]. Previously, surface ship reports were almost the sole source of data concerning hurricanes until the storms approached land. Once advisories were issued concerning an existing hurricane, surface ships tended to avoid its path. Thus in previous years each improvement in the hurricane warning system usually resulted in less data being available to the forecasters and to research workers. Within a year after Colonel Duckworth's first flight it was routine procedure for reconnaissance crews of the Air Force and Navy to make regular penetrations of the violent storms from the Tropics. The development of radar during World War II made available another powerful tool for the hurricane service. Both when carried aloft and when used from ground stations, radar equipment made possible observations about hurricanes in greater detail than ever before. Rawinsonde equipment for measuring the winds, pressure, temperature, and humidity of the air from the ground to levels above 100,000 feet have come into widespread use in recent years. The additional data collected in recent years by aircraft reconnaissance, radar observations of hurricanes, and from an expanded network of upper-air sounding stations have made possible increased understanding and knowledge of hurricanes and greater efficiency of the hurricane warning service.

We now know much more of the vertical distribution of winds in hurricanes. Prof. B. Haurwitz in 1935 [9], after computing the difference in air density that would be required to counterbalance the difference often observed across a hurricane in air pressure at sea level, deduced that intense hurricanes must extend to above 30,000 feet. This has been verified. In general the winds of a hurricane vary relatively little from the surface up to 10,000 feet. From there, up to 30,000–50,000 feet (depending upon the characteristics of the individual hurricanes) the winds gradually decrease with height. Data collected during hurricane Ione of 1955 and hurricane Betsy

of 1956, however, indicated that on particular days in those two storms the maximum wind speeds were about the same even at 20,000–30,000 feet as at the surface.

Data collected by the reconnaissance crews and by radar have demonstrated that hurricanes are much more complicated than was thought a century ago. The spiral rainband was one of the earlier discoveries of the radar meteorologists (pl. 1). Most of the heavy rain in hurricanes occurs in rainbands that spiral in toward the center of the storm. Between the bands, rainfall is relatively light, and near the outer edges of the storm there frequently is no rain at all between the bands. To some extent the highest winds are also associated with these spiral bands. Reconnaissance has also brought out the fact that in tracking the hurricane several different kinds of centers may be specified, and these centers do not always coincide. These various centers are: (1) The center of the wind circulation, (2) the point of lowest air pressure, and (3) the point around which the spiral rainbands or cloud streets rotate. In general, the location of these various centers may differ by as much as 20 miles, depending upon the rate of storm travel. Many of the earlier writers described hurricanes as symmetrical circular storms. We know now that most hurricanes, particularly moving ones, are not symmetrical—the winds are much stronger in some quadrants, the rain area extends out farther in some quadrants, there are asymmetries in the cloud structure, and all three elements tend to be concentrated along spiral bands.

Hurricanes frequently move along an irregular path that oscillates about the relatively straight or smooth curved path that the storms were depicted as following in track charts prepared before the 1940's. The more frequent fixes obtained in recent years confirmed these oscillations, some of which have a relatively short period of 3 to 6 hours duration, and some with a period of 12 to 36 hours. In recent years these oscillations have been attributed to forces within the hurricane (Yeh [25]).

It has been well established that the primary energy source for hurricanes is the warm moist tropical air that is found in the areas where hurricanes form. As this warm moist air converges in toward the storm center, it accumulates additional latent and sensible heat from the warm ocean surface. Near the center the air rises rapidly (fig. 4) and most of its water vapor is condensed to liquid water, thus releasing great quantities of latent heat. Only a small proportion of the heat energy thus released is converted into kinetic energy for driving the hurricane winds, and the mechanism for transforming the energy still remains pretty much a mystery.

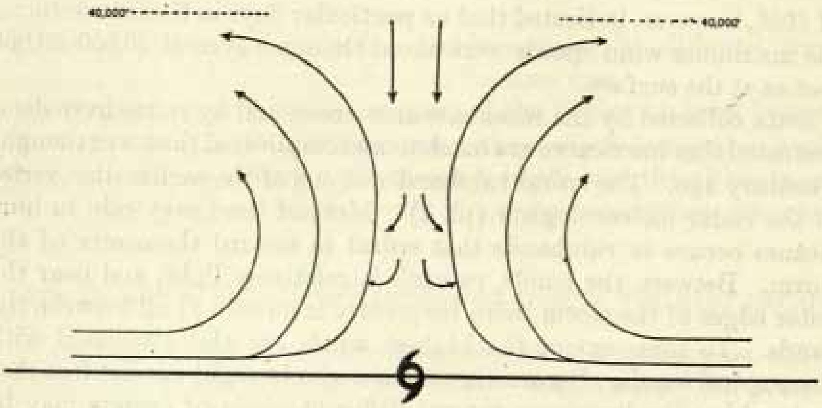


FIGURE 4.—Cross section through a hypothetical hurricane showing a highly schematized model of part of the vertical circulation.

HURRICANE FORECASTING

The forecast problem may be subdivided into six units:

1. Forecasting inception.
2. Forecasting the movement of the hurricane.
3. Forecasting changes of intensity.
4. Forecasting the rainfall resulting from the hurricane.
5. Forecasting floods associated with hurricanes.
6. Forecasting the height of the storm surge.

1. INCEPTION OF HURRICANES

During the past century, tropical meteorologists thought tropical storms developed when there was excessive heating some place in the Tropics. The heated air should rise and cause clouds with great vertical development and showers. The explanation was given that the more intense the heating, the heavier became the showers until finally a storm formed. Close examination of the data, however, revealed that hurricanes formed in areas where there was very little change in the sea-surface temperatures for great distances. The theory that hurricanes were formed by intense heat merely associated the shower activity with the storm formation and offered no definite mechanism for organizing the showers into a circular pattern and furnished no means for predicting whether the tropical storm would form. Since showers occur over the tropical oceans during much of the year and since only a very small percentage of even the areas of heavy showers ever develop into tropical cyclones, these are serious limitations. Among the first mechanisms suggested for concentrating and intensifying the disturbed areas into tropical storms was the Norwegian model of an unstable frontal wave. In this model a front is the boundary surface between two masses of air that come from different source regions and that have different

densities and moisture content. Under certain conditions a wave forms along such a boundary and if it becomes unstable it may release enough energy to cause a storm to develop. Such occurrences are frequently observed in middle and northern latitudes in winter. This idea as applied to the Tropics had to be abandoned as it became recognized that true fronts seldom, if ever, exist over the tropical oceans. Another serious limitation of this explanation was presented in a paper by Gordon Dunn in 1940 [5], which showed that many of the hurricanes in the Atlantic formed in easterly waves (deformations in the steady trade-wind flow) entirely within a single air mass where there was not even a suggestion of a front of the Norwegian unstable frontal wave type.

It is now well known that hurricanes form only over the tropical oceans where the water temperature is high, at least 80° and in most cases 83° to 85° (Palmen [13] and Fisher [8]), and where showers are occurring. The higher ocean temperatures are required for heating the air until it is buoyant and for making it possible for the air to hold a sufficient amount of water vapor. (Warm air will hold more water vapor than cold air; hence, warm air makes possible the release of a greater amount of latent heat when the moisture is condensed from the rising air.)

For a hurricane to form it is necessary to have warm moist tropical air and to have a preexisting disturbance in the normally steady trade-wind regime of the Tropics. These are necessary but not sufficient conditions. Only a relatively small percentage of the tropical disturbances that frequent the Caribbean area in the summer ever reach hurricane intensity. It is obvious that something else is required. It has been suggested by various investigators, notably Herbert Riehl [16] and J. S. Sawyer [18], that the upper-level flow patterns furnish the key to inception. It seems rather obvious after studying structure of hurricanes that there must be horizontal convergence of the air flow in the lower levels and there must be horizontal divergence of the air flow at some upper level. Professor Riehl, in his study of formation of hurricanes, has suggested that at about 40,000 feet there are certain flow patterns that help to evacuate air from the incipient storm area and are conducive to the formation of hurricanes. It is hoped that the additional data now being collected will reveal sufficient details concerning the structure and energy processes in hurricanes to make it possible to define both the necessary and sufficient conditions for their formation.

2. HURRICANE MOVEMENT

The theories as to what makes a hurricane move may be divided into two classes: (1) Those attributing the movement of a hurricane to internal forces within the hurricane itself, and (2) those attributing

the movement to external forces. In figure 5 there is shown schematically the winds of a hurricane broken into three components:

(a) Those tangent to a circle with a speed ranging from 75 to 150 m.p.h.

(b) Those inward or outward from the center (in the lower levels the winds usually have an inward component and at high levels the winds have an outward component). The speed ranges up to 35 m.p.h. or more in lower levels.

(c) The basic current in which the hurricane is imbedded and in which the speed varies from zero up to about 60 m.p.h. with the average being near 15 m.p.h.

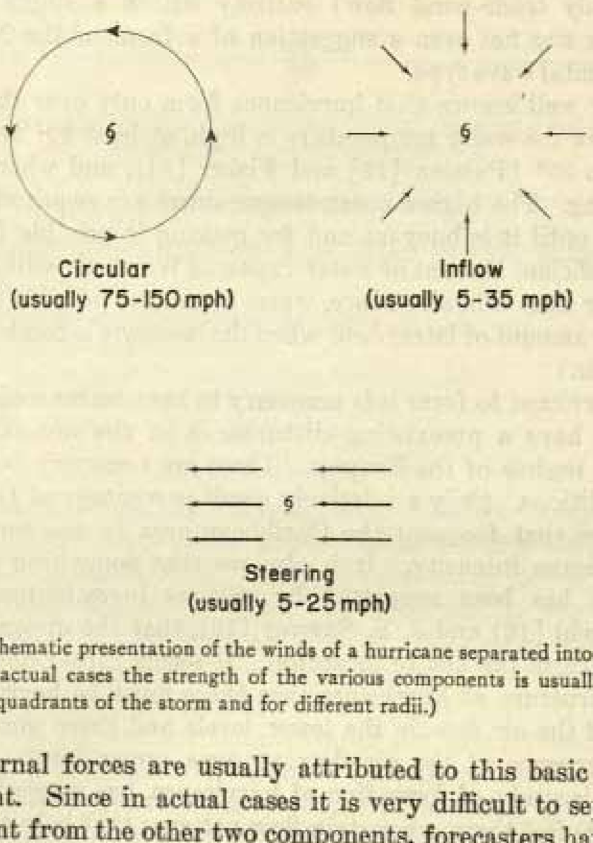
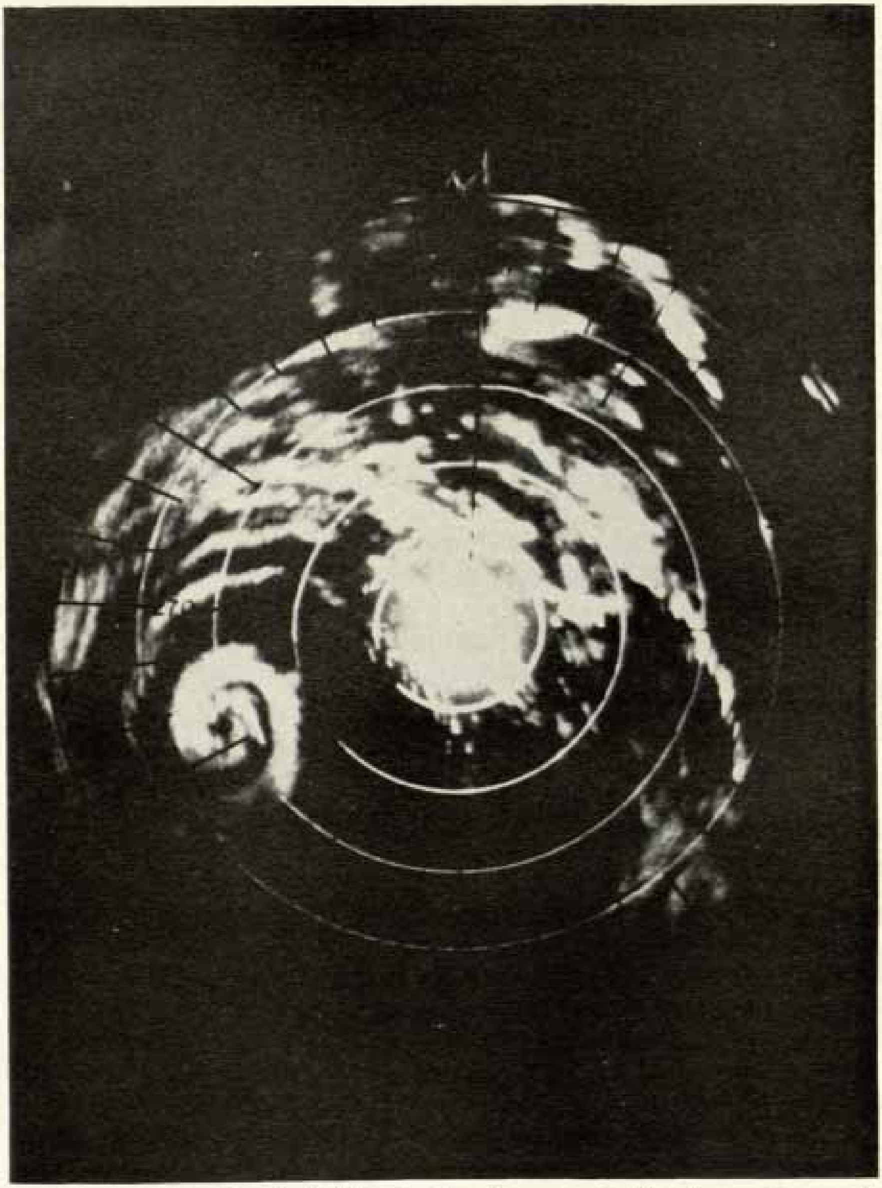


FIGURE 5.—Schematic presentation of the winds of a hurricane separated into three components. (In actual cases the strength of the various components is usually different in the various quadrants of the storm and for different radii.)

The external forces are usually attributed to this basic or "steering" current. Since in actual cases it is very difficult to separate the basic current from the other two components, forecasters have devised many methods for estimating the contribution of "steering" to hurricane movement. It is now generally agreed that most of the rapid forward progress of hurricanes can be accounted for by the effects of the basic current, and that a hurricane moves in approximately the same direction the basic current is flowing.

To determine if the steering current caused a hurricane to move, Mrs. Elizabeth Jordan [11], while working at the University of Chicago, made calculations from mean data. She computed the steering current based on mean winds from an area ranging from 120 to



Radarscope showing the spiral rainbands of hurricane Connie. The dense white area in the very center of the scope is caused by objects near the radar set. All the other white areas indicate the presence of rain. Note that the rainbands spiral in toward the center of the hurricane (to the left and slightly below the middle of the picture).

240 nautical miles about the center of the hurricane at all levels up to 30,000 feet. Defining the pressure weighted mean of the winds in this ring as the steering current, she found that it was 9.7 knots in the direction in which the average hurricane was moving. The average speed of motion of the storms included in this study was 11 knots. This difference is fully within the limitations of the data. Mrs. Jordan also computed the component of the basic current perpendicular to the main movement of the hurricanes and found it to be less than 1 knot. It follows then, in the mean, that tropical storms move in the direction and with the approximate speed of the steering current when the steering current is defined as the pressure weighted mean flow from the surface to 300 mb.

The internal forces result from interaction of the other two circulations, namely, the tangential and radial components of the winds, with each other and with the basic current. Asymmetries of the circulation about a hurricane and small-scale circulations imbedded within the hurricane wind field also contribute to the movement of the hurricane as a part of the internal forces. Since the tangential and radial components of the wind vary from time to time and differ in various sectors of the storm, their interactions build up forces which could reasonably be expected to cause changes in the direction and speed of movement of a hurricane. Low-level wind data and radar observations of hurricanes indicate that locations of areas of maximum mass convergence in the lower levels vary considerably with respect to the hurricane center from storm to storm and from time to time in the same storm. It has been calculated that the hurricane that passed over southern Florida and New Orleans, La., in 1947 drew 2 to 3 billion tons of air per minute into the hurricane circulation through the lower levels of the storm and presumably returned the same amount of mass to the surrounding atmosphere after expelling the air from the storm at high levels. It should not, therefore, be assumed a priori that the internal dynamics of the storm itself play an insignificant role in the over-all physics of hurricane movement.

Let us discuss two of the internal forces that have been investigated. Even a casual inspection of hurricane tracks will reveal that most of the storms have some northward component. This suggests some internal force. Dr. C. G. Rossby [17] argues that the northward acceleration can arise from the variation of the coriolis forces across the width of the storm. (The coriolis is an apparent force caused by the movement of air across a rotating spheroid and varies directly with the sine of the latitude.) In general, the northward acceleration according to the formula developed by Rossby will be greater, the more intense and the larger the hurricane. Dr. George P. Cressman [4] estimated that the magnitude of this northward force would probably

vary from one-half to 2 knots per day for the size storms that occur most frequently in the Atlantic. He further estimated that for the very large typhoons that sometimes occur in the Pacific the magnitude of this acceleration might be as much as 8½ knots per day. Mr. Ando in Japan made a statistical study and found that, on the average, intense typhoons move faster to the north than weaker typhoons.

Dr. Tu-Cheng Yeh [25] has described another internal mechanism that results from the fact that superposition of a vortex on a steering current is nonlinear. This fact becomes manifest through small oscillations with amplitude of 0.5° to 2° of latitude and with a period of 12 hours to 2 days for the normal range of the observed winds, according to Dr. Yeh. Yeh has developed formulas for computing both the amplitude and the period of oscillation, and both of these quantities vary with the wind speed, the size and intensity of the storm. Post-storm analyses of many hurricane and typhoon tracks indicate that there is some oscillation similar to the one which Yeh described. Insufficient data have been available for fully testing the theories of Dr. Yeh, and most of the use that has been made of his ideas in forecasting have been by extrapolating a suspected oscillation into the future.

COMMONLY USED FORECAST METHODS

Statistical approach.—C. L. Mitchell [12] and I. R. Tannehill [23] have prepared summaries of hurricane tracks by months which have been published. José Colón [3] has extended the work started by these two and has computed for each 5° square of latitude and longitude the percent frequency storms have moved along each of the 16 principal directions. He also calculated the probability of a displacement along the modal direction and the average speed of movement (fig. 6). When data are sparse, frequently the best forecast that can be made is one based on charts similar to those prepared by Colón. Fortunately, in the tropical Atlantic area where we ordinarily have very little data, the statistical approach seems to work very well. Even when data are available the statistics can be used as a rough guide to what a hurricane is most likely to do.

Persistence of past movement.—Probably the most commonly used method of forecasting hurricane movement is the so-called "path method." This consists of extrapolating a hurricane movement into the future on the basis of what has happened in the past 6, 12, or 24 hours. Although extrapolation need not consist of projecting the hurricane path forward along a straight line, that is the way it is used most commonly. The "path method" integrates the effect of both the internal and the external forces. If one may assume that the same steering and internal forces will be acting in the next period, the "path method" should give very good results. In this statistical work, Mr.

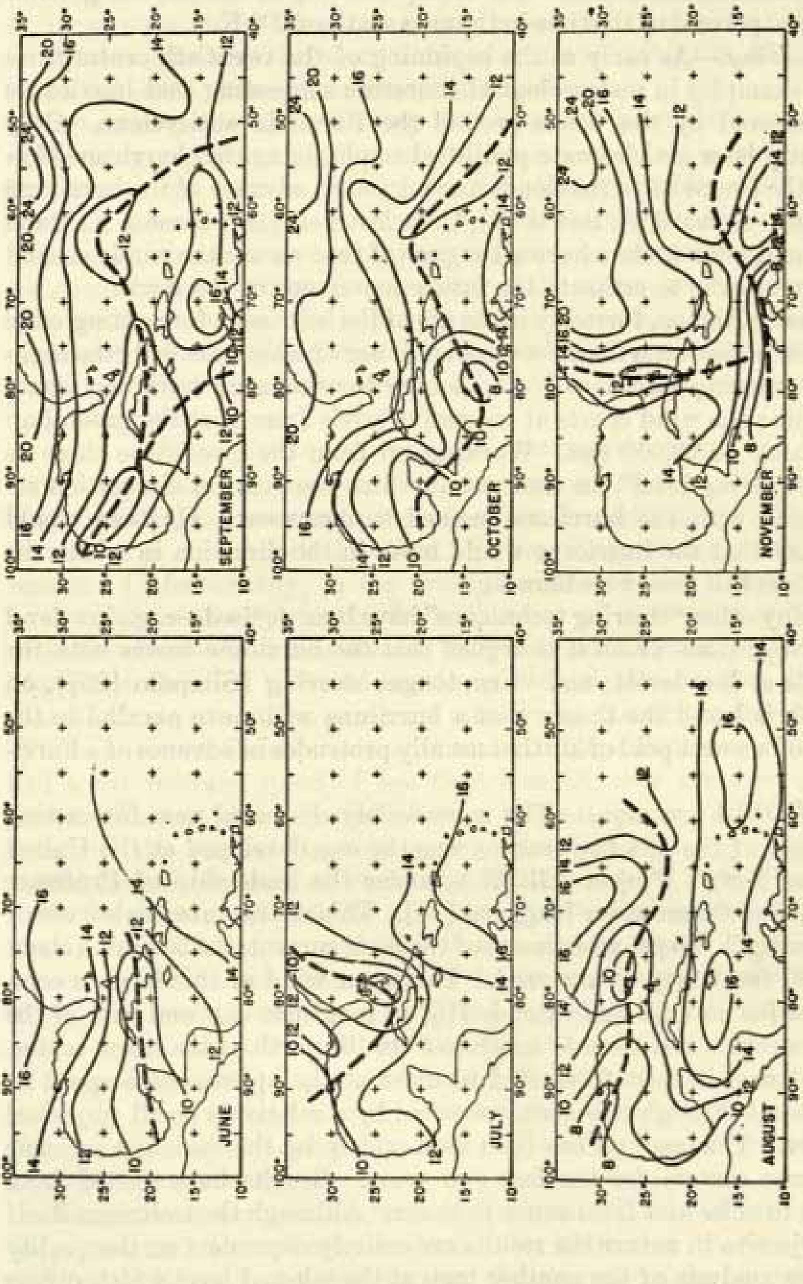


FIGURE 6.—Median speed of motion (m.p.h.) of hurricanes and tropical storms. Heavy dash line shows axis of slowest median speed. (This chart is one of a series prepared by Colón [3] which presents statistical information about movement of hurricanes.)

Colón [3] has computed the probabilities that the track would not deviate more than 10° in direction in the next 24 hours from the path followed the previous 24 hours. He found that during most of the hurricane season straight-line extrapolation gets results this good at least 80 percent of the time in the area south of 20° N.

Steering.—As early as the beginning of the twentieth century, we find examples in meteorological literature suggesting that hurricanes are steered by the winds around the Bermuda anticyclone. Only slightly later articles were published emphasizing that hurricanes follow the course of cirrus clouds moving out in advance of the hurricane center. Edward H. Bowie [1], C. L. Mitchell [12], Gordon E. Dunn [6], and later writers have all suggested that we use the winds around the hurricane to estimate the future movement of the storm.

Grady Norton, formerly in charge of the hurricane forecasting office in Miami, has been the most successful user of what he called "the high-level steering technique." In picking the "steering level" he would examine the wind charts at successive levels from near the ground up to 50,000 or 60,000 feet. Working up from the ground he chose as the "steering level" the first one at which the vortical circulation associated with the hurricane seemed to disappear. He then would predict that the hurricane would move in the direction in which the winds at this level were blowing.

Many other "steering techniques" have been devised—e. g., low-level steering, from which it is argued that the hurricane moves with the winds at low levels; and warm-tongue steering (Simpson [20]), on which is based the theory that a hurricane will move parallel to the axis of a warm pool of air that usually protrudes in advance of a hurricane.

AROWA technique.—The most widely discussed new forecasting method of the last two seasons was the one developed at the United States Navy's Project AROWA, under the leadership of Professor Riehl and Commander Haggard [14]. This method also makes use of "steering." To get an estimate of the basic current, the 500-mb. (about 19,000 feet) map is analyzed. The mean wind at this level is computed for an area that extends 7½° of longitude east and west of the storm center and from 5° south to 5° to 10° north of the storm center. The storm is then forecasted to move at the approximate speed of the wind through this area, corrected by a relatively small empirical factor. This method has been used widely by the various hurricane forecast centers for the last two years. Results have varied from office to office and from storm to storm. Although the technique itself is objective in nature the results are entirely dependent on the quality of the analysis of the weather map at the selected level which differs widely from one analyst to another and from one day to another, de-

pending upon the amount of data available. Professor Riehl and Commander Sanborn of Project AROWA made a series of forecasts during the 1955 season in which they found that the average error for 47 forecasts made 24 hours in advance was 63 nautical miles. These results are somewhat better than those obtained using the AROWA technique at the various hurricane forecast offices.

Numerical prediction.—During 1955 and 1956 extensive tests were made using numerical prediction techniques to forecast movement of hurricanes, and these forecasts have competed in quality with those made by other methods. Forecasts made by the numerical prediction technique in current use are also based on a form of "steering." This technique has the advantage over many of the others, however, in that it is purely objective. As improved and more realistic mathematical models of the wind circulation become available for use in numerical prediction, there should be continued improvement in forecasts made by this method.

SPECIAL PROBLEMS IN FORECASTING HURRICANE MOVEMENT

So long as the hurricane continues to move along the same path at approximately the same rate of speed, either the persistence of the past movement or the statistical method of forecasting usually gives good results. Unfortunately, in the areas near the United States coast, hurricanes frequently change their direction of movement and will often accelerate or decelerate in their rate of forward movement. Hurricane Carol of 1954 and hurricane Ione of 1955 are two storms that illustrate one of the problems continually facing the forecaster. While hurricane Carol was located south of Cape Hatteras, N. C., it had a net forward speed of less than 3 m.p.h. over a period of 60 hours. Then, within a period of a few hours it had accelerated until it moved at a rate of about 40 m.p.h. Hurricane Ione, by contrast, moved toward the coast of North Carolina at a rate of 15 to 20 m.p.h. until the time it crossed the coastline. Instead of accelerating, as hurricane Carol had done, it slowed down, made several loops in its course, and had a net forward speed for several hours of only 2 to 3 m.p.h. Whereas hurricane Carol had moved in the direction between north and north-northeast at about 40 m.p.h. from the vicinity of Cape Hatteras, N. C., to Long Island, N. Y., hurricane Ione turned suddenly toward the east and east-northeast as it left the coast of North Carolina just a few miles south of Norfolk, Va., and moved out into the Atlantic ocean.

Figures 7 and 8 are surface maps of hurricanes Carol and Ione when they were near Cape Hatteras, N. C. An inspection of these maps will reveal few clues as to the widely different types of movement that were to follow. It was pointed out earlier that we have learned that the movement of hurricanes is largely controlled by the flow of air

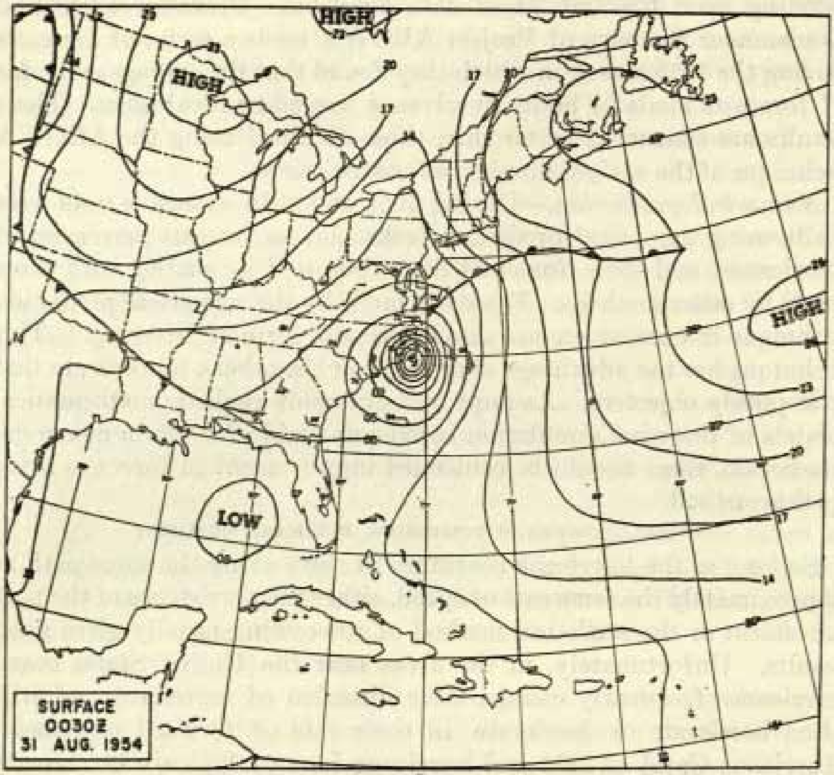


FIGURE 7.—Surface weather map at the time when hurricane Carol was accelerating rapidly. Within a few hours the storm was moving north-northeastward about 40 m.p.h.

around them, up to comparatively high altitudes. To illustrate the point, figure 9 shows the 300-mb. map (about 30,000 feet) when Carol (shown by tropical storm symbol ♁) was located east of Jacksonville, Fla., and was moving slowly. At the 300-mb. level the winds usually blow in a direction approximately tangent to the contour lines and vary in speed inversely with the space between the contour lines. From the contour lines we can deduce that the air currents around the hurricane were very weak and variable in direction. If the hurricane had been farther south in the moderate easterlies, then about 20 m.p.h. at Havana, Cuba, it would have moved faster. Figure 10 shows the 300-mb. map at the time when Carol was moving northward at about 40 m.p.h. The close spacing of the contour lines indicate that the wind should be strong southerly all around Carol. At Washington, D. C., winds were about 55 m.p.h. at 31,260 feet, and at Caribou, Maine, they were south 35 m.p.h. at 19,000 feet. The long, heavy arrow in figure 10 extending from Cape Hatteras, N. C., through New Hampshire into Canada shows part of the track of Carol.

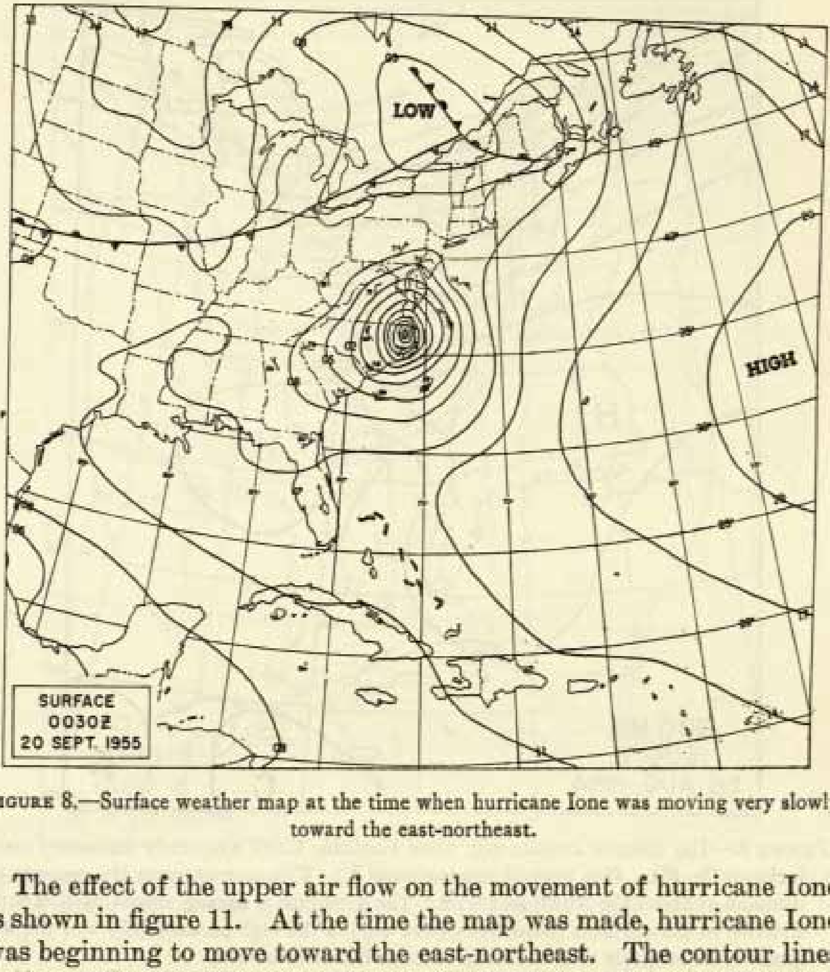


FIGURE 8.—Surface weather map at the time when hurricane Ione was moving very slowly toward the east-northeast.

The effect of the upper air flow on the movement of hurricane Ione is shown in figure 11. At the time the map was made, hurricane Ione was beginning to move toward the east-northeast. The contour lines indicate a strong flow from the west only a short distance north of hurricane Ione and this indicates that hurricane Ione could not move very rapidly toward the north. (The wind direction and speed in knots are indicated on the map for Washington, D. C., Portland, Maine, and Nantucket, R. I. Several hours earlier when the storm center was still over North Carolina the high-level circulation was not as well defined and it was not obvious in which direction Ione would move.) A few hours after the time of the map, hurricane Ione drifted far enough north to be affected by the strong winds blowing toward the east-northeast and accelerated rapidly in forward movement.

3. INTENSITY

The third major forecasting problem for hurricanes is that of forecasting intensity, which to some extent, overlaps the problem of forecasting inception. As used here, forecasting of inception refers to

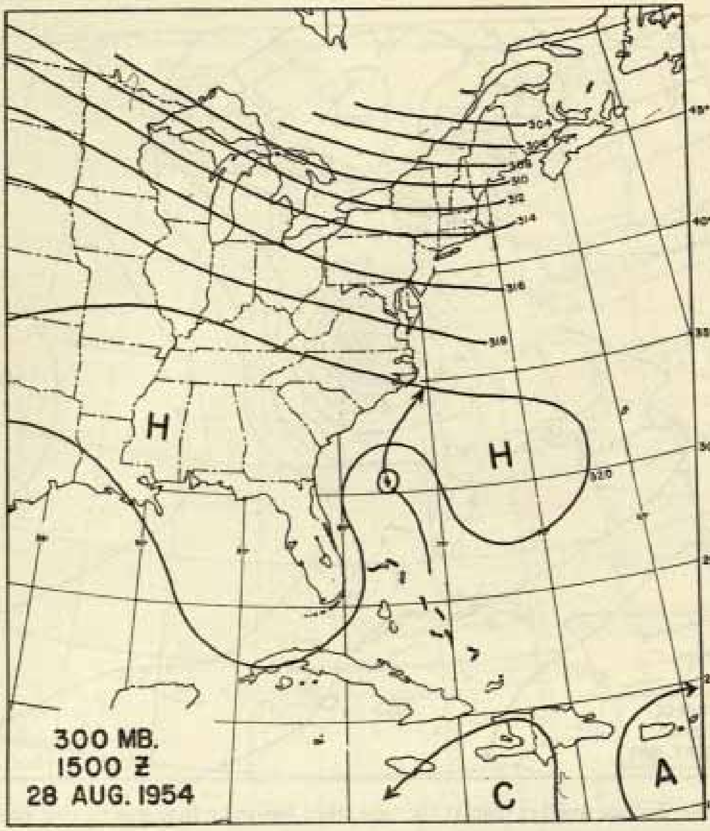


FIGURE 9.—The 300-mb. contour map when hurricane Carol was nearly stationary east of Jacksonville, Fla. (See tropical storm symbol 6.) This map portrays the pressure distribution at about the 30,000-foot level. The wind flow is usually almost parallel to the direction of the contours (counterclockwise around the high pressure [H]) and the wind speed varies inversely with the space between the contour lines.

the transformation of a disturbance in the Tropics into a tropical storm that has a vortical circulation, maximum wind speed of at least 40 knots, and a center in which the winds are relatively calm. The wind speed, however, is more likely to be at least of hurricane intensity, that is, 75 m.p.h., before the end of the inception period. Forecasts of intensity are those made after the tropical storm has formed and has already become a menace to the life and property of communities that stand in its projected path.

In the hurricane service, warnings are ordered for an area at any time when the winds are expected to reach hurricane force. No stronger warnings are issued regardless of how much the wind speed is expected to exceed 75 m.p.h. The amount of damage that can be done, however, varies considerably with the intensity of the storm.

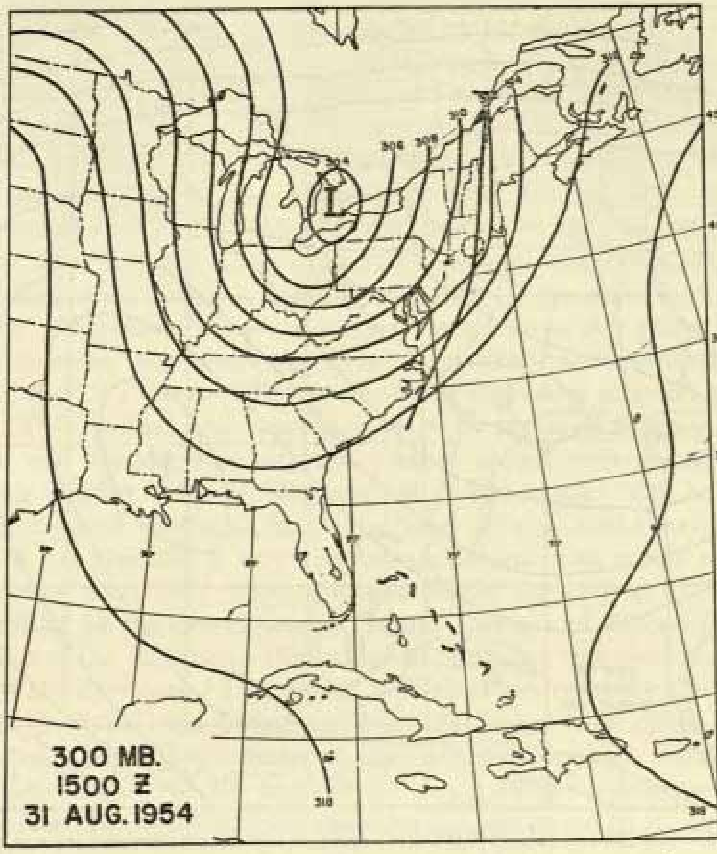


FIGURE 10.—The 300-mb. contour map when hurricane Carol was centered over eastern Long Island and moving rapidly northward. (For further explanation see legend of Fig. 9.)

This is particularly true because the force of the wind increases not with the speed but with the square of the speed of the wind; for example, winds of 150 m.p.h. exert four times as much force as winds of 75 m.p.h. A hurricane in which the maximum wind speed is only 75 m.p.h. may do relatively little damage except in exposed areas and to the weaker varieties of trees and shrubbery. Winds of 150 m.p.h. will, however, tear away and batter most anything that is not securely attached to some sturdy structure. Winds of 200 m.p.h. will do great damage to all except the very strongest of buildings. If it were possible to forecast intensity of hurricane with more accuracy and with greater precision, it should be practical to issue grades of hurricane warnings.

We have had many examples of hurricanes changing intensity within a period of 24 hours. In 1935 a small hurricane started forming in the Bahama Islands area. By September 1 this storm was believed

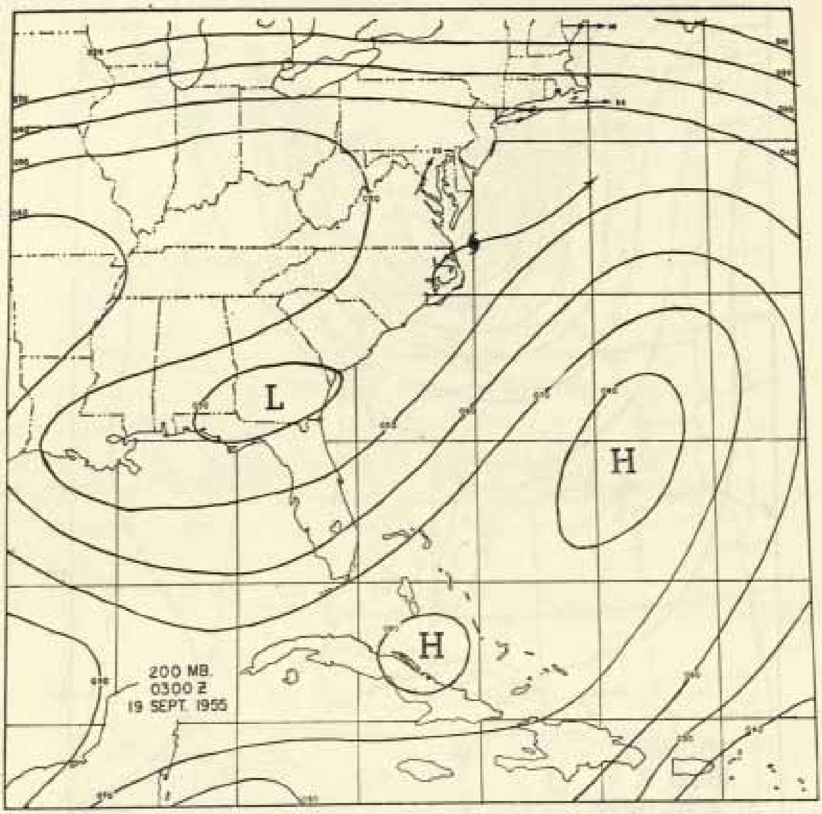


FIGURE 11.—The 200-mb. (about 40,000 feet) contour map when hurricane Ione was beginning to accelerate toward the east-northeast. Wind direction and wind speed (in knots) are indicated at three stations near the hurricane center (see tropical storm symbol ♉). The heavy arrow indicates the past and future movement of the storm.

to have reached hurricane intensity; by September 2 the center passed over the Florida Keys with the lowest central pressure that has ever been recorded at sea level in the Western Hemisphere, 26.35 inches of mercury. Hurricane Janet of 1955 has already been listed as one of the most severe storms of the century. The eye of this hurricane passed just south of the Island of Barbados on September 22. It was described as an immature hurricane with a very narrow band of hurricane winds around the eye. The hurricane reconnaissance plane that observed the storm at this time reported that the wall of cloud around the eye was only 5 miles wide but the turbulence was very severe. Maximum winds were estimated as 110 to 120 m.p.h. on the south shore of Barbados, but the wind speed dropped off very rapidly 20 miles out from the edge of the eye. According to Dunn, Davis, and Moore [7], hurricane Janet proceeded on a course generally toward the west in the eastern Caribbean for the next several days with some

actual decrease in intensity. On September 23 the central pressure was 996 mb. (29.41 inches) and maximum winds 90 m.p.h.

During the early hours on the 24th, according to the Navy reconnaissance plane, Janet never presented a good center definition and it is not certain if the center was found. Late in the afternoon, one very strong spiral weather band was found although the central pressure remained about the same. At 8:30 E.S.T. on September 26, Lieutenant Commander Windham with crew of eight and two newspaper men reported at latitude 15°40′ N. and longitude 78°02′ W. that they were about to begin penetration of the main core of the storm. No further report was ever received from this plane. Janet had become a very severe hurricane. The Navy reconnaissance plane at 10:40 E.S.T. on the 27th reported that the lowest pressure was 938 mb. (27.70 inches) and maximum winds in excess of 115 m.p.h. by a large and uncalculable amount. Janet passed over Swan Island during midday with winds estimated at 200 m.p.h. The hurricane center reached Chetumal, Mexico, about 1:00 a.m. local time, September 28. It was still a very concentrated storm with winds reaching hurricane force only about 2 hours before the arrival of the eye, according to the description of Dunn, Davis, and Moore [7]. In Chetumal the barometer reading of 27.00 inches was recorded in the eye of the hurricane. In Corozal, British Honduras, only a few miles from Chetumal, the barometer fell 2.24 inches in 2 hours and 10 minutes. The anemometer at the airport terminal building at Chetumal registered 152 knots or 175 m.p.h. before it collapsed. The wind later increased and the maximum is estimated in excess of 200 m.p.h.

Hurricane Diane in 1955 is a good example of both rapid intensification and also rapid loss of intensification. On August 11, the first aircraft reconnaissance of Diane reported that the lowest pressure was 1,004 mb. (29.65 inches) and that the maximum winds were 45 m.p.h. This was approximately the same maximum wind speed that had been reported by ship observation on the previous day. During the night the storm changed direction from a northwest course to a northeast course and intensified rapidly. The reconnaissance on the 12th reported that winds had increased to 125 m.p.h. and the central pressure had deepened to 975 mb. (28.78 inches). After the 13th, the storm began to fill and the intensity decreased. When the center passed inland near Wilmington, N. C., early in the morning of the 17th, the highest sustained wind reported was 50 m.p.h. at Hatteras, N. C., with gusts up to 75 m.p.h. at Wilmington, N. C.

What are some of the things that can cause a hurricane to change intensity? It is well established now that if cold or dry air is drawn into the inner circulation of a hurricane, or if the hurricane goes over

rough terrain, the storm will lose intensity; and if the terrain is very mountainous the lower levels of the hurricane's circulation may be completely disrupted.

The fuel that supplies the energy of a hurricane is the warm moist air that is found in tropical oceans. This explains why introduction of cold dry air to the inner core of the hurricane's circulation can cause the hurricane to weaken. It does not explain, however, why some hurricanes will barely reach hurricane intensity even though both types remain over the warm tropical oceans for long periods.

Two types of air circulation are required to keep a hurricane going: (1) Inward-directed flow in the lower levels, and (2) outward-directed flow in the upper levels that evacuates the air from the hurricane. To produce intensification of a storm and to provide lower pressure in the center it is necessary that more air be evacuated from the top than is brought into the hurricane circulation at lower levels. It is quite probable, therefore, that a key to the intensification of a hurricane is in the upper levels of the troposphere. Most of our ideas as to what will cause a hurricane to intensify or to weaken are based on theoretical rather than empirical deductions because of lack of sufficient data to prepare accurate weather maps at the higher levels. Dr. Herbert Riehl, University of Chicago, in private discussions, has expressed the idea that a hurricane is more likely to intensify if the circulation at high levels is such that the air coming out of the hurricane can be rapidly removed from the tropical area. Further intensification is much less likely and, if it does occur, will proceed much more slowly in cases of sluggish circulation at the higher levels.

After a hurricane moves into middle latitudes the warm air of the storm is frequently brought in contact with a colder air mass. This will usually change the character of the hurricane, and it sometimes occurs in such a manner that the storm reintensifies with middle latitude characteristics where the energy is derived from the potential energy made available by the juxtaposition of two air masses of different densities. This was the case when hurricane Hazel moved into Pennsylvania in 1954.

4. RAINFALL

Rainfall associated with hurricanes causes more damage and kills more people than any other hurricane force except the storm surge. Hurricane Diane became the first billion-dollar hurricane in the history of the United States, largely because of the floods following the rains associated with it. One hundred eighty-four people were killed—mostly drowned. The floods following the passage of hurricane Hazel of 1954 over Haiti were estimated to have drowned several hundred people. Likewise, several hurricanes entering Central America and Mexico during the past decade have each drowned over a hundred

people, according to estimates appearing in the press. During the 1955 season the floods caused in Mexico by hurricanes Hilda and Janet and tropical storm Gladys are reputed to have inflicted upon Tampico, Mexico, its greatest natural disaster.

To many people, rainfall is the most sensational result of a hurricane. Rainfall accompanying hurricanes and tropical cyclones is nearly always heavy and frequently torrential. At Baguio in the Philippines, in July 1911, 46 inches of rain fell in 24 hours during the passage of one tropical storm. In the United States the heaviest rainfall during such a storm was 39.7 inches, which fell during one 48-hour period at Thrall, Tex., during the storm of September 8–10, 1921.

The quantity of rain that can fall from one slow-moving tropical storm almost staggers the imagination. In hurricane Diane of 1955, over 16 billion tons of rain fell, according to rainfall estimates prepared by Schoner and Molansky [19], who also estimated that over 30 billion tons of rain fell during the passage of hurricane Connie. Thus, approximately 46 billion tons of rain fell during the two storms.

Many of the heaviest recorded rainfalls have been in storms of less than hurricane intensity. Even in storms that were hurricanes at one time, the heaviest rainfall frequently occurs after the winds are no longer of hurricane intensity. This was the case with hurricane Diane of 1955. Although at one time while it was still at sea the highest winds in Diane were 125 m.p.h., the maximum measured winds along the shore when Diane moved inland were 74 m.p.h. in gusts at Wilmington, N. C. As Diane moved farther inland the winds further decreased, and as the gales subsided, so did the public's concern with the storm. Diane moved northward across North Carolina and Virginia and into Pennsylvania before turning eastward for the coast—then came the deluge! The torrential rains from Diane fell on grounds still saturated from the rains of Connie. From the Poconos of Pennsylvania to southeastern New England rain in excess of 8 inches was reported at many places. The greatest amount—over 19 inches—fell in the highlands northwest of Hartford, Conn. All this rain fell long after Diane had ceased to have winds of hurricane force [24].

Rainfall around a tropical storm is usually distributed asymmetrically. This is particularly true when a hurricane is moving. According to Dr. I. M. Cline [2], very little rainfall occurs in the rear half of storms moving inland on the Gulf or south Atlantic coast of eastern United States. The heaviest rainfall usually occurs in the right front quadrant of the tropical storm, according to Cline. There are exceptions, of course. As a hurricane moves inland, heaviest rainfall frequently occurs far in advance of the storm. This is particularly true

when there are orographic features that cause air in advance of the storm to flow upslope; or when there is a dense air mass several hundred miles in advance of the storm, which acts as a wedge for the warmer moist air around the hurricane to flow up and over.

L. Hughes [10], using mean wind data for a number of tropical storms, after making reasonable assumptions about the amount of moisture that would be carried into storms at low levels, computed the intensity of rainfall that should be expected in hurricanes. The values computed by him are such that if a hurricane passed directly over a station while moving in a straight line there would be a total rainfall of about 11 inches in 48 hours. This appears to be a reasonable value. Cline [2] and other investigators have found 8 to 10 inches occurring frequently under similar conditions in the Atlantic and Gulf storms.

5. FORECASTING FLOODS ASSOCIATED WITH HURRICANES

The problems associated with forecasting floods from hurricane rains may be summarized as: (1) Forecasting the path the hurricane will take; (2) the distribution of rainfall around the hurricane; (3) the effect on the rainfall of upslope motion caused by the air in advance of the hurricane flowing up over a mountain or up over a colder denser air mass; (4) the amount of runoff that will follow the rainfall; (5) the rate of movement of the hurricane; and (6) the intensity of rainfall associated with the hurricane and the various upslope motions given to the air mass in advance of the hurricane.

A good illustration of the necessity for forecasting the amount of runoff to be expected occurred in the 1955 season. Hurricane Connie gave as much rain as hurricane Diane in some of the areas that were afflicted by the death-dealing floods following the passage of Diane. In general, however, the floods following Connie were not very dangerous. The rains from Connie did, however, almost completely saturate the ground. When Diane followed soon after, nearly all the rain that fell was available for runoff and the excess water soon caused mountain streams to rise above the banks and to sweep everything before them.

6. STORM SURGE

The storm surge is the greatest killer and greatest property destroyer associated with hurricanes. In areas where hurricane building codes have been rigidly enforced for many years, relatively little damage is done by hurricanes to buildings away from the waterfront. Even hurricane Janet at Chetumal, Mexico, in 1955 did relatively little damage to solidly constructed concrete houses. In areas near the coast that are exposed to the storm surge, the force exerted is almost irresistible. Recorded history of tropical cyclones reveals many instances of cities and towns being inundated. At Santa Cruz del Sur, Cuba, in November 1932, approximately 2,500 lives were lost out of the total

population of 4,000. At Galveston, Tex., in 1900, the center of the hurricane crossed the coastline southwest of Galveston. According to Dr. I. M. Cline [2], the weather observer, "the water rose at a steady rate from 3 p. m. until about 7:30 p. m. when there was a sudden rise of about 4 feet in about as many seconds. I was standing at my front door, which was partly open, watching the water which was flowing with great rapidity from east to west. The water at this time was about 8 inches deep in my residence and a sudden rise of 4 feet brought the water above my waist before I could change my position." Approximately 6,000 persons lost their lives in this inundation of Galveston. Examples of storms which have done great damage from the storm surge in recent years are hurricane Carol of 1954, the New England hurricane of 1938, and the Florida Keys hurricane of 1935.

The high seas associated with the approach to the coast by a hurricane are caused largely by the depressed air pressure, the wind force, and certain amplification factors. The air pressure in the center of a hurricane is frequently as much as 2 inches of mercury below normal. The decreased weight on the ocean surface will allow the ocean surface to rise approximately 1 foot per inch of mercury deficiency in air pressure. As the hurricane-force winds move across the surface of the water they induce currents in the ocean that can result in the accumulation of excess water when the hurricane approaches the coast. Neither the deficiency of air pressure nor the piling-up of water along the coast by the wind-driven currents will account for the extremely high tides sometimes observed with hurricanes. There are several theories to account for and explain the amplification of the storm surge while the hurricane is crossing the continental shelf, but they are relatively untested and the final answer may yet have to be determined by researchers. There has been great improvement in the forecasting of storm surges in the last two years and the work now being done by several groups gives promise of great progress in the next few years.

RESEARCH NEEDS

At the present time we need more information on almost all facets of hurricanes and tropical cyclones. We need good physical explanations of how hurricanes develop, how they move, why they intensify or weaken, and we need to know more about the structure of hurricanes. In recent years, aircraft reconnaissance of hurricanes has greatly increased our knowledge of the structure of the storm. Even yet, however, we need much more knowledge of the detailed structure, the areas of inflow and outflow in the hurricane, the structure of the eye, and the mechanisms by which it is maintained.

Great progress has been made in developing methods for forecasting hurricane movement. Most of these forecast methods have been

empirical in nature and it is only in the last two years that promising semiobjective methods have been developed. It is reasonable to believe that if we can first fully understand the mechanism of how hurricanes move, it will be possible to make more rapid progress in developing improved methods in the future. At the present time most methods used for forecasting either inception or intensification are very hazy and show relatively little skill when used under operational conditions.

While the possibility for eventual control of hurricanes is probably many years in the future, any rational approach to research on this problem is dependent on first acquiring much more knowledge of their structure and dynamics. The forces released in hurricanes are so much stronger than any of the forces that man can bring to bear against the hurricanes, it is not practicable for us to attempt control by any direct method. The only possibility for controlling either the movement of the hurricane or its formation is first to find some mechanism in the hurricane itself that man can use to make the hurricane control or deviate itself. That is, man must search for power brakes or power steering mechanisms in the hurricane structure that man can activate and thus eventually cause the hurricane to move along a certain path or to weaken and dissipate.

ULTIMATE POTENTIAL FOR FORECASTING

The development of high-speed computers has made possible the use of numerical techniques in forecasting. Experimentation during the last 2 or 3 years leads one to believe that ultimately it will be possible to make forecasts of the movement of hurricanes for 24 to 48 hours in advance with such accuracy it will enable the forecasters to issue hurricane warnings for coastal areas with more precision. This should make it possible to warn people in relatively restricted areas if they are to be affected by hurricane force winds within the next 24 hours and to omit warnings for all people who are very far removed from the threatened areas. It should make possible the alerting of specified coastal areas 48 hours in advance of the possibility of hurricane winds within the specified period without having to alert practically the entire United States coast. One of the purposes of the present research program is to determine precisely what data are needed for making successful hurricane forecasts. Once this is determined it should be possible to collect the required data with less effort than is being expended at the present time in gathering reconnaissance data and other information for use in hurricane forecasting.

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Plantlike Features in Thunder-Eggs and Geodes[1]

By Roland W. Brown

U. S. Geological Survey

[With 6 plates]

Long ago, according to legend, the angry gods on Mount Hood and Mount Jefferson in the scenic Cascade Range of Oregon fought a titanic battle during a violent storm. Amid flashes of lightning and peals of thunder the opposing artillerists hurled thousands of round rocks at one another across the intervening 60 miles. Many of these thunderstones fell, far wide of the intended targets, over a large area to the east of the mountains. The embattled gods presumably obtained these missiles by robbing the nests of thunderbirds. Consequently, when retrieved today they are popularly called thunder-eggs (Renton, 1951, p. 172), although they are not egg-shaped but roughly spherical and quite variable in size. Vivid myth aside, the plain fact is that these thunder-eggs, or spherulitic geodes as they are known among geologists, are restricted to the weathered outcrops of a prehistoric (probably late Oligocene or early Miocene) lava flow, which is now a rhyolitic, welded tuff in whose glassy matrix they originated, without benefit of thunderbirds, as everyone familiar with them in the field knows. Moreover, closely similar specimens occur under somewhat comparable circumstances at numerous other localities not only in Oregon but in distant parts of the world.

The occurrence, appearance, and origin of thunder-eggs have been discussed more or less adequately by amateur rockhounds and professional petrologists (Dake et al., 1938; Renton, 1951; Ross, 1941). Therefore, I shall here refrain from unnecessary repetition of commonly known details but shall deal particularly with a pseudobotanical phase that, at least among collectors of gem materials, has aroused

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considerable interest and speculation—the plantlike structures sometimes seen in the interiors of these intriguing objects. This study is based on the large Hess collection of specimens and sections received by the U. S. National Museum in 1955.

THE FRANK L. HESS COLLECTION

On his many pleasant visits to my office, the late Frank L. Hess, formerly of the U. S. Geological Survey and Bureau of Mines, was enthusiastic in discussing the so-called "mosses," "algae," and other phenomena seen in sections of some thunder-eggs (pl. 3, fig. 1; pl. 4, figs. 1–4; pl. 5, figs. 1–4; pl. 6, figs. 1–4). He was particularly attracted by those from the Priday (now Fulton) ranch near Antelope, Oreg., because they are unusually well formed and are well known as collector's items among lapidarists. Along with others (Benn, 1955, p. 8), he maintained that the slender filaments, threads, strands, mosslike dendrites, fringes, plumes, sheets, ribbons, and branched tubules, found in an infinite variety of form and color in the opal, agate, and chalcedony of these sections, represent species of algae. Strangely, neither he nor anyone else, so far as I know, made the equally possible suggestion that they might be the hyphae and mycelia of fungi. His interest in the algal hypothesis was so devoted that, in an effort to establish its truth or falsity, he spent innumerable hours in his home laboratory cutting and polishing hundreds of sections from specimens he himself had collected or had received from friends, among whom the chief contributors were C. H. Robinson, Sr., Puyallup, Wash., French Morgan, Washington, D. C., Aaron Waters, then at Stanford, Calif., and John L. James, Tonopah, Nev. These sections, according to his and Mrs. Hess's wishes, have now passed through my hands for study. Mr. Hess left no manuscript but many uncoordinated and sometimes fanciful notes bearing on this material. For example, his notations include brief comparisons with living algae, names for "new species," and two frequently recurring adjectives he used to indicate the light requirements of the two large groups of "algae" he recognized: photophile (light-loving) and scotophile (darkness-loving).

Although I repeatedly and firmly stated to him my disbelief in the algal nature of the lifelike filaments and hinted that other observers (Dake et al., 1938, p. 196; Renton, 1951, p. 176) concurred in my view, Hess continued to seek confirmation of his opinion and thought he had found that support in the replies he received from students of living algae to whom he sent sections for examination. Here, for the sake of definiteness, it is necessary to remark that the Hess material is clearly of two distinct kinds: sections of spherulites derived from volcanic rocks, and sections of authentic algal nodules, without filaments, derived from sedimentary rocks. His reluctance or inability

to distinguish between them is the reason for the marked but friendly difference of opinion we held regarding their origin and meaning.

The algal specimens cut from pillars or cylinders that for years had been erroneously called geyser cones, as I have already explained (Brown, 1949), originated by the deposition of lime incident to the life processes of algae around woody snags lodged along the shores of Eocene and Miocene lakes in Wyoming and Nevada. Hess sent a batch of sections of this Nevada material to a noted algologist and received in reply the correct information that algae indeed were in large part the cause of the laminated effects there seen. Whether or not he sent sections of the igneous spherulites to the same or other students of algae I do not know. Be that as it may, he felt sufficiently encouraged to believe that algae also were responsible for the filaments seen in thunder-eggs. My purpose now is to define my position about these colorful and fascinating plantlike objects; and I hope to do this without blemishing Hess's memory or ruffling the feelings of those of his rockhound friends who believe as he did about these things.

FILAMENTS IN THUNDER-EGGS NOT ALGAE

The advocates of the algal theory to explain the "growths" in thunder-eggs deceive themselves in two ways. First, they mistake striking but superficial lifelike resemblances for the real thing. Yet, so closely do these filaments imitate natural growths that self-deception about them is understandable and pardonable, especially for persons untrained in botanical identification. Observant examination of the delicate filaments with a good hand lens or a binocular microscope shows that when well developed they are tubular. They are not segmented or jointed, that is, with cell after cell in linear rows, as they should be were they the filaments of fresh-water algae. Exceptions among such algae are the partitionless greenhouse *Vaucheria* and the parasitic *Phyllosiphon*, but neither of these in other fundamental respects is comparable to any filaments seen in thunder-eggs. Significant also is the fact that no spores or other reproductive structures have been recognized as such among the supposed algal filaments.

Unlike those of algae the filaments in thunder-eggs are individually very variable in diameter and in erratic branching (pl. 5, fig. 4; pl. 6, fig. 3). They thicken and thin irregularly in an unalgalike manner throughout their extent; and their most notable surface feature is a more or less conspicuous, although sometimes much subdued, wartiness and tumescence (pl. 5, fig. 4; pl. 6, fig. 2) that gives them the appearance of microscopic intestines (pl. 4, figs. 3, 4). These minute swellings along their length indicate that the filaments and their branches developed in successive pulses at their free ends.

Second, the proponents of the algal theory overlook or minimize two important conditions in the geologic origin and occurrence of thunder-eggs that affect adversely the interpretation of the filaments as algae. All students of igneous rocks agree that spherulites of the kind that become thunder-eggs are born in a hot extrusion of siliceous, eruptive material from a volcano or volcanic vent soon after the flow comes to rest but before it becomes rigid and before prismatic structures develop. This chemically complex mixture of minerals, liquids, and gases may congeal more or less quickly into obsidian, perlite, or vitreous, welded tuff. Thus the emplacement and early stages of the lava require a temperature so high and sterilizing that no algae or other forms of life can survive in the resulting spherulites or their cavities. Moreover, the incipient thunder-eggs are buried and completely enclosed by surrounding matrix so that no sunlight whatever can penetrate and relieve their pitch-darkness. Hence, even if it be granted that the temperature of the lava after the cavities are formed becomes low enough to permit algae to enter, no algae under this unfavorable light condition can be expected to survive therein, for all algae require some light, much or little, as the case may be. I conclude, therefore, that the physical features of the filaments and the geologic conditions accompanying their origin forbid their identification as algae, mosses, or any other organisms.

THE PSEUDOALGAE, CHEMICAL GARDENS

If the filaments are not algae but inorganic structures, what is their nature and genesis? An intelligible answer to this question demands first a closer inquiry into the origin of the cavity fillings in which the filaments are found embedded. These parts of thunder-eggs are chiefly chalcedony and in section are variously shaped, either geometrically regular or grotesque and fantastic (pl. 1; pl. 2; pl. 3, fig. 1; pl. 6, figs. 1, 4). Much depends upon the direction of cut, and the kind of figure expected can often be confidently predicted before cutting by studying the ridges on the surface, for these are the outward expression of the internal angular projections of the "stars," "cubes," and other forms. After all the external altered matrix is removed many of these chalcedonic interiors look like cubes with hopperlike cavities for sides (pl. 3, fig. 3), often with a ball at the center of one side and an opposing socket at the other. The thunder-eggs containing such figures (pl. 1, fig. 1; pl. 3, fig. 2) seem to show that the vitreous lava when still sufficiently soft was pulled or forced apart, for little effort of imagination is needed to collapse the boundaries of the cavities so that the arch of the ball, for example, will receive the opposite socket, and other features of the outline fit roughly into place. Nevertheless, as in other complex matters, the doctors disagree about the method of origin of the cavities, some claiming expansive

gases as the cause, some the relief of hydrostatic pressure and tension, and still others the recrystallization of the original material of the spherulite followed by formation of a "mud," desiccation, and shrinkage. All apparently agree that in general the evolution is from a solid spherulite (see Renton, 1951, fig. 2, p. 172) to a lithophysa or rock bubble (see Stearns and Isotoff, 1956, pl. 2, fig. 3), sometimes sheared (pl. 1, fig. 2), and finally the filling of the cavity with silica minerals. The process may not have followed a universal rule in each instance but may have differed considerably according to accompanying physical and chemical circumstances. Thus, in many thunder-eggs the original spherulitic center remains intact as a small nucleus or ball and the cavity lies to one side of it (pl. 3, figs. 1, 2). In others the nucleus was obviously disrupted, the separated segments still showing the original radial arrangement of the crystalline matrix (pl. 1, fig. 2). The best analogy, but not necessarily explanation, for the resulting shape of the cavity, is by Iddings (1888, p. 263): " . . . the central mass of the more open [ones] appears to have shrunken and cracked apart like the heart of an overripe watermelon." From these differing views one may draw the conclusion that perhaps before a final statement can be made more field observations and laboratory work are needed to check or imitate the natural effects.

As to how the filaments themselves originated and became embedded in chalcedony at least two known phenomena point to explanations. These are the natural helictites sometimes seen in caves and other sites, and the so-called chemical gardens grown in the laboratory.

Natural limy helictites (not stalactites or stalagmites) are moderately small, irregular, twisted, tubular structures that develop from cave ceilings, walls, and sometimes stalactites. They grow at their free ends, being fed by internal solutions flowing distally from the points of attachment. Thus, so far as method of growth is concerned, they are not quite the same kind of thing as salt and ice ribbons (Brown, 1946), which grow from their bases. Natural helictites can be imitated artificially with simple, chemical apparatus (Huff, 1940).

Did the filaments in thunder-eggs arise like natural helictites by growing out from the walls into empty cavities? Renton (1951, legend to unnumbered figure, p. 175) virtually concluded that they did, but he overlooked the threads subtly concealed within the "stalacites" he described as hanging from the roof of the original cavity and inferred were later embedded in agate that filled the cavity from below. Yet, on the following page he reversed himself and said: "The writer believes that most of the 'moss' seen in thunder-egg agate entered the original cavity from below and the mineral bearing solutions [that became 'moss'] were injected into a silica gel filled cavity . . . "

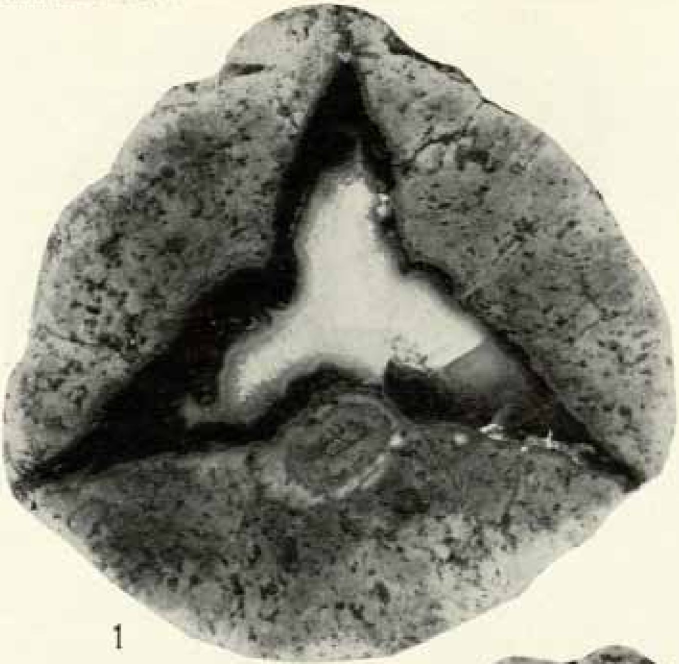
Here the unknown intrudes itself. Assuming an empty cavity to begin with, how long after its formation did it remain empty, except

for air or some other gas? If the gas were in part steam, as seems plausible and likely, condensation began when the lava cooled sufficiently, and the cavities became moist but may not have filled up immediately with watery solutions. Granted such conditions, it is easy to visualize filaments growing as helictites from the moist walls of the unfilled cavities. Perhaps some did so; but, compared with the rather simple natural helictites, the thunder-egg filaments, in their great variety and delicacy, their intricate interconnecting branching networks (pl. 5, figs. 3, 4), and in other features to be discussed, give the definite impression that they did not originate as helictites but grew from any part of the surrounding wall into solutions that, early or late, filled the original cavities.

This probability leads to a consideration of the properties and behavior of artificial chemical gardens, special kinds of which are called silicate gardens. Anyone with a few chemicals and the application of care and patience can produce these interesting, beautiful, and instructive cultures. For example, pour some waterglass or sodium silicate (many other media are now known to be usable) into a beaker. Then drop into the solution small grains of metallic salts, such as those of calcium, cobalt, copper, iron, manganese, nickel, uranium, and others. The more soluble the salt the quicker the result. Shortly, the garden will start to grow, the "seeds" sprouting tubular branched or unbranched filaments remarkably similar to the growths in thunder-eggs. These and other chemical gardens have been known for a long time and have been quite ardently investigated, fairly well illustrated, and satisfactorily explained (Gradenowitz, 1907; Leduc, 1911; Lillie, 1917, 1922; Lillie and Johnston, 1919; Hazelhurst, 1941). In his book The Breath of Life, John Burroughs (1924, p. 167) refers to these experiments: "The chemists have played upon this tendency in the inorganic to parody or simulate some of the forms of living matter. A noted European chemist, Dr. [Stephane] Leduc, has produced what he calls 'osmotic growths' from purely unorganized mineral matter—growths in form like seaweed, polyps, corals, and trees." Aside from the light these experiments shed on the plantlike structures in thunder-eggs, they provide stimulating comparisons with some of the growth forms and processes in plants and animals and possibly contain clues to the origin of life itself (Leduc, 1911; Lillie, 1922; Thompson, 1948). Through all the recent investigations of these chemical precipitates has run a persistent attention to the electrical factors and effects.

SEQUENCE OF EVENTS IN THUNDER-EGGS

That the genesis of the pseudoalgae in thunder-eggs is comparable to that of silicate gardens rather than to helictites seems believable, for it is in accord with all the known facts. In defense of this conclu-



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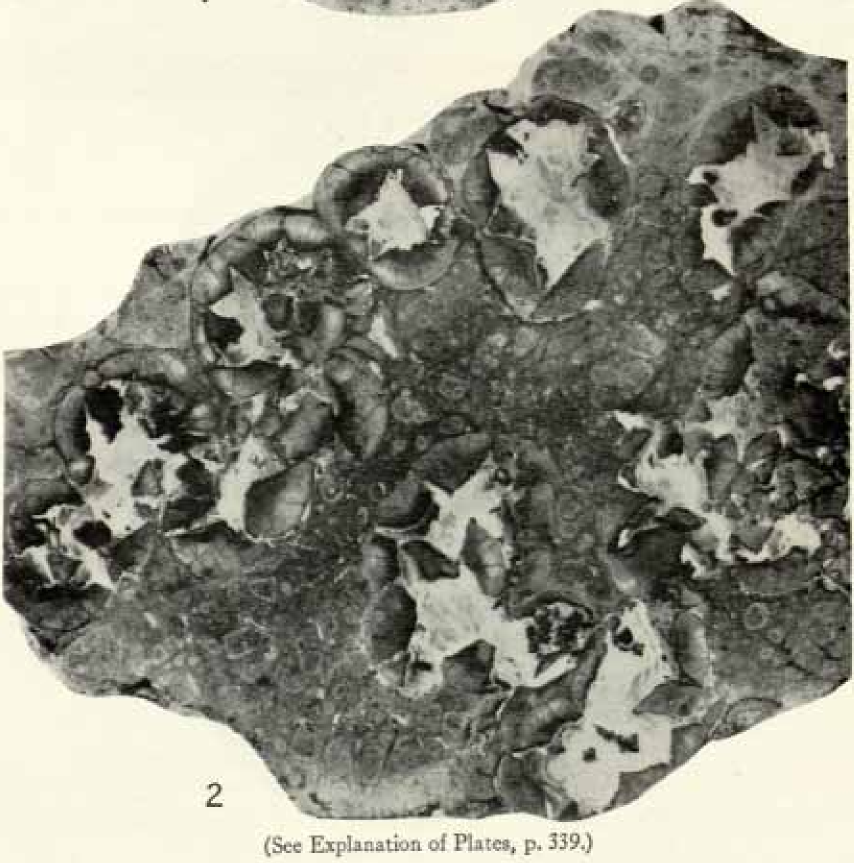

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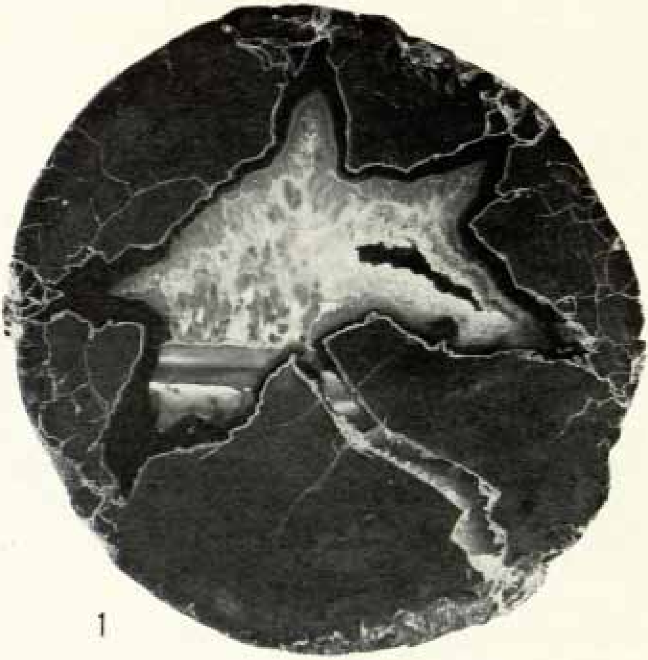
(See Explanation of Plates, p. 339.)



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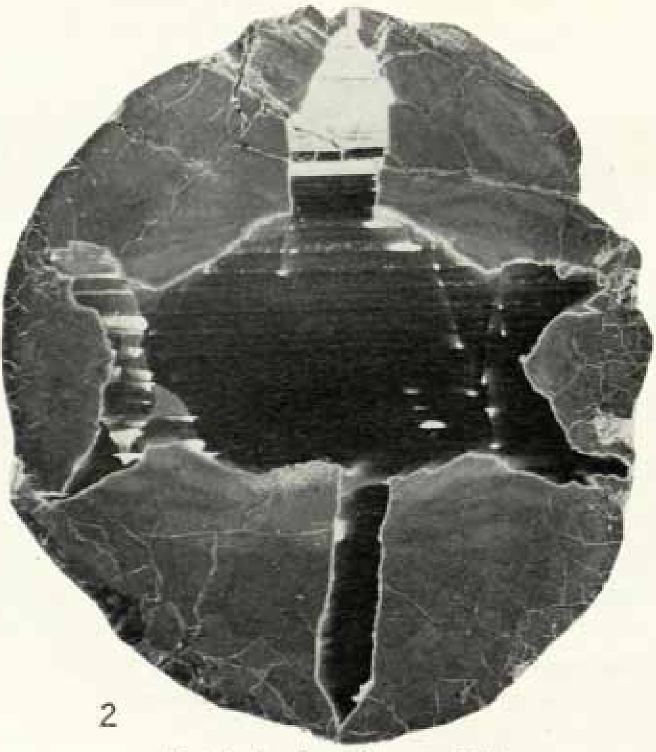

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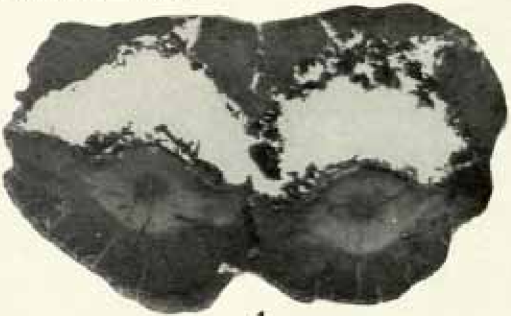

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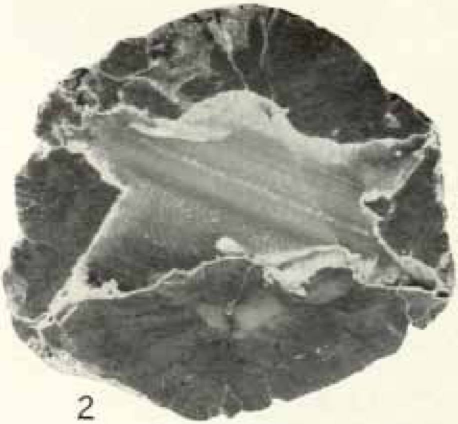

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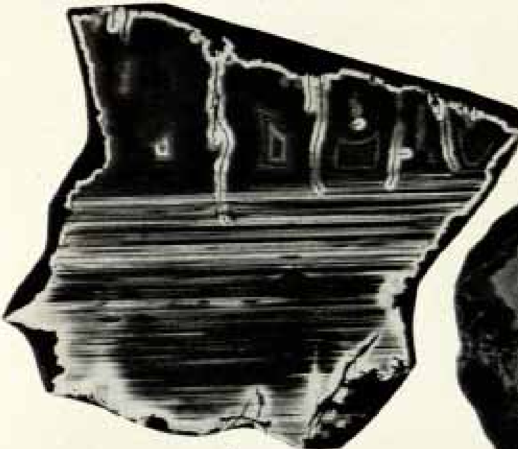
(See Explanation of Plates, p. 339.)



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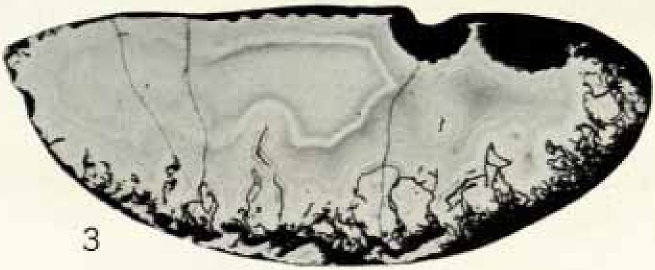

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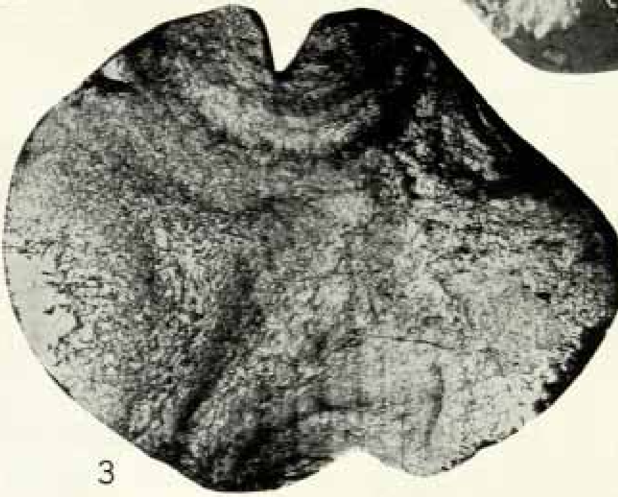

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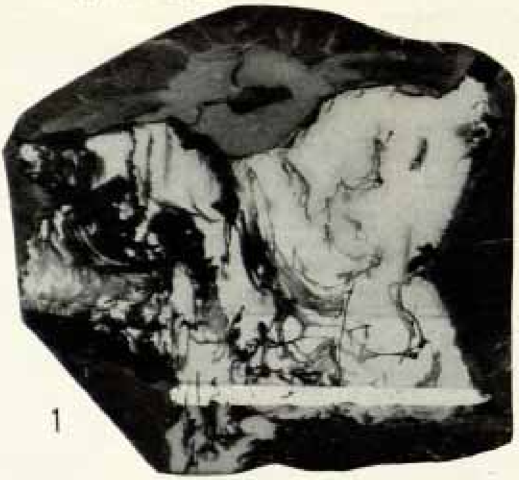

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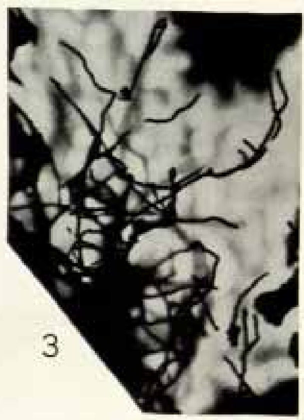

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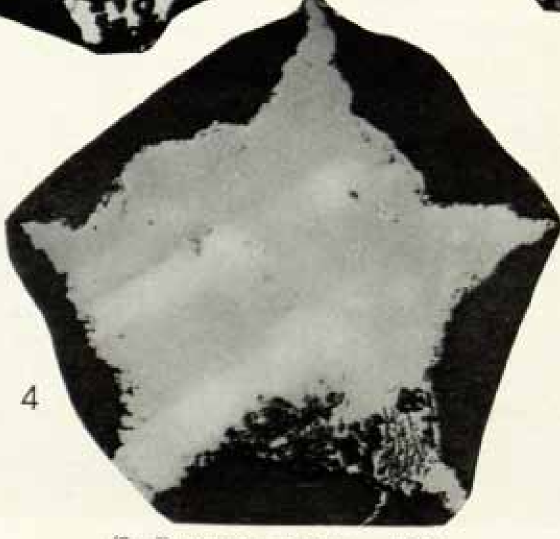

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(See Explanation of Plates, p. 339.)

sion, however, I am frankly unable to explain fully all the chemical details attending their development. As no two specimens are exactly alike, different chemical situations and reactions very likely prevailed at different rates and times. Nevertheless, a generalized picture can be drawn delineating the probable order of events. Consider, for example, the section on plate 4, figure 1, which is similar to Renton's unnumbered figure (1951, p. 175). The photograph was taken by transmitted light, thus making the chocolate-brown outer matrix appear black. Within this is the irregular, squarish figure that outlines a cross section of the original cavity, now filled with chalcedony, horizontally banded below but unbanded above. A number of filaments hang from the upper wall and bound areas of concentric ringed effects, and some arise from the lower wall. Both the upper and lower filaments penetrate the horizontal strata of chalcedony, as do also some shown in plate 6, figure 1, passing through the left end of a thin white band of opal. Further, it should be noted that a narrow, clear (white) zone makes a halo for the filaments and continues around the boundary of the square but is not trespassed by the horizontal strata of the chalcedony. From these particulars it is possible to conclude that in this specimen the sequence of events was roughly as follows: First came the cavity, by one or another of the methods previously enumerated. The cavity was surrounded by a chemically complex matrix that, perhaps when still warm, underwent chemical changes as a concomitant of the circulation of connate as well as surface waters. These waters, having picked up mineral reagents, including salts of iron and manganese, and various silicates, passed through the porous walls or seeped in through cracks, infiltrating and filling the cavity, the solution becoming a colloid or gel. According to gravitational and perhaps electrical factors, such suspended, minute globules of mineral matter as were present or were formed, arranged themselves below in clear and dark stratified, horizontal layers, the upper part of the solution remaining relatively pure and not visibly layered. Then, as soon as the chemical condition of the gel became suitable, there grew into it, from the supply of salts along the walls, the filaments that are now erroneously called algae. These pseudoalgae shot up rapidly in pulses by chemical precipitation (probably as iron hydroxide and silicate), osmosis, and diffusion. During this process, around each filament there was generated a sharply defined field of chemical or electrical influence that not only cleared the immediately surrounding gel but, so to speak, held at arm's length at a fairly uniform distance any suspended globules of mineral matter, thus creating around each filament a transparent halo, the gel outside the halo remaining more or less translucent and, where it contained dark mineral particles, becoming concentrically zoned in the manner of Liesegang rings (Liesegang,

1907). Here, also, the concentricity of the rings was influenced in some way by the presence of the filaments, for the curves of the rings parallel those of the filaments faithfully. It seems clear, therefore, that the filaments originated after and not before the cavity was filled with the gel.

How long the gel in this thunder-egg remained in that state is problematical, but eventually some as yet unknown condition initiated the transformation of the soft gel into cryptocrystalline agate and chalcedony, thus embedding the fragile filaments in a hard matrix and preventing their destruction by earth movements. A binocular microscope reveals that the fibroid crystals of the chalcedony are now arranged radially with respect to the filaments as centers. Apparently not much happened internally to this specimen subsequent to the events just outlined. Externally, it remained a roughly spherical, ridged object in the enclosing tuff until it weathered out as a familiar thunder-egg.

Allowing for variations, the geological story of all thunder-eggs is similar to that just given. Some of the variations need description because they supply, as it were, a supplement to the story. Consider, for example, the section shown in plate 1, figure 1. Here the central white part is solid quartz enclosed by dark chalcedony. In plate 2, figure 1, and plate 3, figure 4, the central parts have unfilled cavities attractively studded with quartz crystals. In these instances probably some change in alkalinity stopped the formation of chalcedony and started the crystallization of quartz, which proceeded until all the remaining silica was used up. This final step may leave a crystal-lined geode filled with water; but there may be no water left because fracturing subsequent to the completion of the geode permitted it to escape. In plate 3, figure 4, the divergent angle between the layers of chalcedony indicates that the rock mass containing the geode was tilted after the first layering ended. In some plume agates, notably those in possession of A. W. Hancock, Portland, Oreg., the plumes occur in a series of conditions from complete burial in chalcedony to perfect exposure in partly filled cavities. From these examples one might get the casual impression that the plumes developed in the manner of helictites in caves and that the silica came in later but did not embed all of the plumes. Such appearances, in my opinion, are deceptive. The more probable likelihood is that the cavities were originally filled with a gel solution and that the plumes grew normally in it but that the gel became too dilute or leaked out before it could be transformed into chalcedony, thus leaving some plumes partially or wholly exposed.

This explanation of the pseudoalgae in thunder-eggs may, in part, also apply to some of the "mosses" in the well-known moss agates. No one, to my knowledge, however, has seriously claimed that these "mosses" represent former living organisms.

As with many other natural phenomena, the attempt to explain origins, although satisfying in general terms, may leave large areas of doubt concerning details. Thus, with reference to the pseudoalgae of thunder-eggs, it is desirable to know more definitely what chemicals, what electrical factors, what temperature and pressure, how much time, and what subsequent changes, if any, are involved in their development. Suitable experiments in a well-equipped laboratory might supply enlightening information.

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EXPLANATION OF PLATES

Plate 1

1. Section of a thunder-egg from 16 miles northwest of Del Norte, Colo. The elliptic, original nucleus lies below the triangle. Inside, a dark rim of chalcedony encloses a white patch of quartz.

2. Perlite from 5 miles south of Buchanan, Oreg., containing a number of thunder-eggs. The original spherulitic nuclei were disrupted and sheared before being filled with chalcedony (white). Collected by French Morgan. Both figures natural size.

Plate 2

1, 2. Thunder-eggs from the Priday (Fulton) ranch near Antelope, Oreg. The angular figures are surrounded by a chocolate-brown matrix. Inside they are opal, chalcedony, and quartz. Natural size. Figure 2 collected by C. H. Robinson, Sr.

Plate 3

1, 2, 3. From the Priday (Fulton) ranch near Antelope, Oreg. 1 and 2 show chalcedony occupying cavities that were eccentric to the spherulitic nuclei (eyes). If the brown matrix were removed from figure 2 the remaining chalcedony would look somewhat like that in figure 3, with a ball on the top side.

4. Geode from 25 miles southwest of Blythe, Calif. The center is studded with quartz crystals. Below, the layers of chalcedony lie at different angles to one another and indicate that the lava enclosing the original cavity was tilted at least twice. All figures natural size.

Plate 4

1, 2. From the Priday (Fulton) ranch near Antelope, Oreg. The photograph of the section shown in figure 1 was taken by transmitted light. Pseudoalgae from above and below penetrate the layered chalcedony. Continuous around the wall and the filaments is a halo of transparent chalcedony (white). Liesegang rings appear between the filaments in the upper part of the figure. Natural size.

3. From Hog Creek, 9 miles northwest of Weiser, Idaho. This section shows that after the pseudoalgae had formed, portions of their substratum loosened and floated in the gel. Natural size. Collected by French Morgan.

4. Righthand part of figure 3, magnified 10 times. The filaments look like small intestines.

Plate 5

1, 2. Filaments and plumes in thunder-eggs from Priday (Fulton) ranch near Antelope, Oreg. Natural size.

3. From a lava flow 17 miles south of Alpine, Tex. Only a color photograph could do justice to this section. It shows an intricate network of minute filaments that developed from several centers as indicated by the arched curves. Natural size. Collected by Frank L. Hess.

4. Lefthand part of figure 3, magnified 10 times. It shows the irregularity in thickness and branching of the pseudoalgae.

Plate 6

1, 3, 4. From the Priday (Fulton) ranch near Antelope, Oreg. Figure 1 shows the pseudoalgae in cobweblike sheets and fringes. Some filaments pass through the lefthand end of the opal (white) band, evidently having grown when the band was still a gel. Figures 1 and 4, natural size; figure 3 magnified 10 times.

2. Locality doubtful, but from the color of the filaments and general appearance of the matrix, apparently Hog Creek, 9 miles northwest of Weiser, Idaho. Natural size.

Exploration for the Remains of Giant Ground Sloths in Panama

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[With 8 plates]

Undoubtedly the giant ground sloths of prehistoric time in the Western Hemisphere had no peer among mammals of great bulk in their grotesque unwieldiness and sluggishness of habit. They rivaled the mammoth and mastodon in body size (pl. 1) but, of course, did not otherwise resemble them, and certainly could not have kept pace in their movements. It would seem impossible that they could have survived and evolved in any reasonably competitive atmosphere or environment. Clearly, the explanation is that together with other edentates—the armadillos, glyptodons, true anteaters, and the somewhat more closely related slow-moving tree sloths of tropical America—they underwent their principal or later development and specialization in South America, isolated from the more highly competitive herbivores and especially the more aggressive predators, such as the wolves, pumas, and saber-tooth cats of the north.

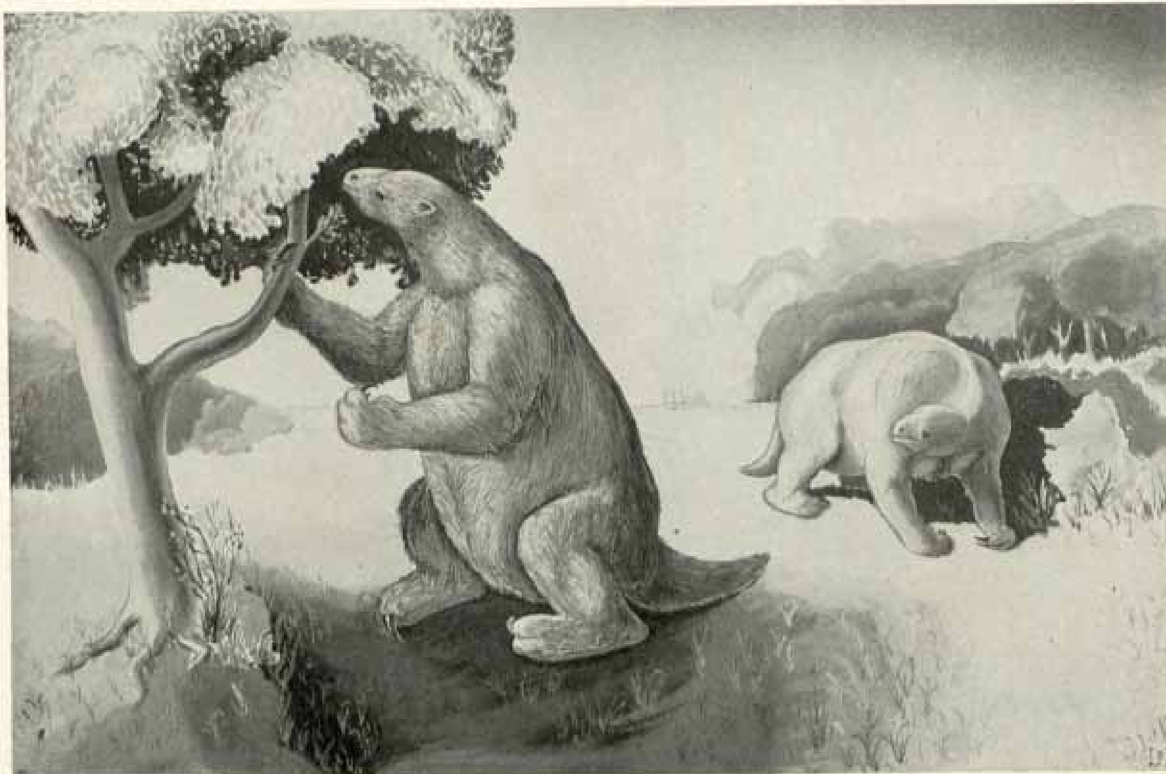
About the beginning of the ice age or Pleistocene time, the northern and southern continents became joined by a land bridge, probably at about the present Isthmus of Panama, or possibly nearer Colombia, permitting rather extensive migrations of land animals. At that time many of the more progressive northern types such as the horse, llama and related cameloids, mastodon, and various carnivores and rodents invaded South America, whereas opossums, porcupines, capybaras, toxodons, and several kinds of edentates, including ground sloths, succeeded in making their way north. Ground sloths, glyptodons with their turtlelike armor, and strange rhinoceroslike toxodons, however, did not survive the Pleistocene. Toxodons did not get north of Central America but certain of the smaller kinds of ground sloths established themselves as far north as Pennsylvania and Idaho. One of these, *Megalonyx*, from a cave in West Virginia, was first described

by Thomas Jefferson. The giant sloth forms, however, as well as the glyptodons came only as far as the southern row of States. Probably the best preserved remains of the giant form found in the United States (now in the National Museum) were encountered over 100 years ago at Skiddaway Island on the coast of Georgia. This animal was named *Megatherium mirabile* by Joseph Leidy, another early paleontologist, often referred to as the father of American vertebrate paleontology.

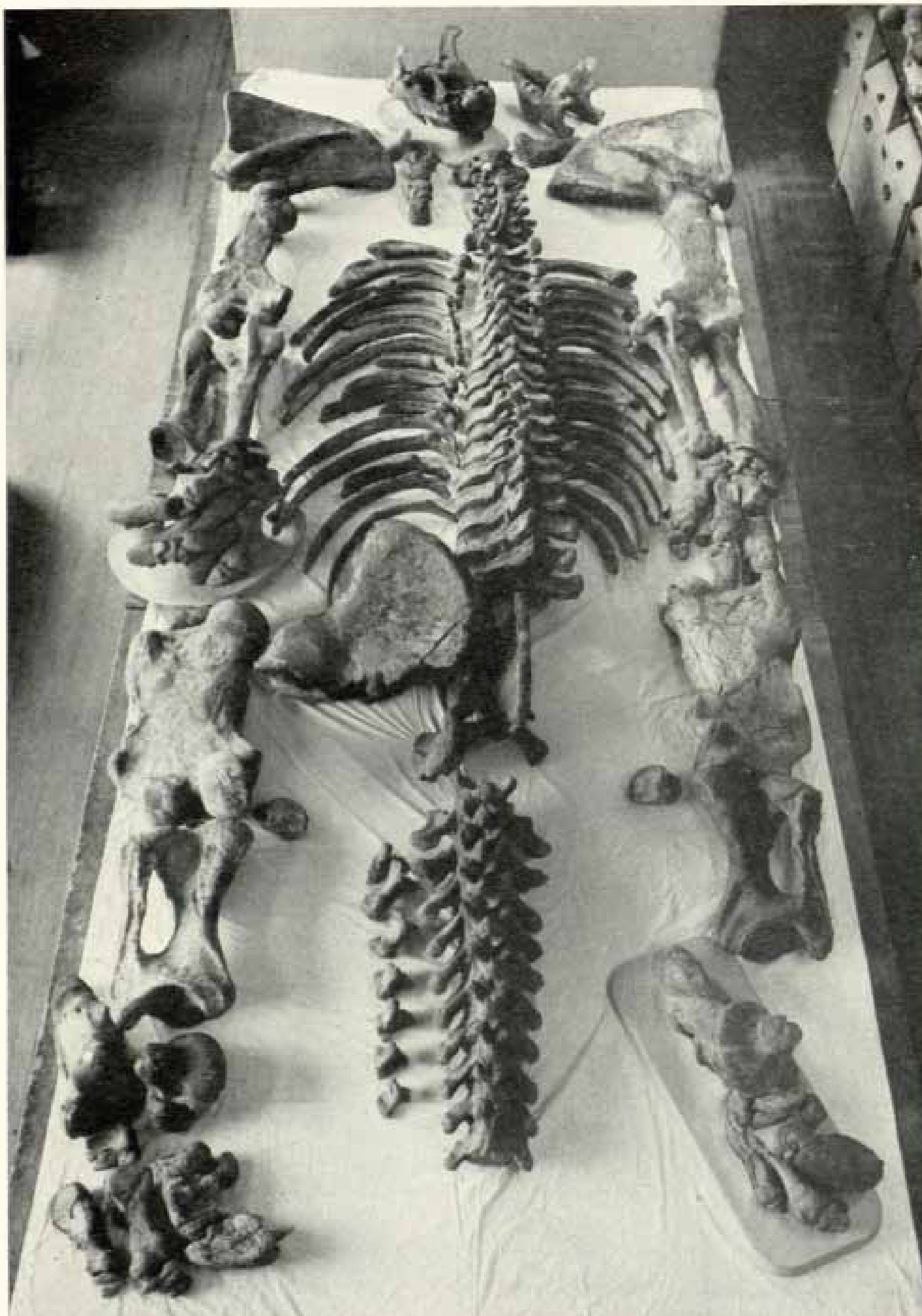
DISCOVERY AND EXPLORATION IN PANAMA

Discovery of remains of the giant ground sloth in Panama, virtually on the land bridge joining the two continents, was evidently made quite independently by various people and at more than one locality. The earliest record with which the Smithsonian Institution was directly associated pertained to the finding of teeth and fragmentary bones at a place called El Hatillo just outside the town of Pesé in the province of Herrera. These were found by an engineer, Caley Johnson, and sent to the National Museum in 1915 by our colleague James Zetek. They were identified by the former assistant curator of vertebrate paleontology, Dr. James W. Gidley, as belonging to the extinct sloth *Megatherium*. I had the good fortune to be shown this locality by Sr. Guillermo Arjona, then (1950) Governor of the province of Herrera, who was involved in the original discovery and recalled as a boy having seen there a number of very large bones. Another fossil site, near but on the opposite side of Pesé, which seems also to have been known for many years by the local people, is on the finca of the local hotelkeeper, Sr. Pablo Aued. Sr. Aued was a little uncertain as to the exact date, but it may have been about 1915, or possibly earlier, that fossil bones were collected on his ranch by a Frenchman (whose name he did not recall). The materials excavated were understood to have been shipped to France.

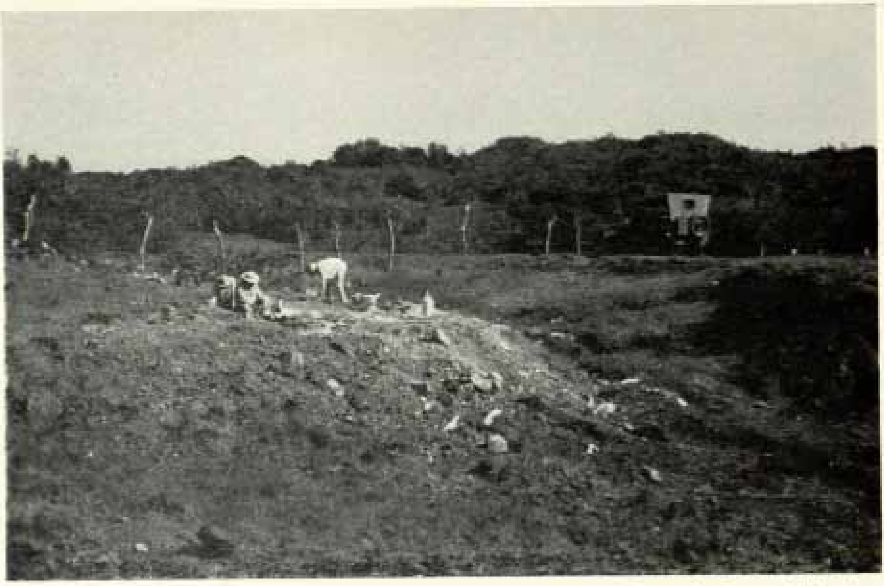
Although the Pesé localities were earlier known, it remained for the people of Ocú to direct full attention to the discovery of "fossil bones of gigantic animals" at La Coca, about 4 miles northwest of Ocú, also in the province of Herrera. Credit for the La Coca discovery has been given Manuel Valdivieso, a "campesino" of the Ocú district who directed several of the townspeople to the occurrence in July 1949. The remains collected at that time, under the enthusiastic leadership of Joaquin Carrizo, manager of the Posada at Ocú, were placed on display at the hotel. The discovery was given considerable publicity in the Panama press and some of the early speculation attributed the remains to dinosaurs. An interesting account of the find, by Dr. Rodrigo Nuñez, was published in the August 1949 issue of the Panamanian magazine *Epocas*.



The giant sloth, *Eremotherium rusconii* (Schaub), of tropical America. Restoration by Lawrence B. Isham from Panamanian materials in the U. S. National Museum. In the posture shown at the left the animal is estimated to be about 12 feet tall. Much of the skeletal anatomy suggests that he frequently assumed an upright or sitting position, propped on his massive tail which formed the third leg of a tripod. Note the very low position of the eyes on the side of the head, two claws on the forefoot and a single claw on the hindfoot. The structure of the feet indicates awkward and by no means rapid locomotion.



Skeleton for the most part of a single, particularly large individual of *Eremotherium rusconii* (Schaub) from El Hatillo, near Pesé in Panama. Although this is an oblique view in which the lengths of limb bones are shown much foreshortened, some conception of size may be gained from the table top which is 20 feet long by 8 feet wide.



1. Northerly view of La Coca occurrence near Ocú. Remains of *Eremotherium* and *Toxodon* were found in the superficial soil and gravel preserved on a small spur of the general terrace level and currently above the spring which may have attracted and mired the animals before the drainage had cut to a lower level.

2. Southerly and closer view of excavation at La Coca. The underside of the partially plastered block of bone and matrix in the foreground has been turned up and is being trimmed before completing the plaster and burlap jacket. Visitors include both local and Canal Zone friends.

1. El Hatillo locality near Pesé. View westerly across muddy flats below spring, shortly after fossil bones had been located in place. Much of the area shown in this photograph had been gone over carefully in the search for the source of bone fragments earlier reported.

2. A northerly view across El Hatillo site as the 1951 excavation progressed toward the spring from the north. Center of spring area is located in swampy ground around bush in center foreground. Later excavating to the right and above spring demonstrated the further occurrence of bone, but of much poorer quality than that encountered below and to the left.

1. Pearce (left) has shown one of the natives, Marteo, the technique of coating all exposed bone surface with tissue paper and an aqueous solution of gum acacia before the plaster of paris jacket is applied. The gum acacia hardens the surface and the paper prevents the plaster from adhering too securely to the bone so that it can later be removed.

2. Pearce here is demonstrating to two of our helpers the procedure involved in bandaging a block of bone and matrix with burlap strips which have been dipped in plaster of paris. After the top coat has set, the block is cut loose, turned over, trimmed down, and the bottom surface plastered.

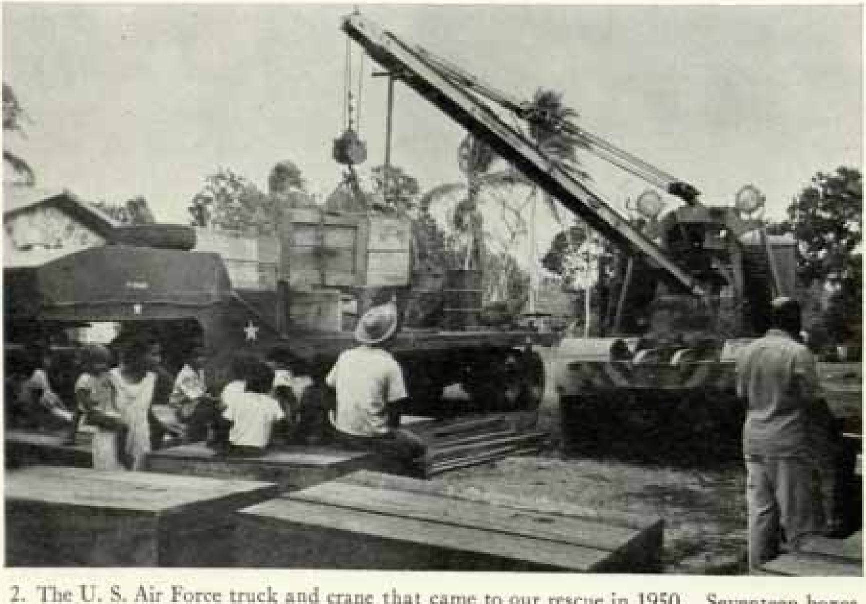
1. Blocks in various stages of removal at the El Hatillo excavation. These include the pelvis and two blocks of vertebrae and ribs belonging to the skeleton of the large individual of *Eremotherium* shown in plate 1. Dr. White (left) is undercutting the pelvis so the plaster jacket will bind while Juan Franco is coating exposed bone with paper. Viviano Valdevieso is further undercutting the third block so that it can be turned over.

2. At another place in the El Hatillo excavation a block containing a scapula and some limb and rib material of the sloth is being turned over and removed from the quarry permitting the bottom surface to be trimmed and plastered under less cramped conditions. Several other partially defined blocks of bone-bearing matrix can be distinguished in background.

1. The wall of the excavation as it neared the spring in 1951. Seepage at this point was particularly annoying. The bone layer in this vicinity was approximately 7 feet beneath the surface and resting on a slightly more consolidated bedrock of decomposed volcanic material that, in contrast to the overlying mud, appeared to be undisturbed.

2. Our native crew at the close of the 1951 season. Most, though not all, of these were the men we started with. They are standing over a part of the excavation after it had been filled and the ground leveled so as to prevent the accumulation of stagnant water, important in mosquito control.

1. The 1951 collection from El Hatillo beside the schoolhouse at Pesé, boxed and waiting arrival of the truck and crane for transportation to Pier 18 at Balboa.



2. The U. S. Air Force truck and crane that came to our rescue in 1950. Seventeen boxes were built and packed behind the Posada de San Sebastian at Ocú and the combined La Coca and El Hatillo collections of that year weighed over 6 tons.

The attention of Dr. Alexander Wetmore, at that time Secretary of the Smithsonian Institution, was directed to the Ocú discovery by several of our friends in the Canal Zone, apparently first by Kenneth W. Vinton, a science teacher at the Junior College. A preliminary investigation of the occurrence was made for the Smithsonian Institution by Assistant Secretary John E. Graf, and arrangements were made with the Panamanian Government, through the kind offices of Dr. Alejandro Mendez, Director of the National Museum of Panama, and Prof. Max Arosemena, then Minister of Education for the Republic of Panama, for a Smithsonian party to carry on excavation work at this site. We are particularly indebted to Dr. Mendez for his very helpful cooperation and kindly personal interest, as well as the never-failing enthusiasm which he showed for the progress and results of our work during the two field seasons.

Dr. T. E. White of the Smithsonian's River Basin Surveys accompanied me on the first expedition to Panama, and we arrived there early in January 1950. We were given a most royal welcome at the Posada in Ocú and every effort was made by the townspeople to facilitate our work and make our stay as pleasant as possible. The actual digging began at La Coca on January 19, but as the occurrence was not of great extent, by February 3 we had it completely worked out (pl. 3). During this time, we were assisted by the discoverer, Manuel Valdivieso, or from time to time by his brother Viviano, and by Juan Franco, a campesino who learned the work quickly and proved particularly helpful to us. Altogether we removed 36 blocks of material from La Coca, each securely encased in a jacket of plaster of paris reinforced with burlap. Through the kindness of "Chin" Carrizo, we were permitted to store our collection, as it accumulated, in a storeroom at the Posada in Ocú. Following the La Coca work we turned our attention for a couple of weeks to various reports of other places where fossil bones were supposed to have been seen, but most of these proved to be rumors without foundation in fact. Nevertheless, one promising lead remained, and about the middle of February, by arrangements made sometime earlier during one of the fiestas in Ocú, we were accompanied to the El Hatillo locality about a mile west of Pesé, as mentioned above, by the Governor of the province, Sr. Guillermo Arjona.

Some difficulty was encountered at first in locating fossil remains; however, after extensive probing with picks and shovels (pl. 4, fig. 1) the source of the material was located at the periphery of a mud deposit in the vicinity of a large and swampy spring. The bones were found to occur at the bottom of the mud near contact with the underlying bedrock, close to the surface at the periphery but increasing in depth toward the spring. Excavation was carried on at El Hatillo with the

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help of six campesinos, two of these being our Ocueño helpers, Juan Franco and Viviano Valdivieso, brought with us to show the new men the various techniques and procedures they had been taught.

Eighty-five plaster-encased blocks were taken up at the new locality (pl. 6), the relative position in which each occurred having been carefully plotted so that the significance of association might be worked out later in segregating the materials by individuals as far as possible. By the first of April there seemed no likelihood of completely exhausting the occurrence before the beginning of the rainy season, so work was discontinued with the expectation of returning the following year. The collection that had been accumulating in one of the rooms of the alcaldia in Pesé was hauled by truck to Ocú where the combined collections were boxed for shipment. Much appreciated help was obtained from the U. S. Air Force as General Beam of the Caribbean Air Command came to our aid, furnishing a truck and crane (pl. 8, fig. 2) to get our 6-ton collection transported to the docks at Cristobal.

Most of the La Coca collection was prepared and restored in Washington, D. C., during the following year, so that at the time of our return to Panama in 1951 we were able to ship back the better part of the sloth material from that locality for exhibition in Panama's museum. With regard to materials that we hoped to exhibit in the U. S. National Museum it was our plan to select from the more extensive El Hatillo collection the best association of materials believed to represent a single individual, adding to this skeletal elements of comparable size from the same locality, completing, for purposes of a free mount, what is known as a composite skeleton. It was to assure ourselves of an adequate representation of the material for this purpose that we returned to Pesé in 1951.

During the second season's work, which lasted from near the end of January to the latter part of March, I was assisted by Franklin L. Pearce, now chief of our laboratory of vertebrate paleontology. With the help of six of the local campesinos (pl. 7, fig. 2), some of whom worked for us the previous year, we drained the small lake which had formed at the old pit at El Hatillo, and by starting new excavations at various places in the vicinity of the spring we were able to determine approximately the extent of the bone deposit. Working in from the northerly margin (pl. 4, fig. 2) toward the old excavation we systematically covered most of the profitable ground and recovered most, if not all, of the worthwhile remaining fossil materials. Additional fossil bones were detected in the mud deposit somewhat higher and to the east of the spring, but these were found for some reason to be much more poorly preserved and not worth taking up, a condition rather similar to that noted for the material observed at Finca Aued.

Our second season at El Hatillo was made particularly difficult by the continuous battle against water seeping from the spring. Evidently the dry season, which lasts from January to about April or May, was this year preceded by more rainfall than the year before. The situation greatly jeopardized our use of plaster of paris, but by diligent bailing it was possible to keep the partially prepared blocks of bone and matrix free of excess water sufficiently long for the plaster of paris and burlap bandages to set (pl. 7, fig. 1). The collection which included over 100 plaster-encased blocks, filled 13 large boxes and was found to have an aggregate weight of about 3½ tons. Again with the help of the U. S. Air Force, our collection (pl. 8, fig. 1) was transported to the pier at Balboa.

The success of our second expedition may be measured by the fact that the additional materials obtained made it possible to select two composite skeletons, based largely on the remains of single individuals, representing mature animals rather near the upper (pl. 2) and lower limits of size. There still remained a rather impressive surplus of skeletal material which has been restored and returned to Panama to join the Ocú collection in the museum at Panamá City.

TAXONOMIC HISTORY

There would seem to be little or no doubt but that the correct name for the giant Panamanian sloth is *Eremotherium rusconii.* The taxonomic history of this form is rather involved and makes an interesting story in itself. The species was first described by the Swiss paleontologist Schaub in 1935 from the province of Lara in Venezuela. He referred it to Cuvier's (1796) genus *Megatherium*, so well known in the Pleistocene of Argentina, but questioned the possibility of its representing *Paramegatherium* as a subgenus. Without reference to Schaub's work on the Venezuelan material, Spillmann in 1948 described a skull and other material from Pleistocene deposits on the peninsula of Santa Elena in Ecuador as the new genus and species *Eremotherium carolinense.* Shortly afterward (1949), but evidently without knowledge of Spillmann's publication,[1] Hoffstetter, working in Ecuador, described additional material from the Santa Elena peninsula which he referred to Schaub's species *M. rusconii*, but gave it the new generic name *Schaubia.* At the same time he described somewhat smaller material as the new species *Schaubia elenense.* Discovering later that the term *Schaubia* was preoccupied for a genus in the cat family, he substituted (1950) the name *Schaubitherium.* Following

[1] Spillmann's paper, published in Vienna, though bearing the date 1948 on the cover is described in a preface as ready for printing in 1945 but held up owing to war conditions. However, it was not received in the library of the U. S. Geological Survey until 1951; hence some question might arise as to the actual date of publication.

eventual distribution of Spillmann's paper, Hoffstetter, in his memoir on the Pleistocene mammals of Ecuador published by the Geological Society of France in 1952, revised his allocation of the megatherid sloths to *Eremotherium carolinense* Spillmann and *Eremotherium elenensis* (Hoffstetter). He regarded the larger of the two, *E. carolinense*, as distinct from Venezuelan *E. rusconii* essentially on the basis of geographic separation.

In the meantime de Paula Couto in Brazil called attention in a note published in Hoffstetter's 1949 paper to the possibility of "*M.*" *rusconii* being a synonym of *M. laurillardii*, a species also having had a complex and confused history, originally described by the Danish paleontologist Lund in 1842 from caves in Minas Geraes, Brazil. Nevertheless, as indicated by Hoffstetter, the type specimen described by Lund consists of two small teeth, scarcely larger than tapir molars, which are evidently immature and clearly inadequate for diagnostic purposes, hence should probably be ignored or the name *M. laurillardii* be left as a synonym of *M. americanum* as treated by Winge. In 1954 de Paula Couto retained both Spillmann's and Hoffstetter's species, as well as Schaub's, and named a new subgenus and species, *E. pseuderemotherium lundi*, on the basis of a composite skeleton from the state of Bahia. I suspect that a single tropical species is represented, as suggested by the Panamanian materials; on the other hand, de Paula Couto's allocation of Leidy's *Megatherium mirabile* from Georgia to *Eremotherium* seems valid and the species may well be different. In this case the Georgian species name would be much the oldest pertaining to *Eremotherium*.

FAUNAL ASSOCIATION AND RELATIVE AGE OF OCCURRENCES

Although representation of the faunas associated with *Eremotherium* at the two principal localities is very sparse, the evidence suggests that the two assemblages were not the same, and may not have been entirely contemporary.

At La Coca, near Ocú, representation of two or possibly three individuals of *Eremotherium* was associated with the rather scant limb and certain other fragmental materials of two individuals of *Toxodon*, the large rhinolike notoungulate characteristic of the Pleistocene of South America. No other forms were represented at this excavation.

The El Hatillo excavation near Pesé, on the other hand, uncovered portions of certainly no less than eight, and probably more than a dozen, individuals of the gigantic *Eremotherium*, including five comparatively good skulls, but with these there was no trace of *Toxodon*. However, there were found associated skeletal portions of a single individual of the mastodon *Cuvieronius*, characterized by tusks having enamel developed in a spiral form. Further representation of the

assemblage, the balance of the collection, is a rather insignificant quantity of material contained in a single collection drawer and consisting of isolated teeth, portions of jaws and other determinable bone fragments. The El Hatillo fauna and the material representing it may be listed as follows:

Pseudemys, sp.—turtle carapace fragments.

Cairina moschata (Linnaeus)—muscovy duck; distal end of ulna.

Eremotherium rusconii (Schaub)—giant megatheriid ground sloth; the great bulk of the collection, although a part of this material may represent a somewhat smaller species described by Hoffstetter as *Eremotherium elenense*, if this can be regarded as distinct.

Cf. *Glossotherium tropicorum* Hoffstetter—broad-snouted mylodont sloth; a lower jaw portion with the greater part of three teeth.

Scelidotherium?, sp.—a long-snouted mylodont sloth; two cheek teeth.

Hoplophorid?, possibly *Lomaphorus*, sp.—a glyplodont sloth; a single hexagonal scute.

Glyptodon, sp.—a large edentate with a turtlelike carapace; two caudal vertebrae and several scutes with typical rosette pattern.

Neochoerus cf. *robustus* (Leidy)—giant capybara; a maxillary portion, fragments of a cheek tooth, and a segment of an incisor.

Cuvieronius, probably *C. hyodon* (Fischer) (=*M. andium* Cuvier)—the South American mastodon; several portions of one individual including two badly worn last molars and sections of the tusks.

Equus, sp.—horse, possibly belonging to subgenus *Amerhippus;* three isolated upper cheek teeth, an incisor, and a toe bone.

Tayassuid, gen. indet.—peccary; canine tooth.

Odocoileus, sp.—deer; small horn.

The El Hatillo assemblage corresponds rather closely to the Carolinian upper Pleistocene fauna described by Hoffstetter from the Santa Elena peninsula in Ecuador. The Santa Elena fauna is better known in number and kinds of animals represented, as well as by the quality of the remains encountered in all but the giant sloth. The representation of *Eremotherium* is in no way comparable to the magnificant series of specimens obtained at El Hatillo. A similarity in the faunas exists also in the absence of any representation of the peculiar ungulate types, such as the toxodonts, which were so characteristic of earlier stages of the Age of Mammals in South America.

The dearth of forms encountered at La Coca, on the other hand, with only *Eremotherium* and *Toxodon* represented, is very like that at El Totumo in Venezuela where Schaub reported only *Megatherium* (this is *Eremotherium*), *Stegomastodon*, and *Toxodon*. I strongly suspect that the La Coca and El Totumo occurrences are a little earlier than those at El Hatillo and Santa Elena, although the evidence is not positive, and that *Toxodon* became extinct between the times represented.

The relatively greater age for the La Coca occurrence in comparison with that at El Hatillo would seem further indicated by the physio-

graphic relations. At La Coca the remains were preserved on the upper surface of a low terrace (pl. 3). The materials were here found weathering out of the thin superficial remnant of mud and gravel, and the spring associated with this occurrence and possibly related to the entrapment is now flowing out from the steeper slopes below the terrace top. This suggests that the shallow ravine below the terrace has been cut since the fossil accumulation was formed. At El Hatillo the picture has a more recent look in that probably there has been less change in the physiography since accumulation of the fossils. Although the surface has a fair slope, the site (pl. 4) is currently a bog and the bones were found near the surface at the periphery of the mud deposit associated with the spring, up to depths of around 7 feet (pl. 7, fig. 1) toward the center of the area where flow of water was greatest. It is of further interest to note that although boggy conditions prevail at the present time, no remains of domestic animals were found, such as dogs, oxen, pigs, and poultry—somewhat surprising considering that the immediate area apparently has been well settled for nearly 400 years.

DESCRIPTION OF THE GIANT SLOTH EREMOTHERIUM

Like *Megatherium*, *Eremotherium* is truly a ground sloth of tremendous bulk. It may be compared in size with a mammoth or mastodon but with, of course, rather striking differences in form and relative proportions. The length of the animal's body, for example, was much greater than that of the American mastodon, with a very much smaller head, a longer neck, and a long and massive tail. The length of the vertebral column in a particularly large individual measured over 16 feet (pl. 2). The hindquarters were particularly robust. This is shown in the striking increase in the size of the vetebrae from the neck back to the sacrum, and the hindlimbs, though a little shorter than in an average-size mastodon, were of much greater width. The femur, for example, while nearly a yard in length, is a few inches shorter than in the mastodon with which comparisons were made, but is 19 inches across the distal portion—more than twice that in the mastodon. The comparable parts of the forelimb of the sloth are a little longer than those of the hindlimb but relatively slender by comparison.

The skull of *Eremotherium* is about 2 feet long with a comparatively slender snout and rather fantastic processes or bony projections on the arches (fig. 1). The animal had no tusks, but there are five long crowned teeth above and four below, averaging about an inch and a half in diameter. The teeth are of a grinding type with two transverse wedgelike crests on each.

As in other ground sloths the feet of *Eremotherium* possessed long powerful claws (figs. 2–6 and pl. 1). In locomotion the forefoot car-

ried its weight on the "knuckles" with the distal extremities of the metacarpals resting on the ground and the palm and the claws turned inward (see figure at right, pl. 1). The hindfoot was turned so that in locomotion the weight was carried along the outer side of the foot with the plantar surface and claw of each likewise turned inward (see figure at left, pl. 1). The length of the hindfoot from the bony core of the claw to the heel in one animal measured 36 inches (figs. 4 and 5), possibly the greatest for any kind of land animal.

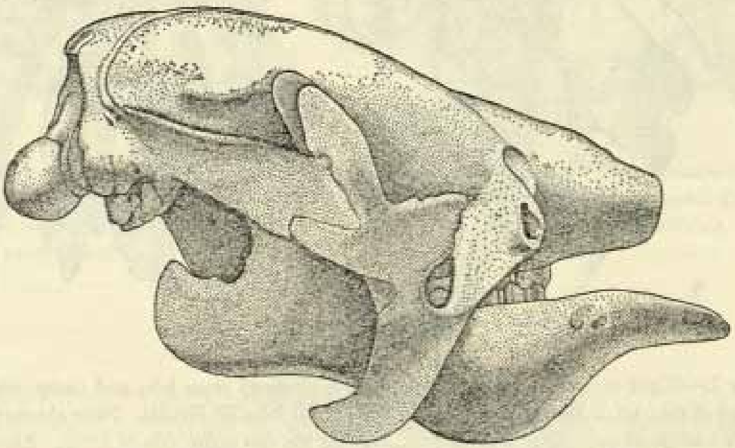

FIGURE 1.—Skull (U.S.N.M. No. 20872) associated with large skeleton of *Eremotherium rusconii* (Schaub) from El Hatillo shown in plate 2, and lower jaws of skull returned to Panama. Note fantastic projections of the zygomatic arch and extremely low position of orbital rim indicating location of eye about on level with teeth. About 1/6 natural size.

Detailed comparison of the skeletal remains of *Eremotherium* with those of the earlier known *Megatherium* of Argentina has brought out several features that indicate clearly that *Eremotherium* is a distinct genus, characteristic, as noted by Hoffstetter, of the more tropical regions of the Americas. In comparing the skulls one notes that the palate and lower jaws did not extend so far forward from the position of the teeth and that the eyes or orbital margins were noticeably lower than in *Megatherium*, about on a level with the grinding surface of the upper teeth (fig. 1). Also the lower jaws, though deep beneath the teeth, were not nearly so much so as in *Megatherium* and the longitudinal profile of the lower margin was not nearly so convex downward. A more detailed comparison of the skulls has been made by Hoffstetter, and certain characteristics of the appendicular skeleton were noted by him, such as the form of the femur. To this may be added that the articulating surface on the head of the femur, for the acetabulum or hip socket, faces more proximally with a more pronounced saddle between the head and greater trochanter. Moreover, Owen's (1860, pl. 38) illustration of the femur of *Megatherium* shows

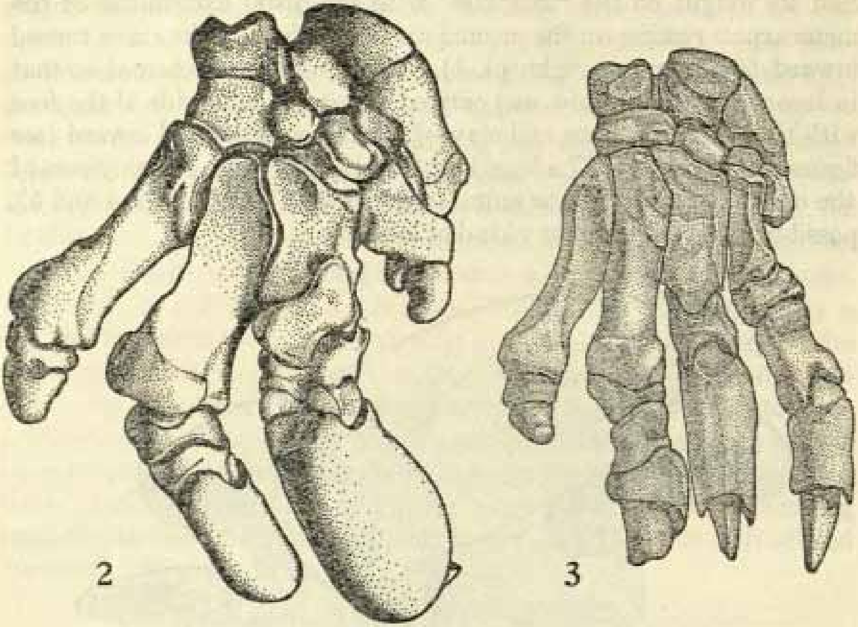

FIGURE 2.—Right forefoot (U.S.N.M. No. 20872, reversed from left, and composite only in part of carpus) of *Eremotherium rusconii* (Schaub) from El Hatillo. Note absence of all but a vestige of second, as well as first, digit or toe (on right side of foot). About 1/8 natural size.

FIGURE 3.—Right forefoot of *Megatherium americanum* Blumenbach (after Richard Owen) from Argentina. Note presence of complete and well-developed second digit or toe (on right side of foot). Only the first digit is vestigial. Slightly less than 1/8 natural size.

a better defined digital or trochanteric fossa, or a less deflected greater trochanter as noted by Hoffstetter.

Probably the most significant difference that distinguishes *Eremotherium* from *Megatherium* lies in the structure of the manus or forefoot, not previously noted because of the incompleteness of earlier described materials of *Eremotherium*. In *Megatherium* the forefoot has four toes or digits (fig. 3). The second, like the third and fourth, is equipped with a well-developed claw, as shown in Owen's illustrations. Moreover, the first and second phalanges of this toe are separate as in the fourth digit, not co-ossified as in the third. The pollex or "thumb," though, is represented by but a "nubbin" of a bone, a much-reduced first metacarpal. *Eremotherium*, however, has only three fully developed digits (fig. 2). The wrist bone, known as the trapezoid, normally adjacent to the proximal end of the second metacarpal, is apparently fused in *Eremotherium* with both the first and second metacarpals, and the second digit is otherwise represented by only a small vestige of a bone, probably the first phalanx, as indicated by a small facet on the distal surface of the fused elements.

Since the fifth digit, which is invariably next to the ground, lacks a claw in both genera, *Eremotherium* has but two claws on the front foot, a distinction rather paralleling that between the living two- and three-toed tree sloths of Central America.

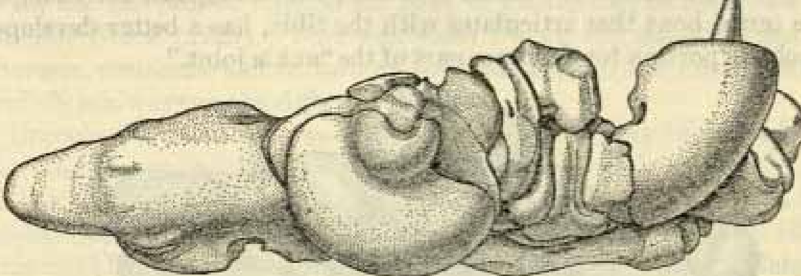

FIGURE 4.—Right hindfoot (U.S.N.M. No. 20872, partially composite among smaller tarsals, and phalanges of fourth and fifth digits restored) of *Eremotherium rusconii* (Schaub) from El Hatillo. Proximal or inner margin of foot which turns upward in walking. About 1/9 natural size.

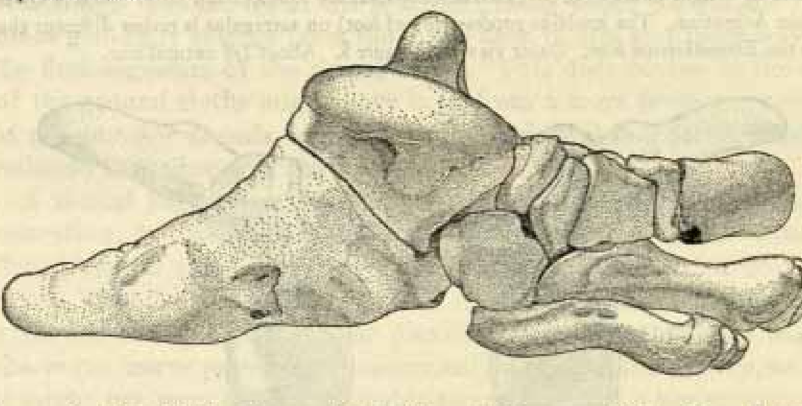

FIGURE 5.—Right hindfoot (same as fig. 4) of *Eremotherium rusconii* Schaub from El Hatillo. Outer view of foot (approximately the dorsal surface of the normal mammalian foot). Note that the hindfoot had only three toes remaining, the third to the fifth digits, and only the upper or third had a claw. About 1/9 natural size.

In contrast to the reduction in toes from the normal mammalian number, a specialization regarded as advanced in character, the *Eremotherium* forefoot is primitive in another respect. In certain instances it was noted that the centrale, a small bone near the center of the wrist, was distinct and not fused with one of the adjacent carpal elements. In *Megatherium* this element has apparently not been observed separate; evidently it early fused with the adjacent unciform. Separation of this element, however, is not invariable in *Eremotherium*.

The hindfoot of *Eremotherium* (figs. 4 and 5) is less distinctive in comparison with *Megatherium* (fig. 6). As in this genus it had but

three toes, the third to the fifth of the normal mammalian foot. Only one of these, the inner or digit III, possessed a claw. Of the lost toes only a mesocuneiform, one of the inner ankle or tarsal bones, remains. Differences from *Megatherium* would appear to lie possibly in the shape of certain of the tarsal elements; the astragalus, for example, the tarsal bone that articulates with the tibia, has a better developed knoblike portion for the inner part of the "ankle joint."

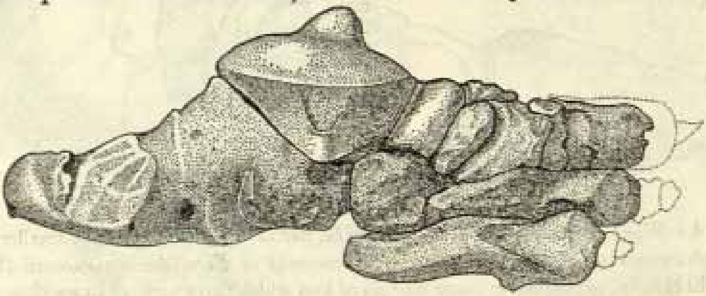

FIGURE 6.—Right hindfoot of *Megatherium americanum* Blumenbach (after Richard Owen) from Argentina. The knoblike process (top of foot) on astragalus is rather different than in the *Eremotherium* foot. Outer view as in figure 5. About 1/8 natural size.

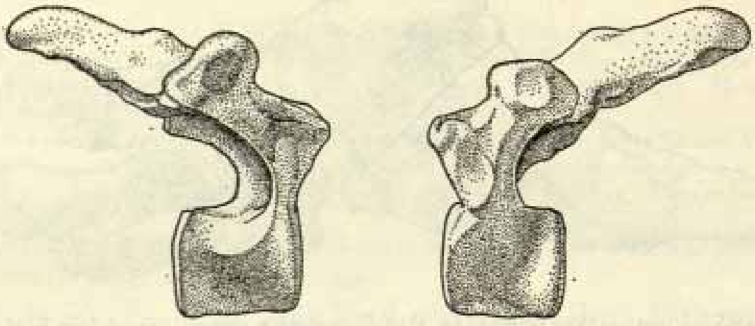

FIGURE 7.—Right (figure on left) and left sides of an anterior dorsal vertebra of *Eremotherium*, showing a remarkable lack of symmetry or difference in development. On the right side of the vertebra (figure on left) the pedicle or support for the arch and spine is strikingly slender, and the upper surface of the centrum below is much more deeply excavated. About 1/6 natural size.

An additional feature, comment on which has not been noted elsewhere for this animal, relates to the lack of symmetry observed in dorsal vertebrae from the third or fourth to about the sixth. In these, the right neuropophysis or pedicle of the neural arch is much more slender than the left (fig. 7) so that there is a much greater opening on the right side between the arches of adjacent vertebrae. Also the top surface of the centrum is noticeably excavated on the right, as though the thoracic nerve on this side were much larger than on the left, or than normal, as it separated from the spinal nerve and passed out between the adjacent vertebral arches.

These vertebrae are normally symmetrical in mammals and there is no mention by Richard Owen of such a condition though probably present, in dorsal vertebrae of *Megatherium*. A single reference to a similar condition was found in the case of the mylodont sloth remains from the tar pits at Rancho La Brea in California, as described by Chester Stock (1925). This was noted for all the second dorsal or thoracic vertebrae and certain of the third; again the more slender pedicle is always on the right.

Speculation as to the cause of this asymmetry may be offered but there is no certainty that any of the suggestions made are a solution to the mystery. The nerves and blood vessels passing between the arches in these positions should be equally developed on the two sides. One might be tempted to speculate on a rather pronounced unilateral development of a certain group of muscles. The nerves emerging from the spinal cord in this region, however, are for the most part related to the back muscles, skin, and certain of the muscles that function in breathing. The nerves of the brachial plexus which control the forelimbs generally emerge from the lower neck region and from between the first segments of the dorsal series. This distribution in the case of the ground sloths might have been from a more posterior portion of the anterior dorsals, but such an implied "righthandedness" is not reflected in the bones of the forearm.

A second suggestion, which probably does not merit serious consideration, is that the branches of the spinal nerve in the anterior dorsal region communicating with the sympathetic trunk or nerve might have been strongly involved in an asymmetric arrangement with, for example, the cardiac plexus. The sympathetic, as well as the vagus, nerve patterns are notoriously lacking in symmetry, so that it might not seem too unreasonable to suppose that a nonsymmetrical tie-in with the spinal nerve could have developed in ground sloths.

As a remaining possibility, in contrast to the foregoing, one might postulate suppression, through some means, of the proper functioning of the nerves on the left side of the column. This would presumably call for compensation through overdevelopment of those on the right. Seeking a direct mechanical cause for possible suppression of nerves on the left one cannot fail to note the proximity of the aorta artery to the left of the vertebral centra. The segments of the vertebral column involved correspond closely to the probable position of the upper portion of the *aorta descendens* very near the arch of the aorta. This in itself is not peculiar to sloths, but the rather tremendous body bulk, coupled with the assumption of an upright posture much of the time, lends credence to the suggestion that the pressure of the undoubtedly large aorta could have been responsible. Further pressure on the thoracic cavity transmitted to the left side of the vertebral

column by the aorta would come from use of the pectoral muscles in reaching out and pulling toward him the foliage of trees composing his diet, while propped in a relatively erect position by his massive tail.

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The Kitimat Story[1]

By Angela Croome
London, England

[With 4 plates]

One hundred and fifty-seven years ago, at the opening of the nineteenth century, aluminum was unknown. In the 1850's a table service that Napoleon III had made of aluminum cost more than the price of an identical one in gold. Yet today the only metal of which there is an annual consumption larger than aluminum is steel. Its price naturally reflects its changed status.

The key to this spectacular expansion was the discovery of a means of cheap production. The ore from which the metal is obtained is not rare—indeed it represents one-eighth of the globe's crust—but releasing the metal from the raw material (bauxite) proved technologically so subtle that this fact alone preserved until 1886 the price of aluminum at the level of the precious metals. The result of the success of Charles Marlin Hall, of Oberlin, and Paul Louis Herolt, of Paris, in reducing aluminum oxide by an electrolytic process promptly cut the price by one-fourth. Nevertheless to exploit this discovery fully, and to produce aluminum in huge quantities at the lowest possible cost, required the bringing into conjunction of features not readily found together in nature, namely, the sources of bauxite, massive electric power, and first-class transport facilities.

The impulse and grand-scale planning of war helped to fuse these elements into the reality of actual development projects. The last war used up most of the aluminum that could be put on the market. The years of cold war since, combined with a period of intensive reconstruction and industrial expansion as well as increased civilian need, have maintained the demand well ahead of supply. But these conditions have quickened engineering imagination, brought into focus parts of the world that have never been thought of together before, and provided the colossal capital sums needed to put through development schemes of the grandest sweep.

[1] Reprinted by permission from Discovery, vol. 17, No. 4, April 1956.

Britain is currently using 252,000 short tons of aluminum per year on new aircraft, new buildings, new electrical installations, and on other work. To supply Britain and other countries of the free world, the wilderness of a forbidding corner of northwestern Canada has been tamed and harnessed in 40 months. A city of 13,000 has risen where formerly only a few Indians wandered in summer months, and to Canadian shores come ships with alumina, the mining and processing of which in Jamaica bring new employment to West Indians half the world away.

The production of 1 pound of aluminum ingot requires 10 kilowatt-hours of electricity. The electrical power consumed in producing a ton of aluminum, it has been estimated, would meet the demands of a normal household for 10 years.

Massive untapped reserves of electricity are nowadays rare. Within the Commonwealth they are to be found in the few large areas remaining undeveloped, such as the province of British Columbia in Canada, and in British Africa. Surveys had been made of the Tahtsa Lake area of British Columbia, once, twice, three times, between 1874 and 1950. The acute world demand for aluminum made the possibilities which these surveys revealed economically workable.

In 1948 the Aluminum Company of Canada started negotiations with the provincial authorities of British Columbia, and funds were raised for the initial capital outlay of a scheme which is expected, ultimately, to cost in excess of £200 million. This colossal development job was now "on." Kitimat found itself on the map.

THE PLAN

"Kitimat" is shorthand for the whole development project. This comprises five distinct engineering schemes and is flung across an area more than 200 miles long. The name actually derives from the site chosen for the smelter at the head of the Douglas Channel, a navigable inlet running 80 miles up from the northern Pacific.

The unusual topography of this coast range of mountains has provided the opportunity which the planners of Alcan [2] have so boldly seized. The crest of the range is only a few miles from the sea. Moreover, owing to heavy glacial action during the Ice Age (when the whole of British Columbia, save the highest mountain peaks, was iced over), long, deep, narrow valleys were scoured out on both sides of the crest. The sea flowed into the westerly valleys to form long fjords; the fjordheads (at sea level), lying within a mile or two of the high peaks of the mountain barrier. The valleys on the eastward side descend more gently, but the heads of the lakes approach equally close to the crest of the mountain range. The westerly point of Tahtsa

[2] Alcan is the term by which the Aluminum Company of Canada is best known.

Lake, at the end of a 150-mile lake chain, is only some 15 miles from sea level (Kemano) on the other side of the mountains.

The engineers' plan had a magnificent simplicity. The outflow of the system of lakes would be stopped at the eastern end. Then, when the narrow boat-shaped vessel of water thus formed was full enough it would be forced back over its opposite "lip," *through* the mountains to the seaward side. Here, the fall of water would be turned into power. Then the electric power in turn would be transmitted to Kitimat itself, some 50 miles away at the head of a navigable channel where the Jamaican oxide could arrive in ships. The power would be used to make aluminum at Kitimat and this would then leave for the markets of the world by water through the same sea channel. Eight hundred and seventy-three billion cubic feet of water would thus be turned into 550,000 tons of aluminum each year.

The successful execution of four unconventional construction jobs was fundamental to the whole plan. The dam necessary to hold back a 150-mile stretch of water from its accustomed canyon outlet would be the largest rock-fill dam in the world. A tunnel running 10 miles through the solid rock of the mountain barrier would bring water in two 2,600-foot-head, 11-foot-diameter pressure conduits (the largest pressure conduits known) to turbines on the other side. At the foot of the mountain a powerhouse containing ultimately 16 of the world's most powerful generators had likewise to be excavated and installed inside the mountain. And, finally, to bring the power to the aluminum smelter, a power line carrying the largest conductors ever made must be flung over 50 miles of ferocious snow-clad mountains. At one point the chain of pylons rises 2,000 feet above the tree line to a 5,300-foot pass, where 80-mile-an-hour gales rage in winter and the snow lies 20 feet thick.

The smelter alone in the project was of conventional design. It was simply to be the largest ever built.

Of course these five main construction features of the total development were not begun in sequence. But it is convenient to treat them here consecutively, beginning at the stage farthest from the aluminum, at the Nechako Canyon through which the lakes had previously been drained to join the Fraser River. In fact the work on the eastward dam (now to be called Kenney Dam) and the clearing of the foreshore at Kitimat in preparation for the smelter, the building of port facilities and a city, began almost simultaneously during the summer of 1951.

THE DAM AND STORAGE RESERVOIR

Rainfall over the watersheds draining into the long lake chain above Nechako Canyon varies from 100 inches a year at the western end to about 20 inches at the lower eastern end. The watershed area above

Kenney Dam is practically 5,500 square miles. A further 290-square-mile watershed, that of the Nanika-Kidprice Lakes, can eventually be diverted into the main system. When the storage reservoir has risen to its scheduled level it will have a capacity of 873×10^9 cubic feet, although the rise in level will only be 15 feet in the Tahtsa Lake, at the western end. The reservoir surface area will then be 358 square miles, double that of the original lakes; even so the depth of water at the upstream face of the dam will be little more than 300 feet. The full reservoir surface level will stand at 2,800 feet above sea level, with the inlet to the power tunnel nearly 100 feet below this surface.

The Nechako Canyon site of the main dam was too deep and narrow for the usual cofferdam procedure for drying out the channel where the dam was to go. A new river channel was therefore drilled into the bank upstream, carried 1,539 feet inside the mountain in a sweeping arc, and the water debouched again into the river well below the dam site. This diversion tunnel was cut and completed in two months during the summer of 1951.

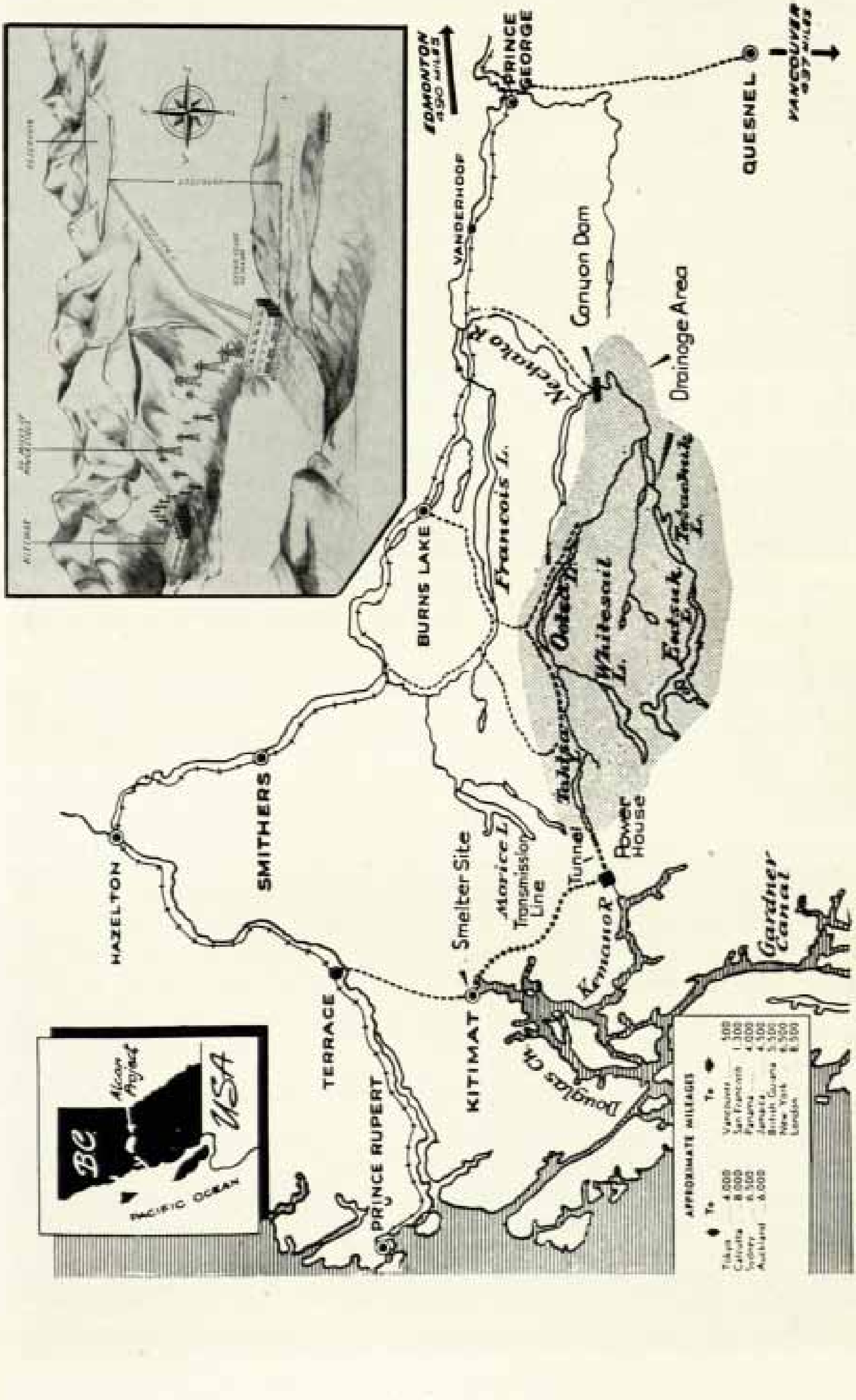
The thousand men working on this section of the development were now able to start clearing the river bed. Canyon walls and water channel were stripped down to the solid bedrock. A concrete slab, 150 by 82 feet and 10 feet thick, was spread on the cleared reservoir floor. Upon this, the placement of the rock of which the dam was to be formed began to rise on May 20, 1952.

The rock came from quarries in the surrounding mountains. Four million cubic yards of filling rock was used. It took the 1,000-man labor force six months to shift and place this material. At 45-second intervals throughout those summer months one of a fleet of trucks dumped its load on the dam, its drivers' movements radio-controlled from a central tower.

The construction of the rock-fill dam is of special interest in the case of the Kenney Dam since it holds a highly critical position at the head of a major tributary of the Fraser River. Here is the technical description of the Chief Engineer of the Power Department of Aluminium Laboratories Ltd.,[3] F. L. Lawton, who has been closely associated with Kitimat:

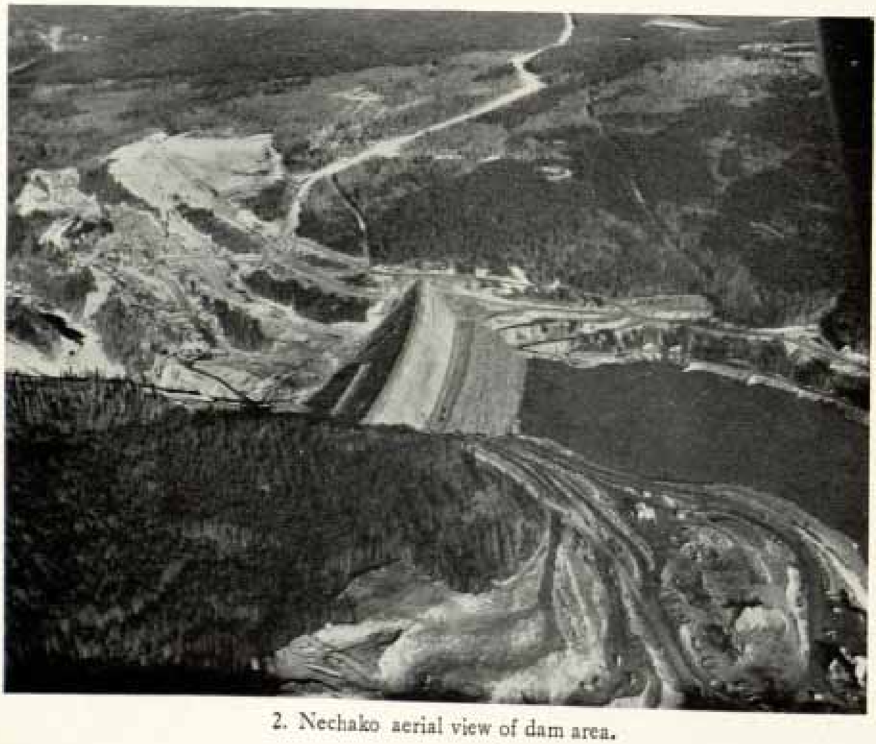
> . . . the load-carrying element is a heavy rock-fill thoroughly sluiced, supporting on the upstream slope an impervious section of rolled-earth construction enclosed between suitable filter layers. The upper section is loaded with quarry-run rock to retain the filter layers and impervious core, and resist wave erosion. The impervious core extends from a cut-off trench in sound rock to near the top of the dam.
>
> The function of the downstream filter layers is to prevent the impervious core material from being forced into the rock-fill by the water pressure, whereas the

[3] Aluminium Laboratories Limited is a subsidiary of Aluminium Limited in the same group of companies as Alcan.

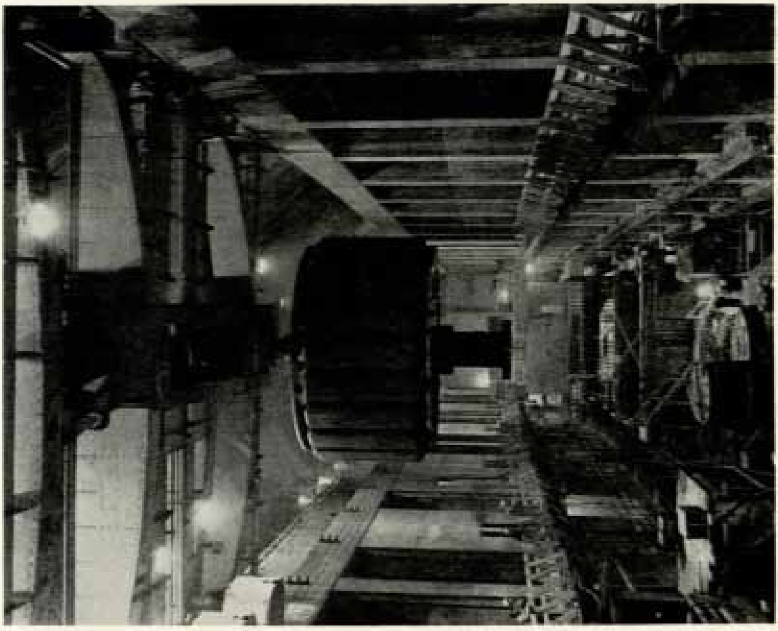


Map showing position of Kitimat.

1. Aerial view of dock and smelter, Kitimat, British Columbia. *Delta King*, former Sacramento River stern wheeler, is at left, now used as a workers' dormitory. Her boilers also furnish steam to heat hospital and other buildings.



2. Nechako aerial view of dam area.



Kemano. General view of powerhouse.

1. Vast underground excavation during work inside Mount DuBose prior to the installation of equipment.

2. The powerhouse receiving a Canadian Westinghouse generator rotor.

1. Stringing of world's largest aluminum cable proceeding along mountain section of 50-mile transmission line from Kemano to Kitimat.

2. Kemano, Camp No. 5, Mount DuBose, Horetzky Valley, and the Jaws. This shot was taken looking east from about 3,000 feet elevation on Mount Powell.

upstream filter layers perform a similar function with respect to the upstream blanket of quarry-run rock. The downstream filters comprise three layers; immediately downstream from the impervious core a layer of sand ¾ inch and smaller; next crushed rock or gravel, 3 inches; and, finally, adjoining the main rock-fill a layer of 10-inch selected rock. The upstream filter is similar but in the reverse sense.

Below the impervious core, effective cut-off is assured by a grout curtain. This was developed by grouting the upper 25 feet of rock at pressures of about 20 lb. per square inch, then continuing to the necessary depth by deep holes drilled through the consolidated upper zone, using higher pressures.

Another point worth noting is that the original 1-in-1.5 slope of the upstream face was increased to 1-in-2.5 during the model tests at the University of California, as an additional safety measure. In view of the dam's elaborate and scientific packing, the claim that its life will be measured "in geological, not historical time" is probably justified.

On October 8, 1952, the diversion tunnel above the dam was closed and the storage reservoir began filling. The water has been rising ever since. The 2,800-foot-elevation level should be reached in 1957.

Coloring an account of the construction of this, the world's largest rock-fill dam nearly 3,000 feet up in the mountains, there should be a sense of the acute inaccessibility of the region and the human hardships that this must bring. Nechako Canyon is nearly 100 miles from the nearest railway station. To bring the heavy equipment and the men to the site a heavy motor road had to be driven 60 miles through virgin country. The Canadians did this in 12 weeks flat.

THE POWER TUNNEL

The storage capacity of the reservoir permits a regulated flow estimated at 6,920 cubic feet per second for the powerhouse turbines. But first the water had to be thrust 10 miles through solid rock to reach those turbines.

The boring of the tunnel started on October 22, 1951, from the western shores of Tahtsa Lake. On November 4 the bore into the mountain from the seaward side began. Two further mining crews attacked from a midway shaft driven into Mount DuBose at Horetzky Creek; one of these crews bored eastward from this point, the other westward.

Mining operations on the western mountain face were complicated by the need to start drilling half a mile up a heavily wooded and almost cliff-steep slope. An overhead-cable railway solved this problem. The cable car, weighing 9 tons itself, could convey 20 tons of machinery or 60 men per trip.

Within the tunnel highly coordinated teamwork operating a newly developed large-scale drilling technique chewed through the rock

at the rate of 15-feet-plus in two hours. A tunneling team consisted of 40 men. Ten worked on each face of the tunnel, perched on four platforms on a movable scaffold known as a "jumbo." Up to 100 blast holes 15 feet deep were drilled. Then the jumbo was pulled back and the drill holes plugged with explosive. After the detonation the broken rock was loaded into trolleys, dragged to the entrance, and dumped. Then the cycle would be repeated. The tunneling continued round the clock, the men working shifts, for 20 months. On December 2, 1953, two grimy miners grinned at each other through a jagged hole deep inside the mountain. The tunnel from the east had met the tunnel from the west—dead on center! Three times the world tunneling time had been cut; the final record was in 1953 when 282 feet were bored in a single 6-day week. (This was through granodiorite, a most satisfactory material for drilling.)

The completed tunnel was 10.1 miles long with a diameter of 25 feet. A second, following the same route but 300 feet away, is envisaged in the final development.

THE POWERHOUSE

Kemano hydroelectric powerplant is to be the largest underground powerhouse in the world. When the full complement of 16 150,000-horsepower generators are installed it will have a total capacity over three times the ultimate installed capacity of Harspranget in Sweden, the closest rival. Work on digging out the powerhouse cavern began at the end of the summer of 1951, and this job alone took nearly two years. The plant is nearly a third of a mile inside the mountain, so a 27-foot-wide access tunnel had first to be driven as far as the location of the power chamber. A total of 570,000 tons of rock made room for this. The cavern necessary to house the full eight generators envisaged at the completion of Stage I (the "6-year plan" for the scheme) is ample to hold the *Queen Elizabeth*. Today the powerhouse is 82 feet wide and 135 high, and is 700 feet long. To install the eight more generators allowed for in the plans the building must be cut another 400 feet into the rock. It will then be more than a quarter of a mile long.

The Kemano generators are driven by the largest multinozzle impulse-turbines ever devised. These turbines are vertical, single-runner, 4-nozzle type designed to produce 150,000 horsepower at 327 revolutions per minute. They drive directly 3-phase, 60-cycle, 13,800-volt generators rated at 122,000 kilovolt-amperes. The power from each group of generators feeds into a bank of three single-phase 89,000 kilovolt-ampere transformers. A 300,000-volt, 4-inch-diameter power cable, with 60 pounds per square inch oil pressure, carries the transformer output 2,000 feet to the surface switchyard. (This power

cable is runner-up for the world record; the only larger one is the 380,000-volt cable in use at Harspranget.)

To carry out all this work a settlement of about 5,000 people was established at the foot of Mount DuBose by 1953. Apart from the forbidding country around, they were snug. They had their own neat homes, schools, churches, and in the cinemas first-run Hollywood films were screened. A 2-lane road ran 10 miles down the valley to the anchorage on Gardner Canal—and the rest of the world.

THE POWERLINE

It is certain that without helicopters the power so boldly seized at Kenney Dam and Kemano would never have been piped across the mountains to the aluminum ore at Kitimat. Grit can get men so far but it cannot swing heavy loads to an eagle's eyrie—and this was the sort of task that was now ahead. Between Kemano and Kitimat lie 50 miles of savage mountain country, clogged with snow and lashed by winds that could rise to an 80-mile-an-hour gale off the sea. At one point on the route the transmission line must go over a 5,300-foot pass, the highest elevation in the whole project. In these conditions hundreds of specially strengthened pylons had to be set up and the massive transmission cables rigged—the biggest ever made and designed to support a 5-inch sheath of ice if necessary. It was difficult enough getting the men to some of the sites, not to speak of heavy equipment.

Seven helicopters were brought to Kitimat, the largest fleet to be used for civilian purposes at that time. But there were other snags. Carl Agar, one of Canada's best pilots, was called west to pioneer high-altitude landings and takeoffs. The rarefied atmosphere and treacherous mountain downdrafts were variables that no one had experienced on this scale.

But the venture worked. In fact the helicopters became so indispensable that on favorable days they flew 75 round trips on a tight schedule—more than at the height of the Berlin airlift, as somebody pointed out! Each machine would work on a 4-hour shift, back and forth, back and forth, without ever touching down.

Meantime on the mudflats below at Kitimat the new aluminum smelter had been going up, and 4 miles away the new town was rising, a planned community scheme to house the rapidly increasing population in the wilderness. Port facilities were also installed on the cleared foreshore. Stalwart as these rapid achievements were they seem dwarfed by the rest of the development story.

On July 15, 1954, the last switch was made. The power from the lakes in the mountains began to heat the smelters. The plant was officially opened by the Duke of Edinburgh a fortnight later and the first ingot poured in his view.

In 1874 when the first survey of this area was made by Charles Horetzky, surveyor of the railways, he wrote of these mountains—"A terrible silence, broken only now and again by the dreadful crash of some falling avalanche, reigned over this scene of desolation." When he led a party of three white men and four Indians through a gap in the mountains and saw beneath the water of Tahtsa Lake like a jewel in the waste, he was immediately struck by its "brilliant light blue colour"—the first excitement for the eye for many weeks.

Now, 83 years later, "the terrible silence" is pierced by the high hum of the turbogenerators and the "scene of desolation" is peopled by a thriving community of many thousands. In 1955 (the first complete year of smelting at Kitimat) over 90,000 tons of aluminum were produced. By the end of 1956, when six generators were in operation, the output had increased to more than 180,000 tons. And, if world demand continues to increase at its present rate, 16 generators producing power for 550,000 tons of aluminum a year may soon be in operation.

Sewage Treatment—How It Is Accomplished[1]

By C. E. KEEFER

Assistant Bureau Engineer, Sewers
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[With 6 plates]

MAN'S DESIRE to enjoy the amenities of urban life has brought with it many difficult problems that demand prompt and adequate solutions. One of these, which up to about 100 years ago had remained unsolved, related to the satisfactory treatment and disposal of municipal sewage. Many factors were instrumental in directing the attention of legislators, sanitarians, and engineers to this problem. Among these factors were the increased use of water, which served as a means to transport municipal wastes to the nearest watercourse, the phenomenal growth of our cities with its concomitant increase in the volume of municipal sewage, the growth of our knowledge of water-borne disease, and an aroused public opinion that clean watercourses are conducive to the general welfare of the public.

WHAT IS SEWAGE?

The purpose of this discussion is to indicate the various methods that are used to treat municipal sewage so that 85 or 90 percent of the organic and suspended materials and at least 99 percent of the bacteria can be removed at a reasonable cost. To understand how the various treatment processes function it is desirable to know what municipal sewage is and how it is collected.

Sewage has been defined as "the spent water supply of a community, together with those human and household wastes that are removed by water carriage, supplemented in some instances by street washings and industrial wastes." Sewage consists of the liquid discharge from

[1] This paper gives a brief description of the more important facilities found in modern sewage-treatment plants. No attempt has been made to describe all of the means available for treating sewage. Those facilities that have been outmoded, that are little used, or that as yet have not become well-established processes have not been discussed.

kitchens, laundries, and bathrooms of residences, hotels, hospitals, schools, and business establishments. This liquid is quite frequently augmented by the liquid wastes, usually called industrial wastes, from various industries, such as dairies, laundries, slaughterhouses, and food-processing plants.

The character and the strength of sewage will generally depend upon the water consumption and the amount of industrial wastes present. Where a city uses a large quantity of water, it often discharges it into the sewers and the strength of the sewage is diminished. On the other hand, if large quantities of industrial wastes are disposed of into the sewers, the strength of the sewage is usually increased.

The type of sewerage system in a city will affect the character of the sewage. There are two types of sewerage systems in general use: the separate system and the combined system. A separate system consists of two distinct groups of sewers, one called sanitary sewers and the other called storm sewers or storm drains. Sanitary sewers receive the discharge from bathrooms, kitchens, and laundries in residences and business establishments and the industrial wastes from food-processing plants, manufacturing plants, etc. This discharge, called sewage, may flow either into a watercourse without treatment or to a sewage-treatment plant. The storm sewers or storm drains receive the storm flow from streets, sidewalks, roofs, lawns, and undeveloped areas. The discharge from storm drains generally flows untreated into nearby watercourses.

The second system of sewers, which is in more general use, at least in medium-size and large cities, is the combined system of sewers. This system receives both the sewage from dwellings, industrial plants, and other sources, and the rain water and surface discharge from highways, roofs, and similar areas. Where the sewage from these two types of sewerage systems has to be treated, some differences in the design of the sewage-treatment works are necessary.

Sewage has an appearance not unlike that of dishwater, in which is suspended a wide diversity of materials such as fruit skins, pieces of paper, match sticks, and fecal matter. One useful measure of the strength of sewage is the amount of suspended solids in it. The quantity of suspended matter in the sewage from cities in the United States will generally average from 0.02 to 0.03 percent by weight and the quantity of water will exceed 99.9 percent. Although the amount of suspended solids when evaluated on a percentage basis is small, the total daily amount from a large city can be considerable. For example, the suspended solids in the sewage from Washington, D. C., amounts to about 113 tons a day. Sewage also contains organic and inorganic solids in solution, together with vast numbers of viruses and bacteria. A useful measure of the strength of sewage, called the bio-

chemical oxygen demand, is the amount of oxygen required for the biochemical oxidation of the decomposible matter at a given temperature within a given time.

SEWAGE TREATMENT PROCESSES

The treatment of sewage can be accomplished in a variety of ways. The type of treatment selected depends upon a number of factors such as the relationship between the volume of sewage to be treated and the minimum flow in the watercourse into which the sewage discharges, the use to which the watercourse is put, the cost, and the land available for a sewage-treatment plant and the nearness of built-up areas to the plant site. A low flow of sewage from a small community, discharging into a large watercourse, may require little if any treatment, whereas a large flow discharging into a small watercourse will require a high degree of treatment. The use to which the watercourse is put will have a decided bearing on the type of treatment. Where there are shellfish areas in the watercourse or where it is used for recreational purposes such as swimming or bathing or is a source of water supply, a high degree of treatment is usually necessary. Where land is costly or where expensive foundations are required to support the sewage-treatment structures, it may be desirable to select those types of treatment units that occupy a small area of ground. The nearness of sewage plants to residential or business areas plays an important role in the type of treatment selected. Where dwellings or business establishments are close to a proposed sewage-treatment plant, that type of treatment should be adopted which will be relatively free of odors and other nuisances.

SEWAGE SCREENS

Practically every sewage plant is provided with a sewage screen. The chief function of screens is to remove large suspended solids that may clog pumps and small pipes. Screens can be classified into two types: coarse and fine. Coarse screens are made of parallel steel or wrought-iron bars with clear openings of about half an inch or more, whereas fine screens have openings well under half an inch.

Coarse screens can be either manually or mechanically cleaned. They are generally placed (pl. 1, fig. 1) in a chamber or channel at right angles to the flow of sewage in an inclined position to facilitate ease of cleaning. Suspended solids in the sewage are caught on the upstream surface of the screen and are raked off manually or mechanically.

Various types of fine screen are in use. One type consists of a drum made of bronze plates, containing perforations varying from about one-sixteenth to one-eighth inch in width. The drum (see pl. 6), which is rotated by an electric motor, is partially submerged with its

horizontal axis parallel with the surface of the sewage. Different methods of cleaning fine screens have been adopted, one of which is by revolving brushes.

Screenings, which are usually quite objectionable, are disposed of by incineration, by burial, or by mixing with municipal garbage. One method that has been practiced to a considerable extent for the past 25 years has been to mascerate the material in a grinding machine and discharge it back into the sewage. This method of disposal is especially applicable where screenings from coarse screens are disposed of, since the quantity of solids involved is small and the ground material can be removed from the sewage by subsequent treatment processes.

A device called a comminutor, which combines the properties of a screen and a grinder (pl. 2, fig. 1), consists of a slotted rotating drum, installed in a sewage channel. The sewage flows through the horizontal slots in the drum. Attached to the outer surface of the drum are a series of projections, on which the screenings are caught. As the drum rotates, it passes through the teeth of a stationary comb and cuts up the screenings into such a size that they flow through the slots with the sewage.

GRIT CHAMBERS

After sewage has been screened, usually the next step in the treatment process consists of removing the grit in one or more tanks, called grit chambers. These chambers treat the sewage from combined sewerage systems, which contains considerable quantities of sand and similar materials in the discharge from highways and unpaved areas, and in some instances are provided to treat the sewage from separate systems. There is a variety of designs. The size of the tank (pl. 1, fig. 2) governs the velocity of flow of the sewage passing through it so that the grit settles on the bottom of the tank and the lighter organic matter passes out with the effluent. The length is such that the sewage is retained in the chamber about 1 minute, and the traverse cross section is usually such that the velocity of the sewage is about 1 foot per second. The quantity of grit removed varies from about 1 to 10 cubic yards per million gallons of sewage treated. Grit is disposed of by incineration and by making fills at sewage-treatment plants.

TANKS

SKIMMING TANKS

As sewage contains considerable grease and oil, specially designed tanks for the collection and removal of these materials have been used to some extent. The tanks are generally small with detention periods ranging from a few minutes to about 15 minutes. One type is rectangular in plan with a V-shaped cross section. It is divided longitudinally into three compartments by two vertical walls, which extend

nearly to the bottom of the tank. Porous diffusers are provided at the bottom of the central compartment along the center line of the tank. When air is blown through these diffusers, it carries any grease and oil to the tank surface where these materials are removed manually.

SEDIMENTATION TANKS

After sewage has been screened and the grit has been removed, it is processed to remove a considerable percentage of the suspended solids by passing the sewage continuously through sedimentation tanks at a greatly reduced velocity. The suspended solids settle out and are removed in a variety of ways. This deposited material is called sewage sludge.

In the United States sedimentation tanks are of such size that the sewage is retained in the tanks for about 2 to 3 hours. During this detention period about 35 to 40 percent of the oxidizable materials and 60 to 70 percent of the suspended solids are removed.

Sedimentation tanks are of many different types and shapes. They are all designed basically to obtain a reduced and uniform velocity of flow throughout the tank, with the ratio of tank surface to tank volume large, and to remove the sludge rapidly and in as concentrated a consistency as possible. They are usually square, rectangular, or circular in plan, with working depths varying from 5 to 6 feet for small units to almost 14 feet for large ones. Various methods have been devised for removing the sludge. In the older designs this was done manually. After a tank had been in service for several days or weeks, the flow was diverted to another tank and the supernatant was pumped or drained off until the sludge was exposed. This material was then squeegeed or flushed with water to a pit in or near the tank and then removed, usually by pumping, for further treatment or disposal.

Another type of tank that still has a limited use is provided with steep floors that slope to a sump. From here there is a drain pipe through which the sludge discharges to some point of disposal.

The type that has come into almost universal use during the past 30 years is provided with mechanically operated equipment for removing the sludge either continuously or intermittently. One type of equipment that is extensively used in circular tanks (text fig. 1) consists of two trusses made of structural steel shapes suspended immediately above the tank floor and supported at the center of the tank. Thin metal squeegees are attached to the bottoms of the trusses and make contact with the tank floor, which slopes toward the center of the tank. The whole mechanism is rotated slowly about the vertical center line of the tank, and the sludge is moved by the squeegees toward the tank center. From here the sludge discharges through a pipe as a result of the hydrostatic pressure of the superimposed sewage. Another type of cleaning equipment adopted especially for rectangular

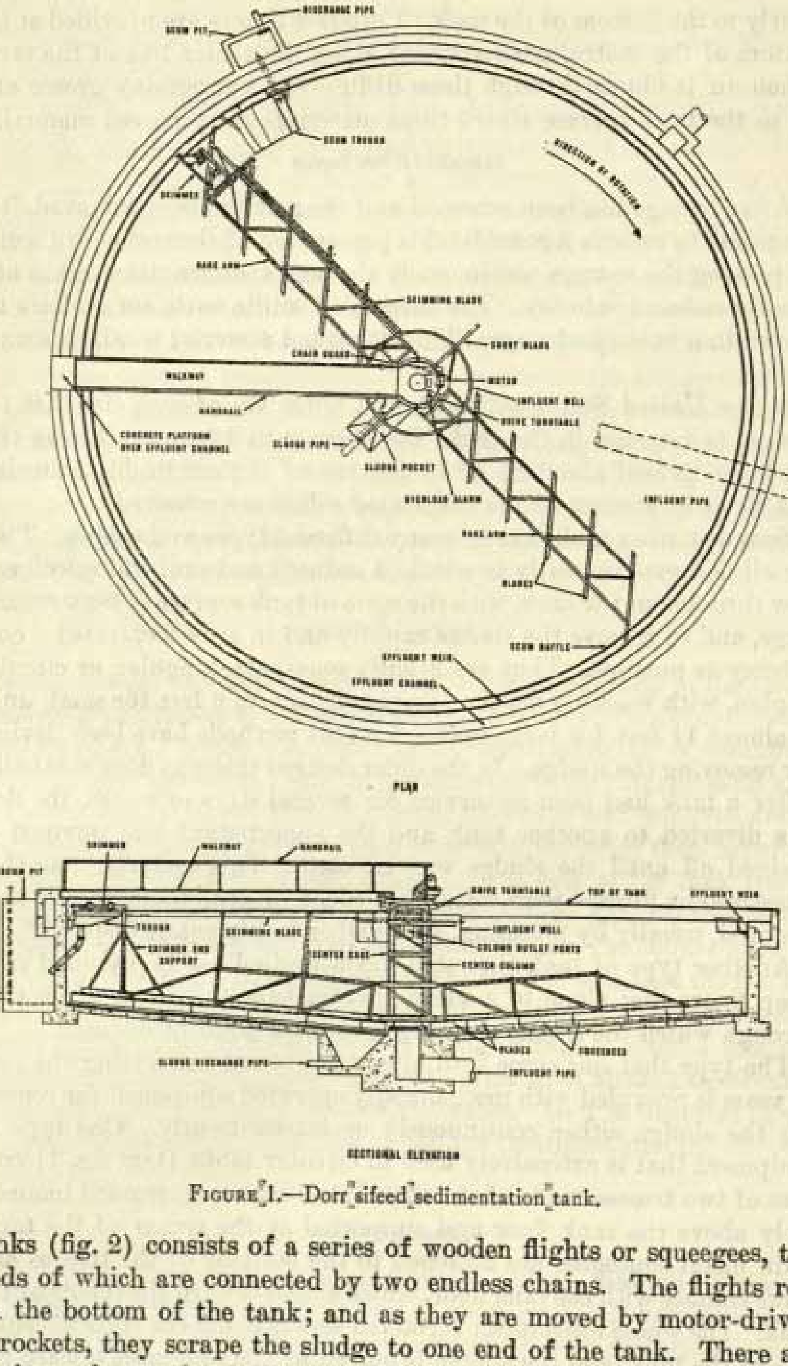


FIGURE 1.—Dorr sifeed sedimentation tank.

tanks (fig. 2) consists of a series of wooden flights or squeegees, the ends of which are connected by two endless chains. The flights rest on the bottom of the tank; and as they are moved by motor-driven sprockets, they scrape the sludge to one end of the tank. There are various other mechanical methods of removing sludge from sedimentation tanks, which are modifications or refinements of the two above mentioned.

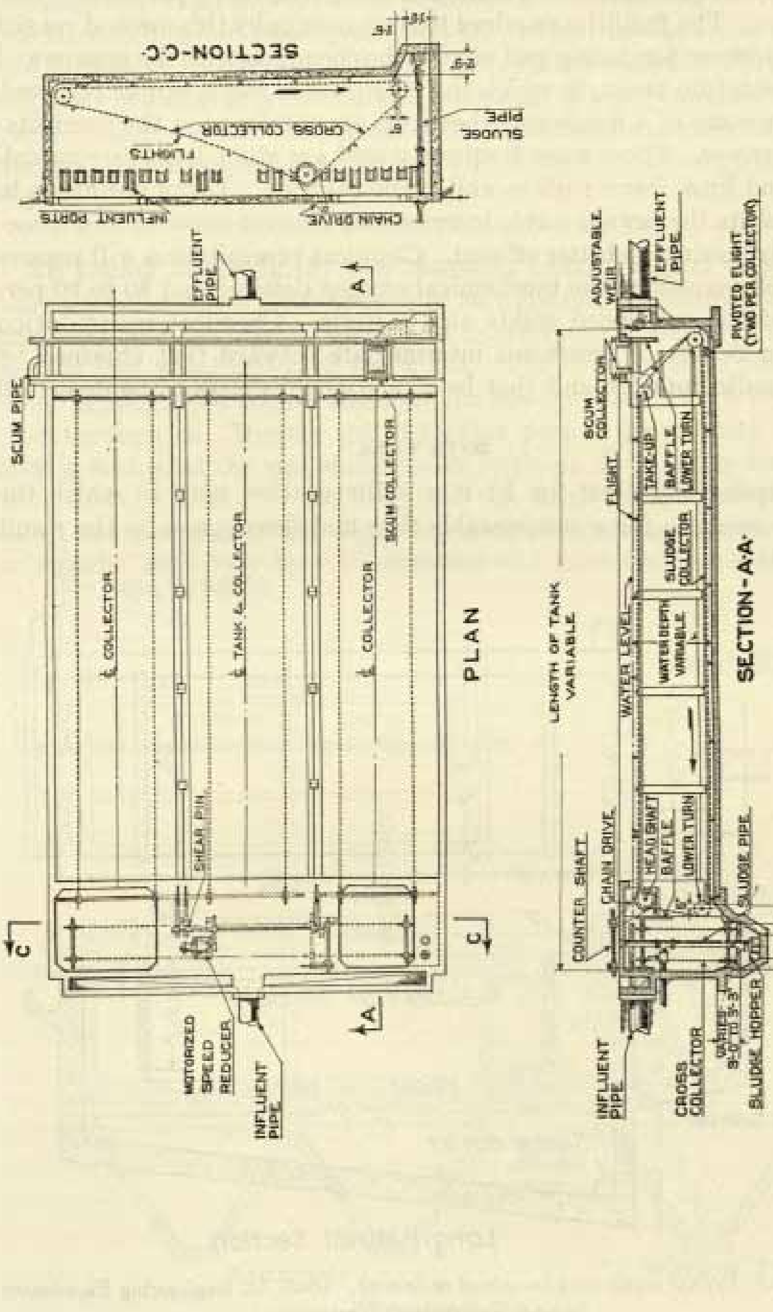


FIGURE 2.—Sedimentation tank with straight-line conveyors. (Link-Belt type.)

CHEMICAL PRECIPITATION

At one time the chemical precipitation of sewage was extensively adopted; today, however, it is little used. The process consists of mixing one or more chemicals with sewage to produce an insoluble or slightly soluble floc, which enmeshes and precipitates particles in suspension. The facilities required to treat sewage by this method consist of equipment for dosing and mixing the chemicals with the sewage and sedimentation tanks, in which the precipitated solids can be removed. One or more of a number of chemicals are employed in the precipitation process. Those most frequently used are alum, lime, ferrous sulfate and lime, ferric sulfate, and ferric chloride. Using chemicals to precipitate the sewage solids increases the amount removed and consequently produces a better effluent. Chemical precipitation will remove 70 to 80 percent of the biochemical oxygen demand and 80 to 90 percent of the suspended solids and bacteria. Chemical precipitation gives a degree of treatment intermediate between that obtained by plain sedimentation and that by oxidation processes to be described later.

SEPTIC TANKS

A septic tank (text fig. 3) is a sedimentation tank in which the sludge remains for a considerable time and decomposes as the result

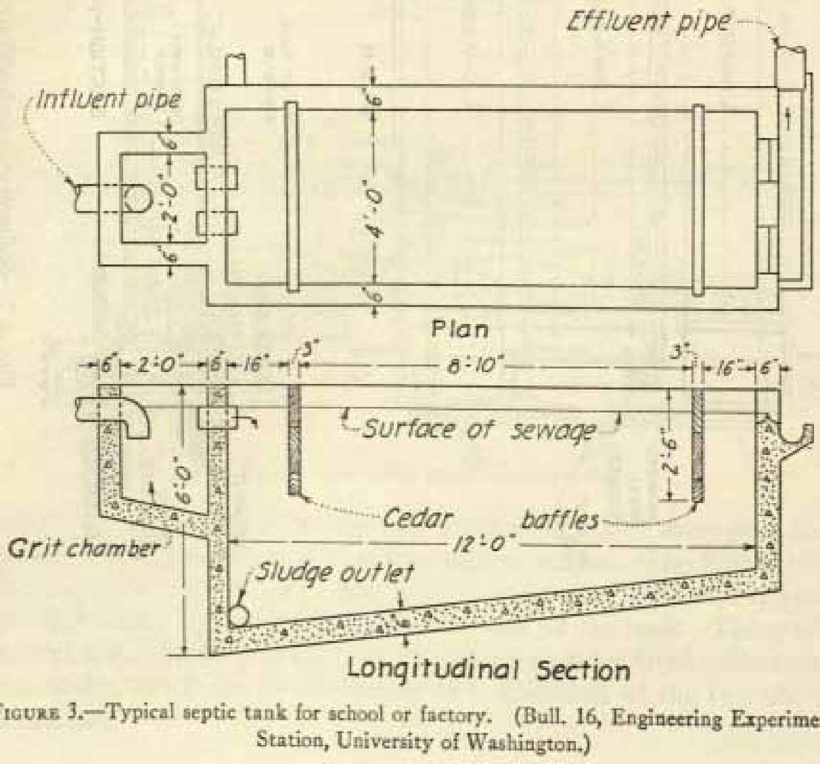


FIGURE 3.—Typical septic tank for school or factory. (Bull. 16, Engineering Experiment Station, University of Washington.)

of anaerobic bacterial action. From time to time after the sludge has digested, it is removed and disposed of. The septic tank was invented by Donald Cameron in 1895 and was adopted by many large cities. The objections to septic tanks are that they produce unpleasant odors and the effluent often becomes contaminated with sludge solids, which, after decomposing on the bottom of the tank, rise to the surface of the sewage and flow out with the effluent. They have not been installed at medium- and large-size sewage plants for many years. Their use has been restricted to treating the sewage from individual dwellings, small real-estate developments, schools, hospitals, etc.

IMHOFF TANKS

An Imhoff tank (fig. 4) is a two-story tank, designed to remove the suspended solids from sewage in an upper or sedimentation compartment and to provide space in a lower compartment for the digestion and stabilization of the solids. The sedimentation compartment is usually of such a size that the sewage takes 2 or 3 hours to pass through it. During this detention period the velocity of the flow is such that the suspended solids settle on the sloping floor and slide through a slot in the floor into the lower compartment. The solids are retained in the digestion compartment for several weeks or months until they have decomposed and have lost much of their

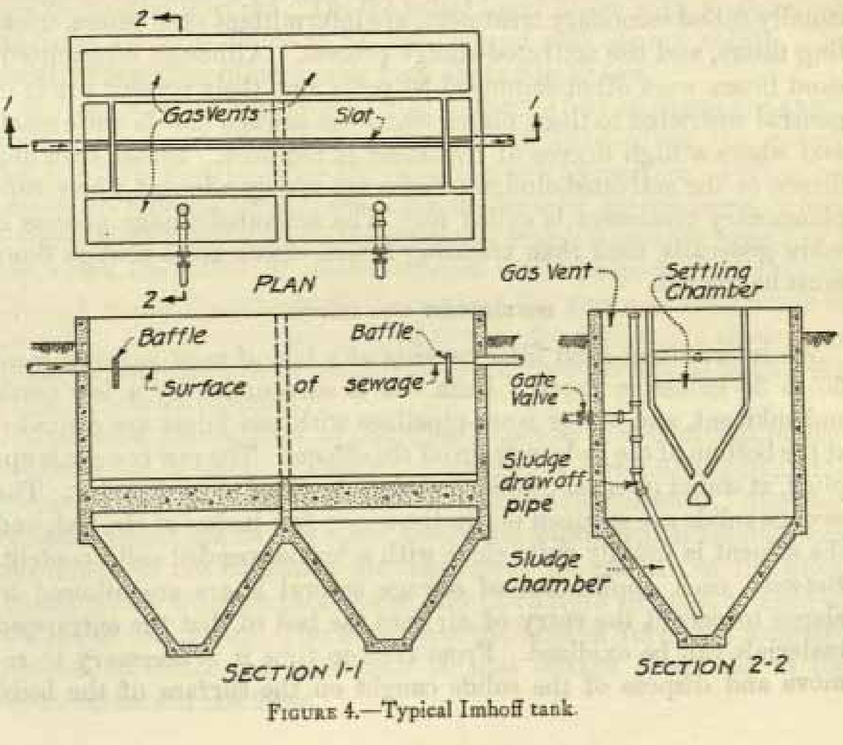


FIGURE 4.—Typical Imhoff tank.

objectionable characteristics. In the operation of Imhoff tanks the top of the sludge in the digestion compartment is maintained well below the elevation of the slots connecting the sedimentation and the digestion compartments to prevent the reentry of sludge into the sedimentation compartment, which would adversely affect the clarity of the effluent. Decomposed sludge is withdrawn from the tank through a pipe (text fig. 4), the lower end of which terminates just above the bottom of the digestion compartment. One distinguishing characteristic of Imhoff tanks is that gas-lifted solids in the digestion compartment, as they float upward, cannot reenter the sedimentation compartment and contaminate the effluent.

Imhoff tanks, which were first adopted in Germany, were a marked improvement over septic tanks and were built at many sewage-treatment plants in this country such as those serving Akron, Ohio; Fitchburg, Mass.; and Fort Worth, Tex. During the past 30 years, however, Imhoff tanks have been superseded by mechanically cleaned sedimentation tanks and separate sludge-digestion tanks.

SECONDARY TREATMENT FACILITIES

In many instances the above-mentioned facilities do not furnish the required degree of treatment. Such is the case if there is an insufficient volume of diluting water into which the sewage effluent discharges. The three principal types of supplementary treatment usually called secondary treatment, are intermittent sand filters, trickling filters, and the activated-sludge process. Although intermittent sand filters were often employed 50 years ago, their present use is in general restricted to those places where the sewage flow is quite small and where a high degree of treatment is required. Either trickling filters, or the activated-sludge process are widely adopted where supplementary treatment is called for. The activated-sludge process is more generally used than trickling filters where large sewage flows must be treated.

INTERMITTENT SAND FILTERS

An intermittent sand filter consists of a bed of sand varying from 30 to 36 inches in depth. Each bed is surrounded by a low earth embankment, and one or more pipelines with pen joints are provided at the bottom of the beds to drain off the effluent. The raw sewage is applied, at stated intervals, to the beds to a depth of about 3 inches. The sewage solids are strained out in the upper few inches of the bed, and the effluent is usually quite clear with a low suspended solid content. Between each application of sewage several hours are allowed to elapse to permit the entry of air into the bed so that the entrapped materials can be oxidized. From time to time it is necessary to remove and dispose of the solids caught on the surface of the beds.

Although it is possible to apply untreated sewage to intermittent sand filters and produce a good effluent, the more general practice is to give the sewage preliminary treatment by coarse screens and sedimentation tanks. Intermittent sand filters are capable of removing as much as 95 percent of the organic and suspended solids from sewage with the production of an excellent effluent. The disadvantages of intermittent sand filters are that they require considerable areas of land where large volumes of sewage must be treated, and they produce disagreeable odors. One of the last large intermittent sand filteration plants in this country was in Worcester, Mass., where 74.3 acres of filter beds treated an average flow of over 4 million gallons a day. They were superseded by trickling filters in 1925.

TRICKLING FILTERS

Trickling filters for many years have been and still are one of the most important treatment facilities for oxidizing sewage. A trickling filter consists of an artificial bed of durable material such as gravel, crushed stone, or slag, on which sewage in the form of a spray is intermittently or continuously applied. The sewage trickles down over the surfaces of the stones and is collected in underdrains in the filter bottom, from which it discharges for subsequent treatment. The filtering medium usually varies in size from about 1 to 3 or 3½ inches. Fine-grained material will produce a better effluent than a coarse-grained medium. On the other hand filters with fine-grained material are more liable to become clogged with sewage solids. The depth of trickling filters varies from about 3 to 10 feet.

Several ways of applying sewage to the surface of filters are available. One much-used method consists of distributing the sewage through a network of pipes laid on or beneath the surface. Projecting vertically upward from these pipes are equally spaced pipes, which are usually 3 or 4 inches in diameter and which terminate some 2 or 3 feet above the filter. At the top of each vertical pipe there is a nozzle through which the sewage discharges in a fine spray on the surface of the stone. Various means are used to vary the pressure in these pipes so that sewage is applied uniformly to the filter both close to and at a distance from the nozzles.

Sewage is also applied to trickling filters by means of rotary distributors (pl. 2, fig. 2). This device consists of a vertical column, into which the sewage enters at the bottom and is drawn upward. Attached to this column are two or more horizontal pipes, which rotate about the center of the column a few feet above the surface of the filter. Sewage flows through these pipes and discharges through a series of nozzles on the filter. The flow from the nozzles furnishes sufficient impulse to rotate the distributor so that sewage is applied to the entire surface of the filter.

When a trickling filter is first put in service, purification of the sewage is not great. However, within about a month or more the filter media becomes coated with slime, containing a multitude of lower forms of life such as bacteria, fungus, fly larvae, spiders, and many types of worms. As the sewage trickles over the surface of this slime, the carbonaceous and nitrogenous materials are oxidized by bacterial action with the production of carbon dioxide, water, and nitrates, and with a reduction of 60 to 85 percent in the oxidizable matter. As the bacteria and other forms of life in trickling filters are affected by temperature, a better effluent is produced in summer than in winter.

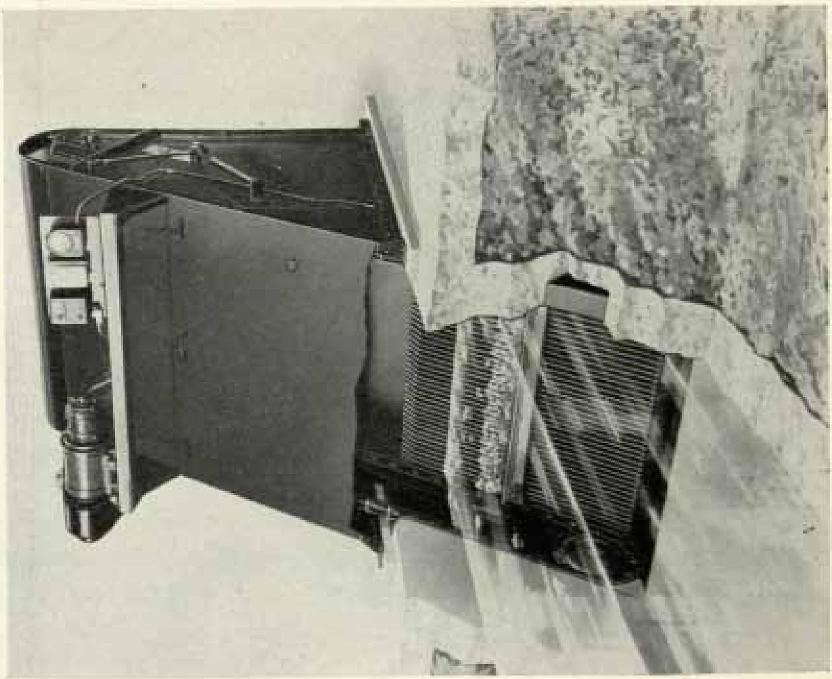
The quantity of sewage that can be treated on trickling filters varies from 1 to 2 million gallons per acre per day, up to 30 million gallons per acre per day or more. Prior to about 20 years ago from about 1.5 to 3 million gallons per acre per day of settled sewage was applied to trickling filters, or about 12,000 to 24,000 persons were served per acre by a filter 6 feet deep. Experimental work and many full-scale installations have since indicated that considerably greater applications of sewage can be made, and that by pumping back a portion of the effluent to the filter influent much larger quantities of sewage can be treated with no decrease in efficiency.

Trickling filters are used in many parts of the world for treating both small and large sewage flows. During the past 20 or 30 years in the United States, where the sewage from large cities requires secondary treatment, the trend has been to provide activated-sludge units instead of trickling filters. The three largest trickling-filter plants in the world are those serving Baltimore, Md.; Bradford, England; and Birmingham, England.

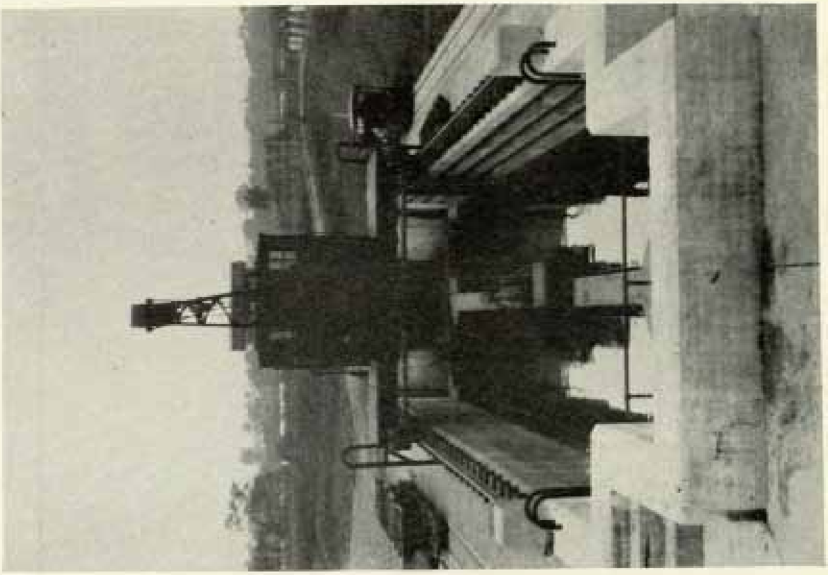
The effluent from trickling filters usually contains from 50 to 100 parts per million of suspended solids. In order to remove these solids the effluent is almost always treated in sedimentation tanks, which are frequently called humus tanks. They generally have a detention period of about 2 or 3 hours and as a rule are provided with mechanical equipment for removing the sludge.

ACTIVATED-SLUDGE TREATMENT

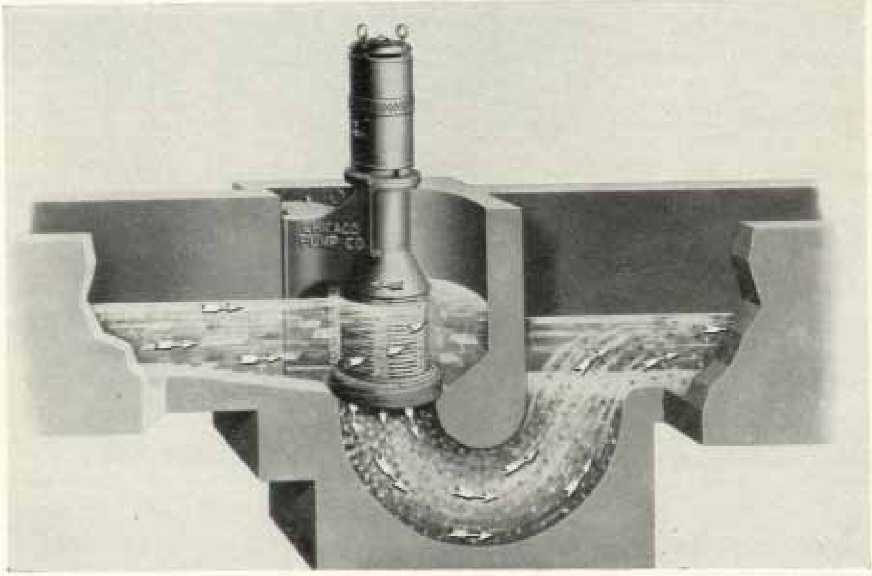
The activated-sludge process, which was invented in Manchester, England, consists of bringing sewage into intimate contact with air and biologically active sludge. As a rule the sewage is first clarified in preliminary settling tanks and then permitted to flow continuously through aeration tanks with a detention period of several hours. Activated sludge is added to the sewage entering the aeration tanks in amounts varying from about 10 to 30 percent by volume, and air is added to the mixture. From the aeration tanks the sewage and



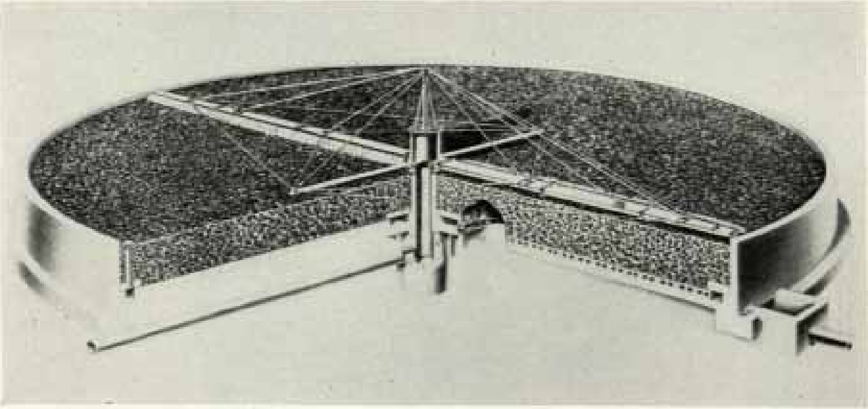
1. Chain belt mechanically cleaned coarse screen.



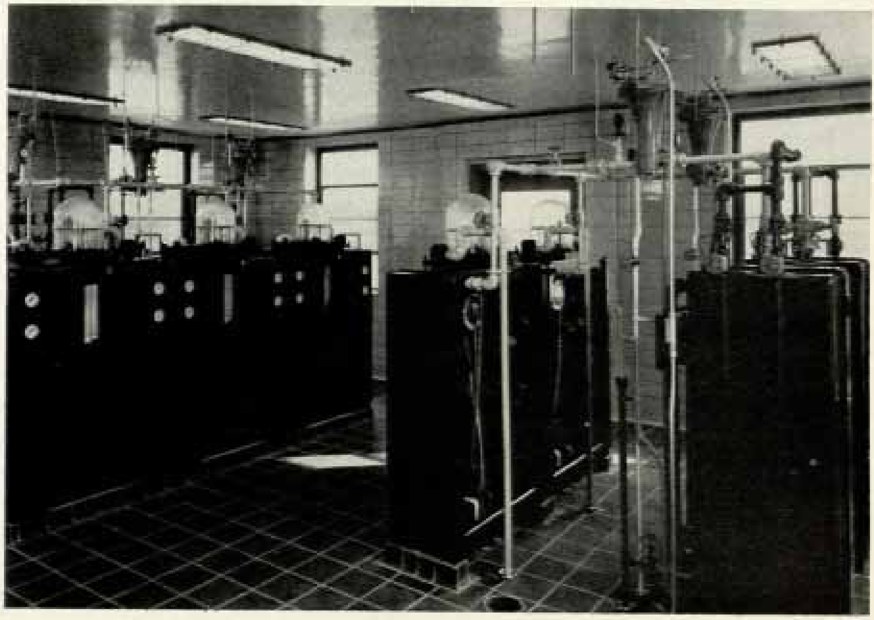
2. Mechanically cleaned grit chambers, Trenton, N. J.



1. Comminutor.

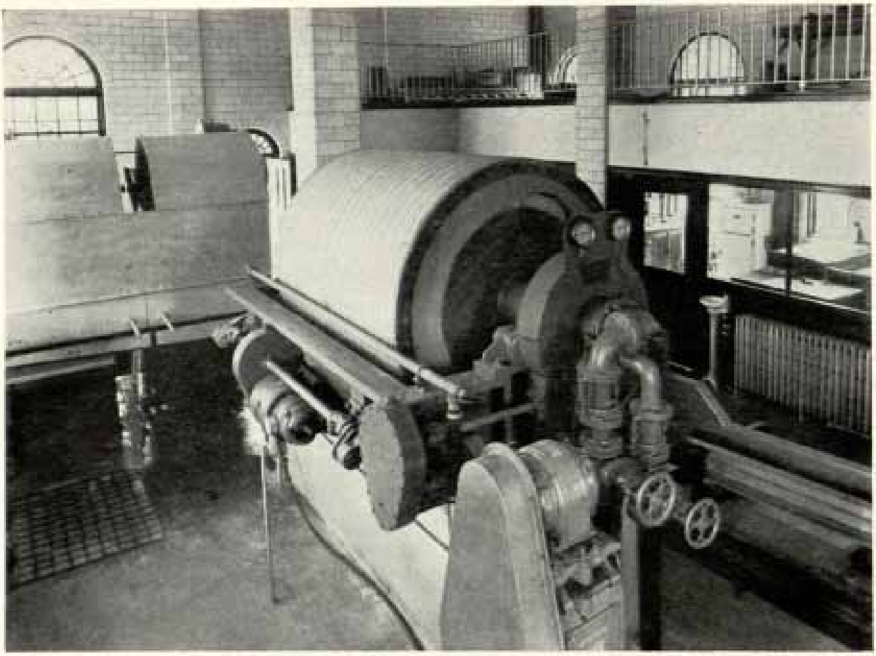


2. Trickling filter equipped with Dorrco rotary distributor.

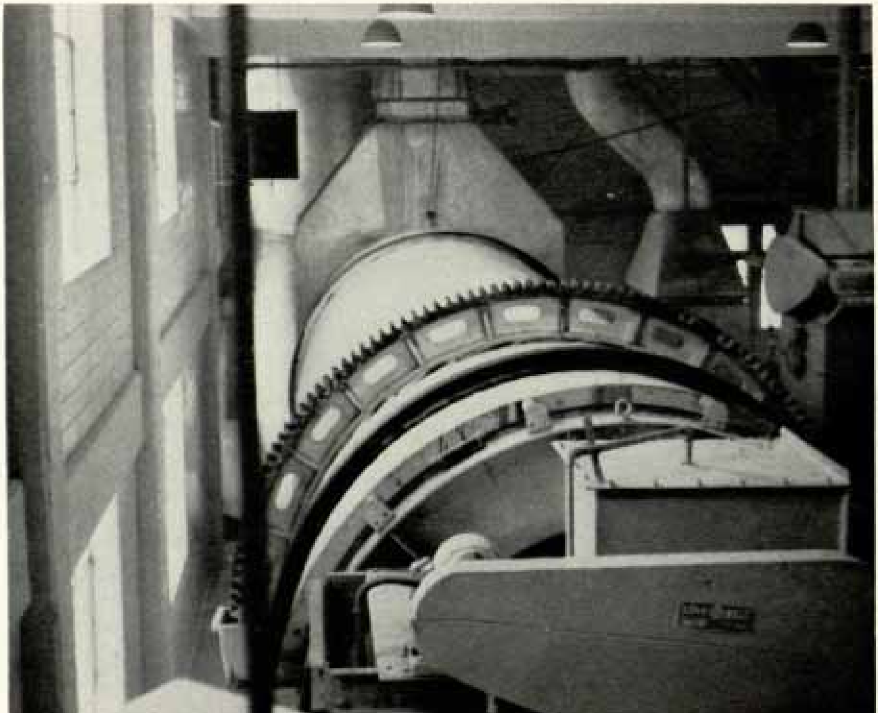


1. Chlorinators at sewage-treatment plant, Washington, D. C. (Wallace & Tiernan Co.)

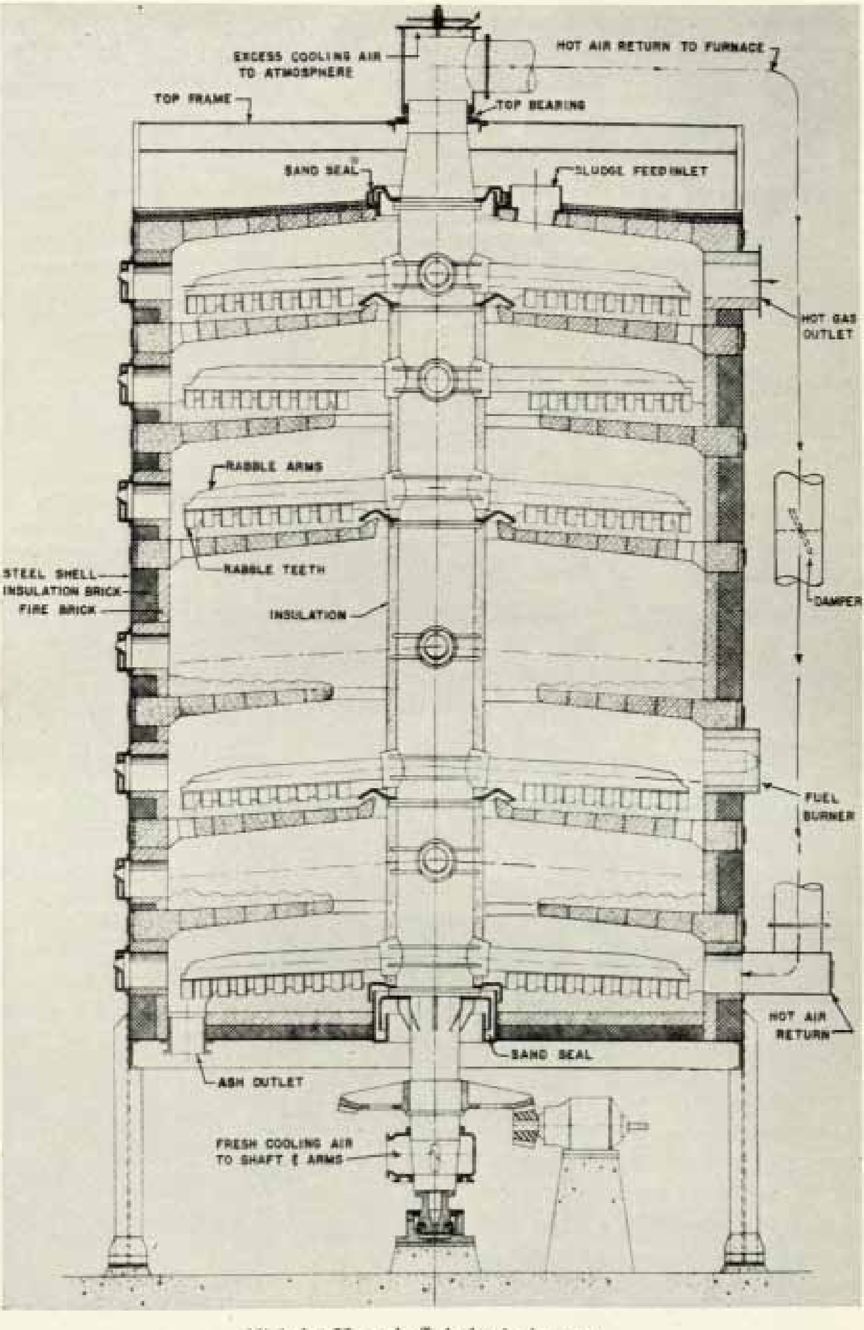
2. Covered sludge-drying beds, New Lexington, Ohio. (Lord & Burnham Co.)



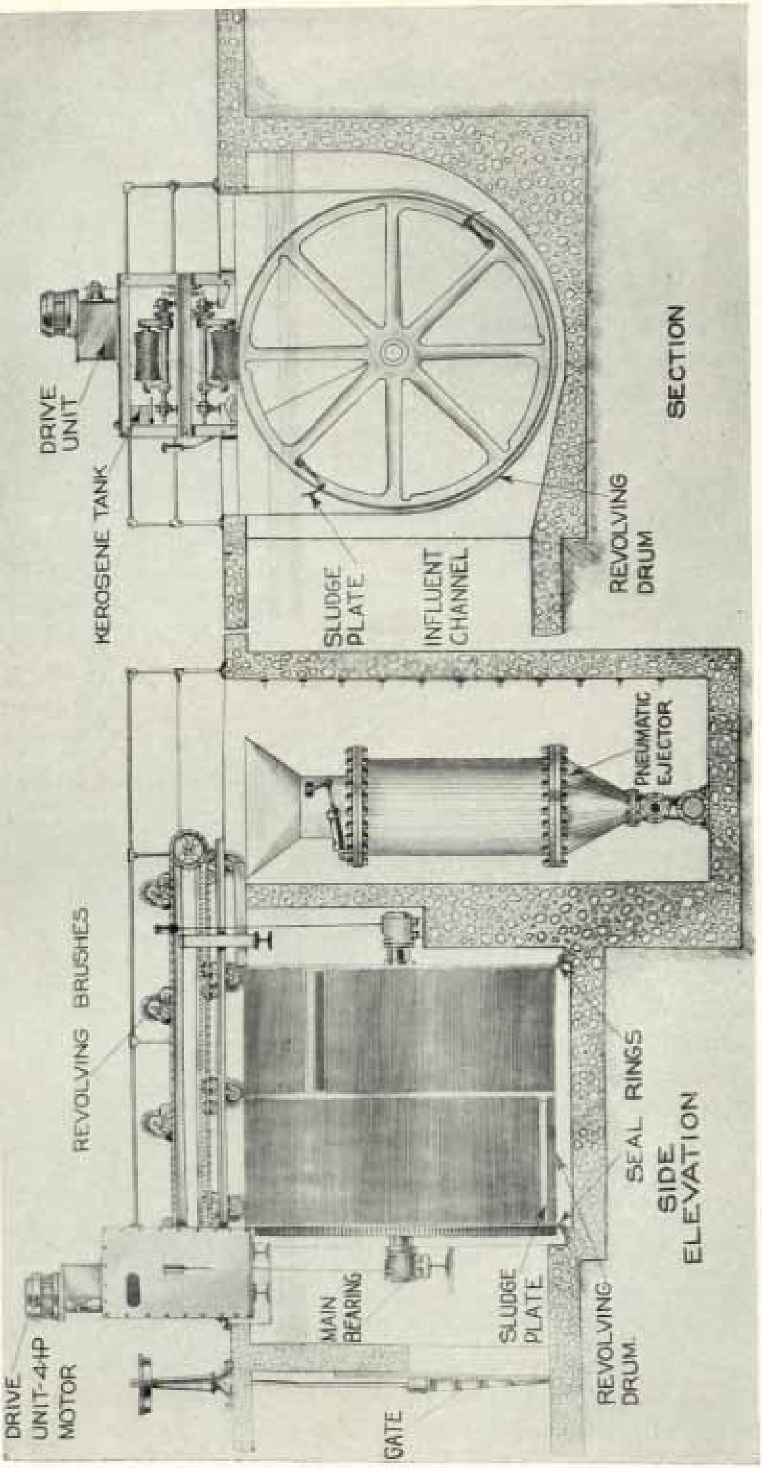
1. Oliver vacuum filter, Middletown, Conn. (Dorr-Oliver, Inc.)



2. Rotary sludge dryer, Fairfax County sewage-treatment works, Va.



Nicholas Herreshoff sludge incinerator.



Tark fine screen.

sludge, called mixed liquor, flows to sedimentation tanks. The clarified effluent from these tanks can be discharged into a watercourse, and the settled solids, called activated sludge, is also removed. The major portion is added to the sewage flowing to the aeration tanks, and the remainder is treated and disposed of in a variety of ways.

The activated-sludge process has several advantages. It is free from odors and flies, and the necessary treatment units occupy less space and are less costly to construct than trickling filters and humus tanks. The disadvantages of the process are that it is costly to operate, and it is frequently adversely affected by industrial wastes in the sewage.

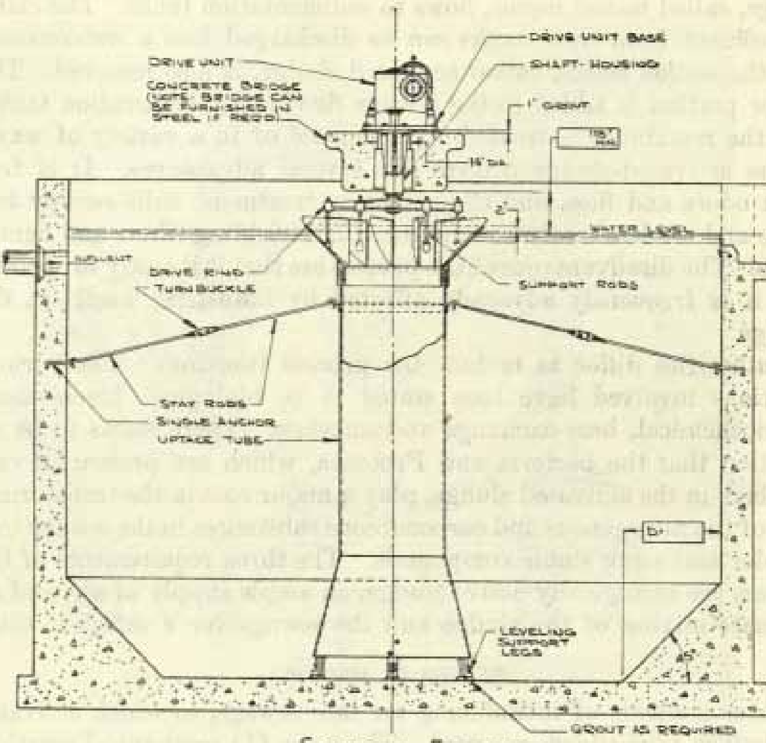
Authorities differ as to how the process functions. The various reactions involved have been stated to be biological, biochemical, physiochemical, base-exchange and enzymic. There seems to be no question that the bacteria and Protozoa, which are present in vast numbers in the activated sludge, play a major role in the transformation of the nitrogenous and carbonaceous substances in the sewage into simpler and more stable compounds. The three requirements of the process are biologically active sludge, an ample supply of air, and an intimate mixing of the sludge and the sewage for a sufficient time.

METHODS OF AERATION

Three methods of introducing air into sewage, to which activated sludge has been added, are used. These are (1) mechanical aeration, (2) diffused-air aeration, and (3) a combination of these two methods. Mechanical aeration consists of providing mechanical means of introducing air from the atmosphere at the surface of the sewage-sludge mixture flowing through aeration tanks. Diffused-air aeration involves blowing compressed air through nozzles, perforated pipes, or porous diffusers at some distance below the surface of the mixed liquor.

Mechanical aeration.—Many different types of mechanical aeration have been perfected. Only two will be described. One of these, called a Simplex aerator (text fig. 5), was developed in Bury, England. This aerator consists of a steel cylinder, which is placed in a vertical position on the center line of a relatively deep tank, with the bottom a few inches above the tank floor. Attached to the top of the cylinder at the surface of the sewage there is a rotating cone with steel vanes, driven by an electric motor. As the cone rotates, it draws the mixed liquid up the cylinder and throws it out over the surface of the sewage in a spray. Oxygen is absorbed from the air by the spray and the agitated surface of the sewage. Simplex aerators have been provided at Princeton, Ill., and Dunsmuir, Calif.

A second type of aerator (fig. 6) embodies the use of a paddle wheel about 30 inches in diameter in the form of latticework, which is sup-



SECTIONAL ELEVATION

FIGURE 5.—Simplex aerator.

ported by and rotates about a horizontal shaft, extending along and adjacent to one of the walls of an aeration tank at the surface of the sewage. A longitudinal vertical baffle, reaching from the surface of the sewage to a point near the bottom of the tank, is provided below the paddle wheel and about 18 inches away from the wall supporting the aerator. As the paddle wheel rotates, it not only breaks up the surface of the sewage, thus exposing it to the atmosphere, but it also imparts a spiral motion to the flow of sewage in the tank. Sewage is drawn upward between the above-mentioned baffle and tank wall from the bottom of the tank. The sewage then flows horizontally across the surface of the tank in contact with the air; and after reaching the opposite tank wall, the flow is directed downward to the tank bottom. Aeration tanks provided with this type of aerator have been installed at Collingswood, N. J., and Fort Atkinson, Wis.

Diffused-air aeration.—Various types of compressors are used to supply air to aeration tanks. During the early history of the activated-sludge process single-stage piston compressors were used. At the present time positive-pressure blowers or centrifugal compressors are generally adopted. The advantage of positive-pressure blowers is that

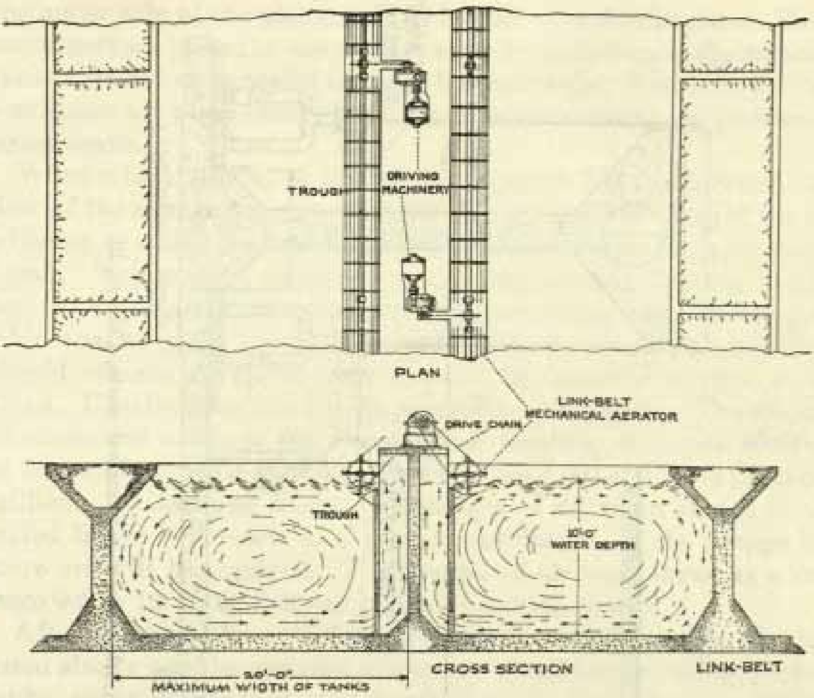


FIGURE 6.—Link-Belt mechanical aerators used in activated-sludge aeration tanks.

their capacity can be varied by changing their speed, and their capacity remains the same even though the frictional resistance to the flow of the air may increase as air diffusers become clogged.

Where air is blown through porous diffuser plates or tubes with narrow air passages, it is necessary to clean the air to prevent the clogging of the plates or tubes with foreign matter. Various methods of cleaning the air are available, such as passing it through a multiplicity of overlapping oil-coated screen panels, canton flannel, or cellulose tissue filters. The mixture of sewage and activated sludge is aerated in long rectangular tanks, a typical cross section of which is shown in text figure 7. Aeration tanks used in the United States are generally designed to have a detention period of 4 to 6 hours. In many instances they are several hundred feet long with a working depth, which has become fairly standard in large installations, of about 15 feet and widths varying from 20 to 30 feet or more.

Many methods have been perfected for introducing air into the sewage in fine bubbles, one of which is to blow the air through porous tubes or plates. Porous plates, 12 inches square and 1 inch thick, are made of crystalline alumina or a high-silica sand. A number of the plates are set in a row in a horizontal position in shallow cast-iron or concrete containers with space provided for the passage of air between

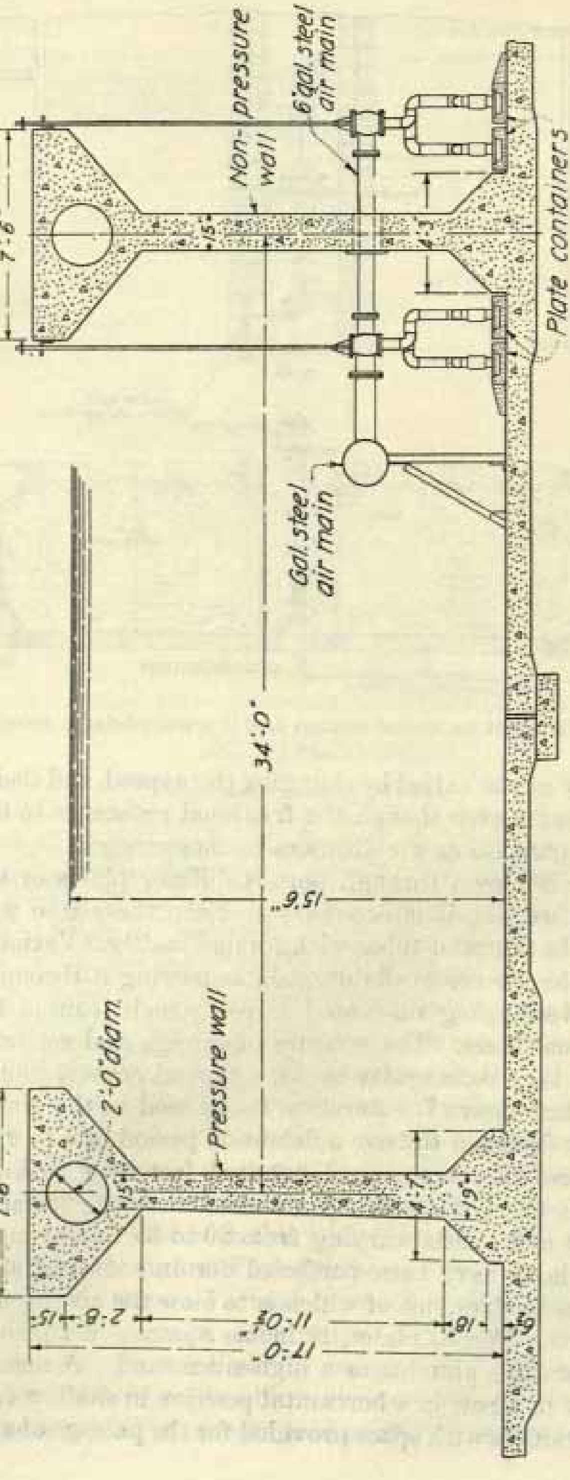


FIGURE 7.—Cross section of aeration tanks at West-Southwest sewage-treatment works, Chicago, Ill.

the under side of the plates and the bottom of each container. These containers are placed in one or more rows in the bottom of the aeration tanks adjacent and parallel to one of the tank walls. From the diffuser containers air pipes extend from the aeration tanks to air blowers or compressors.

When a tank similar to that shown in figure 7 is in operation, the flow of the sewage through the tank and the upward force of the air adjacent to one of the tank walls imparts a spiral motion to the mixed liquor. This motion results in new sewage surfaces coming in contact with the air at the tank surface, permitting the dissolving of additional oxygen. For aeration tanks to be effective the mixed liquor should contain an appreciable quantity of dissolved oxygen at all times. Usually from 2 to 4 parts per million is adequate. The amount of suspended solids in the mixed liquor resulting from the addition of activated sludge is generally kept between 1,000 and 3,000 parts per million. Maintaining higher percentages of activated sludge in the mixed liquor will result in a greater purification of the sewage but more air will be required. The amount of air used varies as a rule from 0.5 to 1.5 cubic feet per gallon of sewage treated.

After the mixed liquor discharges from the aeration tanks, the activated sludge must be removed promptly. Conventional sedimentation tanks, either circular, square, or rectangular, with adequate sludge-removal equipment are usually provided. The sludge must be withdrawn in a fresh condition, as most of it is returned to the aeration tanks for a continuation of the treatment process.

The effluent produced by an activated-sludge plant is generally somewhat better than that from a trickling-filter plant with the 5-day biochemical oxygen demand and the suspended solids averaging from 10 to 25 parts per million. The process has been adopted very widely in this country and abroad for treating the sewage from both large and small cities. A few of the notable installations are in New York, Chicago, and Los Angeles.

LAND TREATMENT OF SEWAGE

The application of sewage to the land and the use of the land for agricultural purposes is one of the oldest methods of sewage treatment, dating back to the middle of the sixteenth century. The sewage thus serves to fertilize and irrigate the soil. A sewage farm must be provided with the necessary pipes and ditches, and the land must be graded to prevent the accumulation of sewage in stagnant pools. Before applying sewage to the land, it is desirable to remove a considerable portion of the suspended solids, which normally tend to clog the soil. The disadvantages of the process are that large areas of land are needed, odors are liable to be produced, and the proper treatment

of the sewage is likely to be neglected for the raising of crops. The process is most applicable in arid countries. Although sewage farms are used to only a limited extent in this country, they still serve to treat the sewage of several large cities in Europe such as Paris and Berlin.

CHLORINATION

Chlorine and chlorine compounds have been used since 1854 for the treatment of sewage. However, it has been only during the past 50 years that chlorine has been employed extensively at sewage-treatment plants. Except at very small plants chlorine is purchased in liquid form in steel containers of different sizes, holding from 100 pounds to 30 tons. It is then fed as a gas in amounts that can be regulated manually or automatically by chlorinators (pl. 3, fig. 1) to any point of application.

The following are some of the uses of chlorine for treating sewage:

1. Odor control.
2. Control of trickling-filter flies.
3. Control of trickling-filter ponding.
4. Reduction of biochemical oxygen demand.
5. Disinfection of sewage.
6. Control of aquatic life.

ODOR CONTROL

Chlorine has been widely used at sewage plants to control odors. Many of the disagreeable odors are due to hydrogen sulfide. When chlorine is added to sewage containing this gas the following reaction occurs:

$$Cl_2+H_2S=2HCl+S$$

Chlorine can be applied to the sewage at one or more points in the sewerage system, at the inlet to or at some point in the sewage-treatment works. It is often preferable and cheaper to apply the chlorine at one or more points in the sewerage system where the sewage is fresh than to apply it at the sewage works where the sewage may be septic and may contain hydrogen sulfide.

CONTROL OF TRICKLING-FILTER FLIES

Practically all trickling filters are the habitat of small flies, called *Psychoda alternata*, which frequently create a nuisance in the vicinity of sewage works. Of the many methods adopted to control them the application of chlorine to the influent of trickling filters has proved quite effective. A sufficient quantity is used for several hours at weekly or biweekly intervals to reduce the adult fly population.

CONTROL OF TRICKLING-FILTER PONDING

One of the difficulties in operating trickling filters has been the clogging of the filtering material with organic solids. The clogging is

often so pronounced that it is impossible to get the sewage to flow through the filter bed. At times it is necessary to remove the filtering material and wash it. As this process is quite expensive, cheaper ways of correcting the difficulty have been devised. One of these is to add a small quantity of chlorine to the sewage being applied to the filter bed.

REDUCTION OF BIOCHEMICAL OXYGEN DEMAND

Chlorine can be used to reduce the biochemical oxygen demand of sewage. This reduction is probably caused by the oxidative action of chlorine. Chlorine reacts with nitrogenous bodies to produce chlorine substitution compounds, some of which are probably useless as bacterial food and are therefore less putrescible. Every pound of chlorine added to sewage is capable of reducing the biochemical oxygen demand about 2 to 2.5 pounds. Using chlorine to reduce the biochemical oxygen demand is not a routine procedure, because the expense is considerable and other cheaper methods of sewage treatment are available.

DISINFECTION OF SEWAGE

Where sewage effluents are discharged into watercourses that are used for bathing, for the culture of shellfish, or for sources of water supply, chlorine is often used to disinfect the effluent. The amount required will depend upon the degree of treatment the sewage has received; sewage that has undergone complete treatment will require less chlorine than that partially treated. Dosages vary from 2 or 3 parts per million up to 25 to 30 parts per million. When sewage effluents are disinfected with chlorine, it is essential that the chlorine be thoroughly mixed with the sewage and be maintained in contact with it about 15 to 30 minutes. If the proper operating procedures are followed, chlorine will kill more than 99 percent of the bacteria.

CONTROL OF AQUATIC LIFE

Where sewage effluents are discharged into some watercourses, both the organic and inorganic matter serve as a source of nutriment for aquatic life such as fungi and algae. These growths may become very prolific and produce nuisances. Chlorine has been applied in a number of instances to inhibit these biological growths.

TREATMENT OF SLUDGE

SLUDGE DIGESTION

The sewage solids, which collect in sedimentation tanks, contain 90 percent or more of water and from about 60 to 80 percent of organic matter on the dry solids basis. Within a few hours after sludge is drawn from sedimentation tanks, it becomes highly odorous. Many ways of treating and disposing of it are available. One method frequently adopted is to store it in tanks, called sludge digesters, where

the material decomposes and eventually loses its objectionable odor. Furthermore, the digested material can be more readily dewatered than the raw sludge. The first digesters were open masonry tanks, in which the sludge was stored for several months before being removed for further treatment or disposal. The first two large sludge-digester installations were put in service about 1911 in Baltimore, Md., and Birmingham, England.

In the 10- or 15-year period following World War I, as a result of considerable research, many of the factors affecting sludge digestion were determined. These included the effect of temperature, the pH value of the sludge, and the percentage of well-digested sludge used for seeding purposes. As a result of this work many improvements were incorporated in the design of digesters. These improvements consisted of providing digesters with rigid or floating covers to collect the sludge gas and prevent the escape of heat from the sludge, facilities for heating the sludge, and equipment for mixing the tank contents.

When sludge is maintained at a temperature ranging from 85° to 100° F., digestion can be accomplished in about 30 days. During the past two or three years, by following certain procedures, satisfactory digestion in about 10 days has been reported by some investigators.

SLUDGE-GAS COLLECTION AND UTILIZATION

When sewage sludge digests, it produces considerable volumes of gas. As this gas contains from 60 to 75 percent of methane with a net heat value of from 540 to 675 B.t.u. per cubic foot, the usual procedure is to collect and utilize it. The quantity of gas produced, which depends upon the amount of organic matter in the sludge, averages about 1 cubic foot per day per capita served by the sewage plant. The gas is used for many purposes, the chief of which is to maintain a suitable temperature in digesters so that the decomposition of the sludge will continue at a rapid rate. The gas is also used for generating power, heating buildings, incinerating sewage screenings, and drying and incinerating sewage sludge. In a few instances the gas is sold to municipal gasworks for general use.

Several methods of heating digesters have been perfected, one of which consists of using the sludge gas to fire boilers and produce steam or hot water. The hot water is pumped through pipe coils suspended in the digester. Another method of heating involves the use of a gas-fired heater, which contains a series of pipe coils. Sludge from the digester is pumped through these coils back again into the digester.

Sludge gas is extensively used as a fuel in internal-combustion engines for power production. About 17 cubic feet of gas with a heat content of 600 B.t.u. per cubic foot will produce one horsepower-hour.

Gas engines usually operate electric generators, centrifugal sewage pumps and blowers. Gas engines can be obtained that use either sludge gas or oil as fuel. If there should be insufficient gas, there need be no interruption in operation, since oil can be used. The advantages of using sludge gas as fuel for gas engines is that considerable power can be developed and at the same time the water used to cool the engine can be pumped through pipe coils in sludge digesters for heating purposes. Many sewage plants have been provided with gas engines. Typical examples are the plants serving Miami, Fla., Toledo, Ohio, and Peoria, Ill.

SLUDGE DEWATERING

As the sludge drawn from digesters contains from 90 to 95 percent water, it is desirable to reduce its volume by decreasing its water content. The two most widely adopted methods of accomplishing this is by sludge-drying beds or vacuum filters.

Sludge-drying beds.—These are level beds of porous material, situated out-of-doors and consisting usually of sand, superimposed on a layer of gravel. Underdrains with open joints are provided under the gravel at regular intervals. Sludge beds are generally divided by means of wood planks or thin concrete partitions into compartments to facilitate operating procedures. The wet sludge flows to the beds through pipes or open channels. The necessary sludge bed area, which depends upon climatic conditions, amounts to about one square foot per person served by the sewage works. Under favorable atmospheric conditions well-digested sludge can be dried in about one or two weeks. When its moisture content has been reduced to about 70 percent or less, the sludge can be removed and another application can be made.

At many sewage-treatment plants (pl. 3, fig. 2) the sludge-drying beds are covered with greenhouses. The advantages of this type of construction are that a somewhat smaller drying area is needed, the problem of odors is less acute, and some sludge can be dried in winter.

The use of drying beds for dewatering sludge has several disadvantages. In the first place unpleasant odors will result if the sludge is not well digested. Moreover it is impossible to dry sludge when the weather is very cold. Extra volume, therefore, must be provided for the storage of the sludge in tanks during the winter.

Vacuum filters.—Vacuum filters (pl. 4, fig. 1) have been used for a number of years in this country to dewater both raw and digested sludge. The moisture content of wet sludge, which will vary from about 90 to 99 percent, can be reduced to approximately 65 to 83 percent by filtration. The amount of water removed will depend upon a number of factors such as the type and characteristics of the sludge, the rotating speed of the filter drum, and the kind and amount of coagulant used.

Several different designs of vacuum filters have been perfected and are in general use. One widely adopted consists of a wooden drum that is supported with its axis in a horizontal position in a lead-lined steel tank. Attached to the outer surface of the drum are a number of narrow wooden strips, parallel with and equidistant from each other. These strips, which divide the periphery of the drum into a number of shallow compartments, support a coarse-mesh screen, around which a filter cloth made of wool, canton flannel, or some synthetic material is wrapped. Vacuum pipes on the inside of the filter drum connect each of the compartments with an automatic valve at one or both ends of the filter. This valve connects with piping that supplies a vacuum to the filter cloth. Sludge enters the filter tank through a sludge supply pipe; and as the filter drum rotates about its axis, a layer of wet sludge about one-half inch thick adheres to the filter cloth. The differential in air pressure between the surface of the sludge cake and the under side of the cloth forces the water out of the sludge and through the vacuum pipes away from the filter. By the time sludge cake reaches the discharge side of the filter, its moisture has been greatly reduced.

One essential step in preparing the sludge for filtration is to coagulate it with a suitable chemical such as alum, ferric sulfate, chlorinated copperas, ferric chloride, or ferric chloride and lime. Of these, ferric chloride is the most effective. Another step in the preparation of sludge for filtration, especially if the material has been digested, is to remove a considerable percentage of the bicarbonates, which are formed as the sludge digests. Since they combine chemically with any coagulant used, it is desirable to reduce their concentration so that less coagulant be required. The concentration of bicarbonates is reduced by mixing the sludge with a large volume of water or sewage effluent and allowing the sludge to settle out from the liquid. The bicarbonates diffuse into the water and are removed.

Sludge filtration is used in many cities in the United States. Three of the most notable installations are in Chicago, Milwaukee, and Los Angeles.

SLUDGE DISPOSAL

The satisfactory disposal of sewage sludge is often a vexing problem that confronts the operators of sewage-treatment plants. In most instances sewage, after it has received partial or complete treatment, is discharged into a watercourse, which quickly removes it from its source; it frequently happens, however, that sewage sludge remains to plague the operator. The following are the more common methods of sludge disposal:

1. Disposal in water.
2. Disposal on land.
3. Heat drying.
4. Incineration.

DISPOSAL IN WATER

Where sewage-treatment plants are situated near sufficiently large bodies of water that can dilute and carry away the sludge without creating unsanitary conditions, this method of disposal has been adopted with considerable success. The sludge is pumped into specially designed steamers that transport and dump it at some remote spot. Sludge has been disposed of in this way for many years at Elizabeth, N. J., and New York, N. Y., in this country, and in London, Manchester, and Glasgow in Great Britain.

DISPOSAL ON LAND

The most generally adopted method of sludge disposal is to apply it to the land, either wet or dry, raw or digested. The methods of land application include lagooning, trenching, flowing on land, depositing in dumps, and distributing for fertilizing purposes.

Lagoons consist of natural or artificial depressions in the ground enclosed by earth dykes. Wet sludge in a semidigested or digested condition is pumped into the lagoons. The disadvantages associated with lagoons is that they occupy large areas of ground, they are frequently odorous, and they are usually a temporary expedient.

Another method of disposal is to pump the wet sludge into trenches, which are then covered with earth. After the sludge has decomposed and the water has drained away, it is often possible to reuse the same land.

At a few plants wet digested sludge is pumped through pipes and channels and allowed to flow over the ground. The sludge serves to irrigate and fertilize the soil. Any crops that are grown should be such that they will not be contaminated by the sludge.

At many sewage plants such as those serving Baltimore, Md., and Washington, D. C., sludge that has been dewatered on sludge-drying beds or by vacuum filters is deposited in dumps. Sludge dumps are unsightly and frequently produce odors; therefore, they are not looked upon with favor by sanitary engineers.

Sludge that has been dewatered on sludge-drying beds or by vacuum filters is widely used by gardners and farmers as a soil conditioner. The water content of the material, which may vary from about 50 to 75 percent, is such that it can be readily applied to and incorporated in the soil. The chief advantages of sludge are that it has excellent moisture-retaining characteristics and contains a considerable percentage of humus. The nitrogen and phosphates in sludge are low. Primary tank sludge contains about 1 to 2 percent of nitrogen on the dry basis, and activated and humus-tank sludge contains 4 to 6 percent. The phosphates in sludge vary from approximately 2 to 3 percent. At many sewage plants a small charge is made for air-dried

sludge or vacuum-filter cake. In other localities where the demand is not great, the material is given away.

HEAT DRYING SLUDGE

When sludge is heat dried, its moisture content is reduced to 10 percent or less. In this condition the material is more easily handled, it can be used as a base for fertilizer, and transportation costs are reduced.

Two methods of heat drying, which have been most generally adopted in this country, involve the use of rotary heat driers and flash driers. A rotary heat drier (pl. 4, fig. 2) consists of a steel drum with its longitudinal axis, about which it slowly rotates, set in a horizontal position. At the end of the drum where the wet sludge cake is added a coal- gas- or oil-fired furnace is provided. As the drum rotates, the wet sludge cake is lifted on the inside of the drum to such an elevation that the sludge falls through the hot gases back to the bottom of the drum. By the time the sludge reaches the discharge end of the drum, its moisture content has been reduced to 10 percent or less. The outstanding rotary drier installation is in Milwaukee, Wis. Rotary driers have also been used at Houston, Tex., Grand Rapids, Mich., and Baltimore, Md.

The flash drying system (text fig. 8) is the second method of heat drying sludge that has been extensively adopted. Heat, which is generated in an oil- gas- or coal-fired furnace, is supplied to a cage mill or flash drier. Wet sludge, to which a known quantity of previously dried sludge is added, is introduced continuously into the drier and is intimately mixed with the hot gases by means of a rotating cage in the drier. The mixture of sludge and hot gases flow vertically upward through a duct into a cyclone separator, in which the sludge is separated from the gas stream. Flash driers have been installed in Chicago, Ill., Los Angeles, Calif., and Houston, Tex.

SLUDGE INCINERATION

One method of sludge disposal that is being more widely adopted is burning it. The two types of incinerators most generally used are multiple-hearth furnaces and furnaces used in conjunction with flash driers. A multiple-hearth furnace (see pl. 5) is cylindrical in shape with a number of horizontal hearths, spaced equidistantly apart. Passing vertically up through the center of the furnace is a motor-operated shaft, attached to which are a series of rabble arms, suspended several inches above each hearth. Wet sludge is introduced on the top hearth, and as the rabble arms rotate they push the sludge from one hearth to the next lower one. Several oil- or gas-fired burners, attached to the side of the furnace, provide the necessary heat to initiate incineration. The bottom hearth is furnished with an outlet for the discharge of the

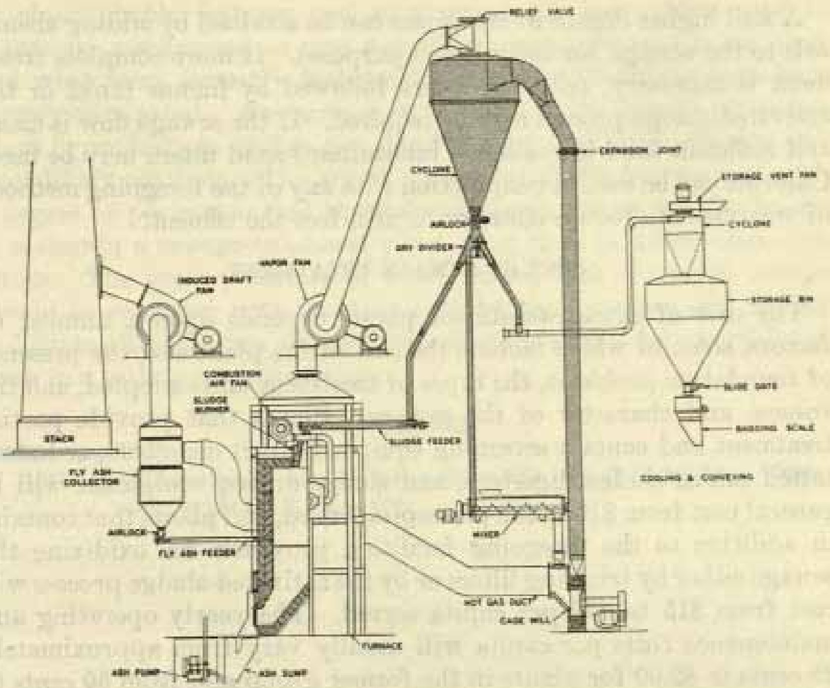


FIGURE 8.—Flash drying and incineration system, Combustion Engineering, Inc.

ash. Furnaces of this type are provided at Detroit, Cleveland, and Minneapolis-St. Paul.

The second type of incinerator combines flash-drying equipment with facilities for conveying the dried product to the drying furnace, where the material is incinerated. This type of incinerator is used at Buffalo, N. Y., Washington, D. C. and Neenah-Menasha, Wis.

COMBINATIONS OF SEWAGE-TREATMENT PROCESSES

The foregoing sewage-treatment processes can be grouped in a number of ways. The processes that are selected depend upon several factors. If the ratio of the volume of diluting water to the volume of sewage is great, it may be that the removal of only the coarse suspended materials is necessary. Should such be the case, fine screens may suffice. Fine screens have been in service for many years at the Canal Street plant and the Dyckman Street plant in New York City.

Where a somewhat higher degree of treatment is required, sedimentation tanks are generally provided. They are preceded by coarse screens and also by grit chambers if the sewage is from a combined system of sewers. The use of sedimentation tanks requires facilities to treat and dispose of the sludge that is produced. Plants of this type serve Buffalo, N. Y., Detroit, Mich., and Washington, D. C.

A still higher degree of treatment can be attained by adding chemicals to the sewage for coagulation purposes. If more complete treatment is necessary, trickling filters followed by humus tanks or the activated-sludge process may be required. If the sewage flow is small and sufficient land is available, intermittent sand filters may be used. Chlorine can be used in conjunction with any of the foregoing methods of treatment to reduce odors or to disinfect the effluent.

COST OF SEWAGE TREATMENT

The cost of sewage-treatment plants depends upon a number of factors, some of which include the cost of the plant site, the presence of foundation problems, the types of treatment units adopted, and the volume and character of the sewage. Plants that provide partial treatment and contain screening equipment, grit chambers, sedimentation tanks, sludge digesters, and sludge-drying equipment will in general cost from $10 to $30 per capita served, and plants that contain, in addition to the foregoing facilities, provision for oxidizing the sewage either by trickling filters or by the activated-sludge process will cost from $15 to $50 per capita served. The yearly operating and maintenance costs per capita will usually vary from approximately 25 cents to $2.00 for plants in the former group and from 50 cents to $4.00 for plants in the latter group. These costs do not include fixed charges.

WHAT OF THE FUTURE?

The growth of the urban population in this country is such that the need to build and enlarge sewage-treatment facilities and sewerage systems will continue perhaps indefinitely. Coupled with this need is the increasing demand by the public for clean streams and watercourses. It is estimated (McCallum, 1955) that $5,330,000,000 will be required within the next 10 years to keep up with this demand.

If the future advance in sewage-treatment continues as in the past, a greater use of mechanical equipment seems likely. There are possibilities that the efficiency of the activated-sludge process can be materially increased, that the time required to digest sewage sludge can be reduced, that the efficiency of sludge filtration can be improved, and that better ways of heat drying sludge will be developed. It is most important that adequate funds and personnel be made available so that research relating to sewage treatment can be continued on a university, city, State, and national level. Much of the future advance in sewage treatment will depend on the emphasis placed on research.

SUMMARY

Sewage-treatment processes have been perfected to such an extent that most any degree of treatment can be obtained with a minimum

of objectionable features and at a reasonable cost. Most modern plants are mechanized so that a much smaller personnel is required, and what were formerly disagreeable working conditions have been largely eliminated. An increase in the use of such sewage-treatment plant byproducts as sludge gas, dried sludge, and plant effluents will most likely continue. The art of sewage treatment has reached such a degree of perfection that there should be no excuse for the failure to maintain a sewage-treatment plant other than in a first-class condition. The gross pollution of watercourses with untreated sewage should be regarded with disfavor both by the taxpayer and by city and State officials, since adequate means are available for maintaining them in a satisfactory condition.

REFERENCE

McCallum, G. E.
1955. 6,685 sewage plants and trunk lines will cost $5.33 billion. Wastes Engineering, vol. 26, p. 504.

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of objectionable features [illegible] plants are mechanized, so that a [illegible] personnel is required, and what were formerly grossly offensive working conditions have been largely eliminated. [illegible] plant byproducts [illegible] most likely continue. [illegible] a degree of [illegible] in maintaining a [illegible] dition. The [illegible] should be [illegible] and that a [illegible] them in a satisfactory [illegible]

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Pioneer Settlement in Eastern Colombia

By Raymond E. Crist and Ernesto Guhl [1]

[With 8 plates]

INTRODUCTION

One of the last great frontiers in the world is the vast tropical rain forest found on both sides of the Equator in Africa and South America. Extensive desert areas have been made fruitful as technical developments brought them life-giving water. The cold lands of Canada and Eurasia have experienced great development during the past half century as man became better and better equipped to cope with the cold. To be sure, millions of people, engaged in agriculture and household crafts, do live in tropical lowland areas, such as the islands in the Caribbean and the Pacific, as well as on the mainland of monsoon Asia. But hundreds of millions of acres in the wet lowland tropics of Africa and South America are still covered by a rank growth of dense forest, and other millions of acres are grasslands or savannas. These vast tracts have remained an almost 100-percent physical environment, on which man has seemed barely able to make a dent, in contrast to the continental expanses of Eurasia and northern North America, which are about 100-percent cultural landscape. But these

[1] The senior author is professor of geography, University of Florida at Gainesville. His field and library work for this article was made possible by a grant of the John Simon Guggenheim Memorial Foundation. Observations along the Pasto-Mocoa route and a reconnaissance trip from Neiva to Florencia were made in 1949 while he was stationed in Popayán, Colombia, as cultural geographer of the Institute of Social Anthropology of the Smithsonian Institution, in charge of its Colombian program of collaboration with the Instituto Etnológico of the Universidad del Cauca. The wholehearted cooperation of the junior author, in the field, in library research, and in the organization of material is hereby gratefully acknowledged.

The junior author, one-time professor of geography in the Escuela Normal Superior, later technical collaborator in the Instituto Colombiano de Antropología, and at present director of the Comisión de Planeamiento de la Seguridad Social Campesina, Ministry of Labor of Colombia, acknowledges his indebtedness to those organizations in helping to make possible his contribution to this article as well as to the geographic literature of his adopted country.

trackless forests are gradually being penetrated and settled, along their borders as well as along the great rivers that drain them. In what might be called the "Wild East" of the Republic of Colombia, there is a broad transition zone where low-lying, grass-covered plains, the llanos, and the great rain forests of the upper Amazon and its tributaries seem to break on the foothills of the towering Andes like billows on a rock-bound coast. This is a sector of the vast area mentioned in "Partners in Progress," the report to the President by the International Development Advisory Board (March, 1951):

> In South America, east of the Andes, runs a 2,000-mile-long stretch of fertile valleys and plateau land which may lend itself to development. If carried through successfully, it would open up a new major source of food for the entire Continent, as well as a home for settlers from the most densely populated areas of Western Europe. (P. 38.)

This sector of Colombia has been of interest to geographers for many years. Perez wrote almost a century ago:[2]

> What was there in the Europe beyond the Rhine in Caesar's time? A vast forest unknown to the Romans, but from which later issued a horde of barbarians who invaded and destroyed the eternal empire. Today in this same forest, now covered with rich and populous cities, kings and emperors who govern a population of 100,000,000 people, display their power.
>
> It is certain that within one or two centuries Colombia will have a very large population. Meanwhile the growing population of Pasto, Popayán, and Neiva will push across the Cordillera Oriental; it will fell the forests, open roads, found towns, and gradually penetrate the vast plains of the immense Amazon Basin. (P. 441.)

The scarcity of agricultural land in the mountain sectors of Colombia—indeed of Andean South America—has grown ever more acute, especially during the twentieth century. In those areas blanketed by volcanic ash, soils were rich and deep, the inhabitants were industrious, frugal, and prolific, and the ownership of land was the summum bonum. Land was rarely bought or sold; it was divided equally among the numerous heirs each generation, with the result that plots became so small as to be uneconomical to work and not productive enough to support the owner and his family. Thus land hunger in the mountainous sectors became acute.

In other parts of Colombia, both in hot country and in cold country, much land formerly intensively cultivated has been incorporated into large estates devoted to cattle grazing.[3] At the same time the intensive agriculturalists have had to move ever higher into the mountains onto

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[2] Perez, Felipe, Jeografía física i política de los Estados Unidos de Colombia, Bogotá, 1862.

[3] Crist, R. E., The Cauca Valley, Colombia, land tenure and land use, 118 pp., Baltimore, 1952; The personality of Popayán, Rural Sociology, vol. 15, pp. 134–135, June 1950; Fixed physical boundaries and dynamic cultural frontiers: A contrast, Amer. Journ. Econ. and Sociol., vol. 12, No. 2, pp. 221–230, April 1953.

the steeper, less fertile sectors, until even the poor areas were taken up. Then these people, face to face with hunger, were forced to migrate or perish. The great estates absorbed very few of these docile, submissive workers, and even those few at ridiculously low wages. Many of these uprooted workers sought employment in the mines or on the highways under construction in various parts of the country; still others were willing to venture into the virgin country to the east and south of the great wall of the Cordillera; it is with these latter that this paper will in large part be concerned.

Over a period of many years field investigations have been carried out in the transition zone between the Andes and the lowlands to the south and east, in Venezuela, in Colombia, and in Bolivia. Some of the results of these studies have been published in various journals.[4] It is proposed in this paper to make a preliminary survey of actual settlement in the Republic of Colombia of the eastern slopes of the Cordillera Oriental and the adjacent plains, or llanos.

Although there are many passes across the Cordillera Oriental, the observations on which this paper is based were made largely along those highways that are the most significant, actually or potentially, in giving access to the sectors of lowland eastern Colombia tributary to the Orinoco and to the Amazon. Field studies were also made along the mountain front itself, as well as on the great plains, or llanos. The sectors served largely by the highways listed below will be discussed:

Bogotá–Villavicencio.
Neiva–Florencia.
Sogamoso—Agua Azul.
Pamploma—Río Frío.
Pasto–Mocoa.

THE BOGOTÁ-VILLAVICENCIO HIGHWAY

CLIMATE

Most readers are more vividly aware of climatic conditions if they know some details about day-to-day temperatures, rainfall, humidity, and winds than if they see "fossilized" weather on a climatic map. Hence some introductory remarks are in order on the elements of weather and climate of Villavicencio, a typical "gateway-to-the-llanos" town.

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[4] Crist, R. E., Along the Llanos-Andes border in Zamora, Venezuela, Geogr. Rev., July 1932, pp. 411–422; A cultural traverse across the eastern and central cordilleras of Colombia, Bull. Pan American Union, March 1942, pp. 132–144; Bolivia—land of contrasts, Amer. Journ. Econ. and Sociol., vol. 5, No. 3, pp. 297-325, 1945; Along the Llanos-Andes border in Venezuela—then and now, Geogr. Rev., April 1956, pp. 187–208.

The rainfall at Villavicencio, 500 meters above sea level, is high, with an average for the 6-year period (1941 through 1946) of 4,670 millimeters (184 inches). It is fairly well distributed throughout the year, with more than 400 millimeters a month from April through November. The evaporation rate is high and the runoff rapid, and one does not feel any marked oppressive humidity. Temperatures at night are about 70° F. and the maximum day temperatures fluctuate between 86° and 93° F.[5] Thus cool evenings and nights follow hot days in pleasant succession, and the annoyances that are thought of by so many people as being synonymous with a tropical climate are minimal.

Precipitation at Buena Vista, 1,200 meters above sea level but only 6 kilometers from Villavicencio, is 6,400 millimeters, or just twice that received at Puerto Lopez, 75 kilometers east of Villavicencio, which is the head of navigation on the Meta River.

From the Venezuelan frontier southward and westward to the Macarena Massif (some 50 miles southwest of Villavicencio), stretches of savanna alternate with densely forested areas. From the Macarena mountains to the border with Ecuador, the entire area is forested. This steep-sided block-fault mountain seems to lie in a zone with a climate transitional between that of the Orinoco area, where the wet and dry seasons are marked, and the Amazon region in which abundant precipitation falls throughout the year;[6] further, although itself uninhabited and located in a sector where there are at present no permanent settlements, impressive petroglyphs are to be seen that have been carved in hard quartzite.[7]

SOILS

The extremely sandy, permeable soils of many of the foothills and of the alluvial fans laid down by intermittent streams have been used largely as open range for what too often is rangy scrub cattle. Prospects for crop production on such soils are poor. However, low yields of dry rice could probably be obtained. In general it would probably be best left as rangeland on which improved pasture could be introduced. It might be mentioned, however, that many of our concepts of geography, acquired in middle latitudes, may be subject to revision. Marked and rewarding changes might perhaps be inaugurated in the cropping practices of these soils if the annual savanna fires are prevented, if the hard crust is broken up by deep plowing,

[5] Bates, Marston, Climate and vegetation in the Villavicencio region of eastern Colombia, Geogr. Rev., October 1948, p. 570.

[6] Philipson, W. R.; Doncaster, C. C.; and Idrobo, J. J., An expedition to the Sierra de la Macarena, Colombia, Geogr. Journ., vol 117, pt. 2, p. 191, June 1951.

[7] Gansser, August, Altindianische Felszeichnungen aus den kolumbianischen Llanos, pp. 85–98.

and if animal fertilizer, phosphates, nitrates, lime, and trace elements are used wherever necessary.

Usually just beyond the front ranges or foothills there is a zone of predominantly light-textured alluvial soils, with occasional belts or strips of heavy-textured soils, and the vegetation grades from low rain forest to bunch grass interspersed with scattered brush and small trees. These soils are generally of dark color to a depth of a foot or more, and the water table seldom falls to more than 3 feet below the surface even in the dry season; they are cleared and prepared for cultivation with relative ease. With good crop adaptation and management these moderately fertile soils would be very productive. At present, yuca, corn, and plantains are generally very successful on the better types of this soil. Much of the rice cultivation around Villavicencio is on the deep soils of this type, and any substantial expansion of rice production will probably be brought about through mechanization and the introduction of chemical fertilizer on this same type. Peanuts would probably do very well on the better drained soils of this type. Those phases of this soil type that are light in texture and poorly drained have been largely used for pasture on a rather empirical basis. If attention were paid to improving both pastures and livestock, production per unit area would surely be greatly increased. Sugarcane is grown, mainly for local use. Yields are fair and replanting is usually done after three or four years of ratooning. The use of a soil-building crop, adjusted to this climate, in a crop rotation would certainly increase productivity of many of the crops now being grown on these soils. Between Villavicencio and Puerto Lopez the extensive treeless sectors of claypan soils, underlain by an impermeable layer, would seem to be ideal for the large-scale production of paddy rice if abundant chemical fertilizer were used.

The deep, well-drained, medium-textured, fertile, alluvial soils in heavy rain forest are well adapted to the production of plantains, corn, yuca, vegetables, citrus fruits, and improved pasture for cattle. These soils of sandy loam have a pH content of 6.0 to 7.0 to a depth of 3 feet or so. At present, one of the limiting factors in developing this kind of land for large-scale commercial agriculture would be the expense involved in clearing. However, the labor and time of the pioneer with a machete are his own, so he does not count the cost. With reasonably good soil management this kind of land is extremely favorable for cultivated crops for a period of years; even without the use of fertilizers it will not deteriorate rapidly.

The soft shales and limestones in the vicinity of Cáqueza, on the Bogotá-Villavicencio highway, make an excellent soil, on which live in dispersed settlements a dense population. This area was originally peopled by settlers from mountain slopes higher up and still receives recruits from there in spite of the fact that this sector in turn, owing

to population pressure, supplies recruits for the settling of the piedmont forest and of the llanos at lower elevations. In somewhat the same manner Yankees migrated *from* New England at the same time that French Canadians migrated *to* New England, for living conditions that seemed grim to Yankees seemed rosy to French Canadians. Once the motor highway was constructed across the mountains, from Bogotá to Villavicencio, that "gateway-to-the-llanos" town began to flourish. The piedmont forest was soon cut away and land-hungry settlers entered the great plains themselves.

For centuries the vast grassy plains, or llanos, of Colombia, like those of Venezuela, have been ideal for the extensive grazing of cattle. However, with the construction of the Villavicencio-Bogotá motor road, intensification of agriculture is possible over large areas, rice is being grown as a cash crop, and land values are increasing. Rice production for the local market began about 40 years ago, during World War I, when there was an influx of immigrants, mainly from Cáqueza and Quetame, where population pressure had built up. During the twenties, there was vigorous trade between Villavicencio, Cáqueza, and Bogotá, in spite of the appalling state of the mule trail. The highway between these towns—the result rather than the cause of settlement—was completed between the years 1932 and 1936 and was later extended to Puerto Lopez on the Meta River. With its completion there was a second wave of immigration, and rice became an increasingly important crop when it could be sent by truck to the Bogotá market at a handsome profit. The immigrants spread over the area of fine-textured alluvial soils between the Guatiquia and Guayuriba Rivers. Here they could grow dry rice (secano), mostly on plots of from 5 to 10 acres in size. A few farmers cultivate from 100 to 250 acres. The crop is harvested and sacked by hand, and then transported by pack mule to one of the rice mills in Villavicencio (pl. 1, fig. 1). Farmers' lots vary in size from 1 or 2 muleloads to as much as 150. In the mill the crop is dried, threshed, hulled, and sacked. Then it is piled neatly on a platform where it is tested by buyers, loaded on trucks, and shipped to Bogotá.

A third wave of immigrants has been arriving in the Villavicencio area since the political disturbances between 1950 and 1953. Most of these recent comers are from Tolima and Caldas. It is indeed fortunate that this third wave of immigrants, and the second wave to some extent, is able to enjoy the advantages of certain modern public health measures. A vigorous health campaign has all but wiped out malaria, once the scourge of this fertile area. To appreciate the significance of this change one has but to read the accounts of travelers a generation or two ago:[8]

[8] Rice, Hamilton, Further explorations in the northwest Amazon Basin, Geogr. Journ., vol. 44, No. 2, August 1914.

Villavicencio is no place for persons of nervous temperament, nor are the people whom one begins to meet a day before the town is reached [over the trail from Bogotá] pleasant to look at, with their lemon-tinted, gaunt, emaciated faces and hands of horribly lethal thinness. (P. 140.)

Traveling in this sector is even today not without its hazards. Even the main road to the southwest, between Villavicencio and San Martín, is graveled only part way. The forest has been cut away and corn, yuca, plantains, and rice are grown for the Bogotá market. The bridge for heavy traffic across the Humadea River has been under construction for years. Motor cars or empty trucks can cross the narrow, shaky suspension bridge, but loaded trucks must be unloaded and their cargoes carried across. Each handling, of course, increases the price the consumer must pay for his foodstuff (pl. 2, fig. 1). While waiting for the station wagon to cross the bridge we visited with a family, originally from Tolima, who had settled in good faith on what they understood was state-owned land (terrenos baldíos), on which they had built a clapboard-roofed house and cleared plots for their cash crops (pl. 1, fig. 2).

They are now engaged in a dispute with a person from San Martín who claims that the land legally belongs to him, and who has a paper (escritura) to substantiate his claims. Of course, he had never done anything himself that would give the land value; he merely shows up to take advantage of the fruits of the labors of others. The woman of the house is the mother of 10 children, three of whom are grown and work their own plots of land in this sector. All her children are living. The public health factor is extremely important. Whereas a generation or so ago half or more of the children would die in infancy, now a much higher percentage lives to maturity. And the child bearing days of this particular woman are probably not over—as the local idiom has it, she still has "la casa ardiendo"—roughly equivalent to "still going strong."

Many of the mountaineers who came into this area to work as laborers when the highway was under construction cleared land and settled on it after the work was completed. Many of them are now planting coffee and cacao, which will make them a tidy income later. They grow rice, corn, and yuca as subsistence crops; any surplus finds a ready market.

San Martín was founded by the Jesuits as a mission in the seventeenth century, yet 40 years ago it consisted only of "rambling houses and a half-completed church built around an enormous plaza." [9] But there is good reason why the village did not prosper. In 1912 Hamilton Rice, a medical doctor, found the tertian form of the malarial parasite, sometimes in conjunction with the subtertian, in all the 250

[9] Rice, loc. cit., p. 142.

cases of adults and children whose blood he examined. His picture of the tiny struggling village is indeed pessimistic:

> San Martin, with its innumerable puddles, ditches, and foul house yards is a prolific breeding ground [of the malarial mosquito], and, owing also to the existence there of an especially virulent form of malaria which the rubber-collectors and muleteers bring in from the adjoining swamp district, the town has a notoriously and deservedly bad reputation. The town carpenter, whose most lucrative business is the making of coffins, and who thus serves as the only available bureau of vital statistics, assured me he made from two to three a week, but added, with a grim smile, that many have no pesos with which to pay and are buried without boxes. (Loc. cit., p. 142.)

San Martín has experienced rapid growth during the past generation. It would not be recognized by those who saw it 30 years ago. The best-selling item in the large drugstore is face cream, closely followed in importance by nail polish and lipstick! Safety-razor blades are sold at the rate of slightly over 3,000 a month. Many migrants pass through here on their way south and west, to areas as yet unsettled, particularly around Boca de Monte, 8 miles south of San Martín (pl. 2, fig. 2). This village, only a few years ago a cluster of palm thatch huts literally at the edge of the forest, as the name implies, is now a thriving center, owing largely to the arrival of some 300 people from Armenia (Caldas). These settlers told of the grim struggle for existence in their former locale, where land is scarce and hopelessly subdivided into plots so small as to be uneconomical, and where wages are pitifully low; they have brought with them their seasoned habits of frugality and hard work, and have carved farmsteads out of the public lands on which corn, yuca, and plaintains are grown for home use, and rice for the market (pl. 3, fig. 1). As the edge of the forest recedes the name Boca de Monte will have a significance more historical than actual (pl. 6, fig. 1).

The Ariari River southwest of Villavicencio is the boundary line between conservatives and liberals, who have a fierce and deadly hatred of each other. To quote a normally mild-mannered bus companion: "It is necessary to kill a lot of people, but those who *should* be killed are the ones who are *ordering* people killed." The conservatives on the left bank have the road, but the liberals on the other side have the good land. These enemies are trying to cooperate enough to put up across the river a cable, which can be used by both factions. Perhaps if the federal government built a road and a bridge the political hatred, reminiscent of the religious intolerance and intervillage feuds of the Near East, would die down somewhat. The serious workers do want peace and work, rather than fighting and revolutionary activity. Everyone was happy that the coup d'état (June 1953) of President Rojas Pinilla put an end temporarily to fratricidal strife and opened the way for productive effort again. Some there were who had ac-

quired the habit of stealing rather than working, during the years of civil strife, but fortunately they were rapidly returning to the good old-fashioned custom of hard work.

THE NEIVA-FLORENCIA HIGHWAY

During the war with Peru in 1932, when the most deadly enemy proved to be the diseases so often associated with the Tropics, Colombian Amazonia assumed great importance for the nation. The national government hastily planned roads into a vast tropical area that had been so long neglected as to create serious differences of opinion as to just where the international boundary line should be drawn. The road as originally planned was to run from Neiva to La Tagua on the Caquetá River, via Florencia and Tres Esquinas, the latter town at the junction of the Caquetá and Orteguaza Rivers.

FLORENCIA

In the last decade of the past century, gatherers of wild rubber and quinine made clearings along the Orteguaza and Hacha Rivers on which they planted yuca, corn, and plantains. Shortly after this a clearing was made for the planting of cane, and a still was set up for distilling raw rum. The first settlement was called La Perdiz, but the name was soon changed to Florencia. Then depression struck the wild-rubber and quinine industry and very shortly all that remained of Florencia was the name.

The town of Florencia was officially founded in 1908 when 37 of the principal settlers agreed to construct their houses in accordance with a map drawn up by the Capuchin priest, Father Fidel de Montclar.

The highway reached Florencia from Altamira in 1932, at the time of the war with Peru. The construction of the road meant that this potentially rich area became economically tributary to a hinterland from which it attracted immigrants and to which it could ship its products. In this instance the highway was the cause rather than the result of settlement.

The people who actually settle on the land are the advance columns who make it possible for the bridgeheads along the piedmont to survive. The highways and rivers are the arteries along which flow people, the lifeblood of any area. A major factor that animates the heart that pumps this blood is demographic pressure. The more one sees of active, voluntary colonization the less faith one can have in settlement projects sponsored by the government. For one thing government agents, representatives, or inspectors, are little interested in going to zones in which actual pioneering is taking place. They want to "inspect" areas that are already equipped with airstrips, hotels, or guest houses, and other modern conveniences. In several places it

was pointed out to me that "no one from the government ever comes out here. A man from Bogotá might spend the day in Florencia between planes, but *we* never see him!" The bus drivers were amazed that I should want to go to Montañita, the end of the line.

In the environs of Florencia, with a radius of 8 to 10 miles, the forest has been cleared away and permanent pastures have been established. This area has been settled long enough so that trees and stumps have all completely decayed. However, from Venezia southeastward to Montañita the country has been cleared much more recently; dead trees are still standing in the fields and not all of the felled trees have rotted away. The foothills of the mountains look as if they had had a very irregular "soup bowl" haircut.

SOILS

The soils between Florencia and Montañita, in the areas with almost no gradient as well as on the slopes of the low hills, are fine-textured but fairly well drained. Those southwest of town, on the road to Belén, are poorly drained. Ponds of water, some small, others acres in extent, stand in the pastures for days after each rain. They dry up only when there is a week or so without rain.

MONTAÑITA

Montañita itself, 20 miles southeast of Florencia, is in an area of rapid colonization. It was just a group of houses (caserío) till 1940 when a central square, or plaza, was laid out where meat and other products were brought in for sale. The case of Mr. Muñoz is typical (pl. 5, fig. 2). He had settled on a piece of land half a mile from Montañita when he came to this sector in 1922. The whole area was in forest at that time, and tied to the outside by a very poor mule trail. He worked on the telegraph line for four years while clearing land for pastures and food crops. By now he has some 300 hectares cleared—75 where he lives and 225 on the trail to the village of Puerto Rico. The farmer is self-sufficient as far as basic foodstuffs are concerned. He has 1¼ hectares of plantains, one-half hectare of yuca, and one-quarter of sugarcane. The cane continues to produce enough sweet juice each year for household use, although it has not been replanted in 30 years. The soil is good, but not so good as it is in Huila. It is especially poor in calcium, and deficient in nitrates and phosphates. Fertilizers would be a great boon, but chemical fertilizers are too expensive, and animal fertilizer is not collected. The existence of vast areas of unoccupied land means that ranchers are not interested in intensification in the use of land already cleared to the extent of stall feeding of soilage crops in order to make use of the stable manure for restoring the fertility of fields under cultivation. Citrus fruits would do well, but no one plants or tends them systematically. Vegetables

are little planted or used. There is plenty of meat available, a little milk, but practically no cheese.

The son-in-law of the rancher, Mr. Diaz, was worried about the generally inadequate diet and its relationship to death-dealing diseases, such as malaria, or *paludismo* (almost any fever goes under this name), and to tropical anemia, caused in large part by hookworm infestation. Mr. Diaz himself had had yellow fever and was very near death's door, but had recovered—thanks, he felt, to the fact that he had always had a fairly adequate diet. He hoped that some kind of extension service, which would bring farmers advice on agriculture and on diet and health, would be inaugurated by the federal government. But he was not too hopeful. He did mention a case of the unexpected consequences that can come from man's interference with the natural environment. In the days of banana-patch plumbing, the well-drained area of Montañita and vicinity was relatively free of mosquitoes. However, the construction of privies has meant the creation of stagnant pools of water in which mosquitoes find an ideal built-in breeding place. The result is a plague of those pests and a high incidence of malaria. In spite of this hazard, however, everyone seemed happy to be in this pleasant spot. "The climate in Huila may be more salubrious, but here it is easier to make a living," commented the head of the house. And those born and brought up in this part of Colombia are in love with everything about it and have no desire to go anywhere else. The oldest son had returned to Huila for his bride, but he had no desire to stay there. All the women seem extraordinarily fertile. The man of the house told me of the wonderful remedies to be found in the forest, particularly for such indispositions as a "touch of fever," or constipation, or a bilious attack (quina [wild quinine], mochilita, and higuerón, in that order).

The influence of a highway is felt over a wide zone. For example, the small village of Puerto Rico, northeast of Montañita, and San Vicente del Caguán, a good day's horseback ride beyond, both formerly shipped their products by mule train across the mountains to Algeciras and Neiva. However, with the extension of the road from Florencia to Montañita, the commercial activity of Puerto Rico is oriented in the direction of the end of the truck route at Montañita. The produce from San Vicente, however, still moves over the mountains by muleback to Algeciras.

LARGE ESTATES AND SMALL CLEARINGS

Southeast of Florencia, at the confluence of the Orteguaza and Hacha Rivers, the extremely wealthy Lara family has bought an estate of some 15,000 hectares of land, on which several thousand head of steers graze. They got government land cheap, tied to a well-populated hinterland by a fairly good road. The investment is bound to

increase in value. They have a small port on the estate, called Puerto Lara, to which settlers from downriver bring their produce in great dugout canoes, or *bongos*. Bags of yuca, corn, rice, and plantains, along with fattened hogs, chickens, exotic birds, sewing machines, suitcases, and household effects, are here transferred from the dugouts to trucks for shipment to Florencia, Neiva, or even Bogotá (pl. 5, fig. 1). Some canoes were loaded entirely with huge planks of mahogany and tropical cedar. The dugouts are no longer paddled by hand. Every one of them has a little outboard motor attached to it, and this means a relatively cheap and rapid means of transport for both goods and passengers. The head of canoe navigation on these rivers running from the eastern Andes into the llanos is now, thanks to the internal combustion motor, easily reached by people living 50 miles or more out on the plains. When canoes had to be paddled by hand the settler had to live within 10 or 15 miles of the head of navigation. One settler on the Rio Pescado, 25 airline miles away, brought two immense hogs, fattened on corn and yuca, to be loaded on the truck and marketed in Florencia (pl. 4, fig. 1). It would have been impossible to transport them by dugout canoe when the trip was measured in days instead of hours. About 80 percent of the settlers who are establishing their beachhead farms on the rich *vega*, or natural levee land, along the rivers are from Huila. This man with the fat hogs for sale originally came from Armenia, Caldas, 17 years ago. He has some good pastures on which he would like to fatten cattle, but he has been unable to find any lean steers for sale.

FOOD CROPS AND VILLAGE TRADING TECHNIQUES

The frontiersman in the Andean foothills plants his patch of yuca, corn, or plantains, depending on the local climatic and edaphic conditions, and on the starch to which he has always been accustomed. However, the favorite starch food for the dweller of the llanos is the *topocho* (*Musa paradisiaca* L.), a small eating and cooking banana that is resistant to high winds, drought, and lack of care. Rice and corn are frequently planted between the rows. When harvested, the rice is kept in sacks in the loft while the ears of corn are tied in pairs by the husk and hung near the roof over the open kitchen fire. This protects it from weevils. Once a topocho patch is started it continues to bear for years; it is bread, the very staff of life, for the llanero. When grated and dried in the sun it is used in making fecula for feeding small children; green or ripe it is used at every meal—boiled, baked, roasted, or fried. The topocho is also used as chicken and hog feed, and is fed to work animals and milk cows. The leaves are used as wrapping paper in an area where that commodity does not exist.

In the tiny stores on the streets nearest the public market an infinitesimal amount of goods is sold each day—possibly not more than 5

pesos' worth. However, it is impossible to get at the real economic life of most storekeepers in terms of statistics. Books are simply not kept. Further, urban and rural functions are so tightly interwoven that it is next to impossible to unravel the individual strands. For instance, María Vermeo has a plot of 10 hectares ("more or less") of land 2 miles west of Florencia. She raises corn, plantains, yuca, rice, and sugarcane, and grinds her cane and makes crude sugar in a primitive *trapiche*, or mill. She also has 10 milk cows. Two of her sons have a tiny store on the plaza where they buy, sell, and trade chickens, hogs, eggs, plantains, or anything that comes along. They take one meal a day at the Tolima Hotel, owned by a cousin, to which their mother purveys firewood, milk, crude brown lump sugar, and cooking bananas. Hogs on Doña María's farm are fattened on the slops from the hotel. But statistics of any kind are lacking wherewith to analyze the economic lives of these people, most of whose activities cannot be tabulated by IBM machines. Some 80 to 90 percent of rural Latin Americans live what are to them very satisfactory lives, completely beyond the realm of statistics. Although from the point of view of classical economic theory they do not exist at all—a fact that adds zest to the study of man's incumbency on the earth in that whole vast cultural area—Latin Americans are making increasingly efficient use of their human and natural resources.

FOREST SETTLEMENTS

On the weekly flight from Florencia to the frontier military post of Puerto Leguízamo, on the Putumayo River, the only intervening stop is at Tres Esquinas, where the Río Orteguaza joins the Caquetá. Colonists have penetrated the heavy forest on a wide front south and east of Florencia as far as the point where the Río Pescado empties into the Orteguaza. From there on to the Putumayo one flies over continuous treescape with a totally unlived-in aspect. Tres Esquinas, Puerto Leguízamo, and La Tagua on the Caquetá, are typical of settlements made for strategic purposes along rivers. The river bank is cleared for a half mile or so on either side of the settlement, but only a few hundred yards behind the settlement the dense forest swallows up a trail or a road and holds sway in all majesty. Such settlements have no hinterland, and hence contrast sharply with the settlements at the foot of the mountains, such as Florencia, Mocoa, or Villavicencio that do have a hinterland, and are tied to it by a highway. For even a poor road is better than no road at all. Landslides can and do block passenger and truck traffic for days at a time. However, the caravans of cars and trucks thus blocked do eventually get through, even in the rainy season, and even if truck drivers have to help run bulldozers and bus passengers, in relays, have to help push the bus or shovel earth (pl. 3, fig. 2).

THE SOGAMOSO-AGUA AZUL HIGHWAY

It should always be kept in mind that a highway is built and is used for two-way traffic. If, for example, a road is built from a densely populated sector, X, to a frontier zone, Y, in which a sparse population is precariously established, the road can be a boon to the people of Y, for they can now send produce to, and import goods from, X. However, if an epidemic should break out, or if the political situation should become menacing, or if other physical or man-made catastrophes should arise, then the role of the road is reversed, as it were. That is, people will use it to flee from Y in order to achieve the relative safety of X, and Y will be drained of its inhabitants. A case in point is the area south and east of Sogamoso, a prosperous urban center set in a valley worked by thousands of industrious small-plot agriculturalists. The highway connecting this mountain center to the llanos crossed the high, cold *páramo* country around Lago de Tota, where the inhabitants earn the barest of livings by grazing sheep on the bleak mountain sides or by growing tiny patches of potatoes. Only very gradually had this hard-working population begun to seep over the mountains to the llanos, along the precipitous trail used for walking rangy steers from the great plains to market. The road was a boon to the area; settlers came in in greater numbers, army posts were established in Pajarito and in Agua Azua, and what had formerly been almost exclusively a cattle trail became a busy highway with thriving two-way traffic. Then came the civil disturbances—the years of *la violencia*, as the internecine strife is referred to locally. Rival factions engaged in indiscriminate killing. Many people on both sides lost their lives, many more took to the wilder, more rugged terrain and waited for the storm to blow over, but an even greater number very early in the struggle reached the comparative security of the large cities by simply using the highway. Thus the area was effectively drained of a great number of its hard-working, peace-loving inhabitants. Only in 1953 and especially during 1954 were they beginning to come back.

To be sure, many of the settlers left the mountains for the eastern frontier zone for social and political rather than purely economic reasons. They sought a new world in which to enjoy freedom from societal restraints rather than a geographic frontier in which to work out their economic freedom. But their very cultural heritage militated against their being able to take full advantage of the resources offered by virgin, unsettled territory. A reflection of this situation was the revolutionary movement in the eastern llanos during the years 1950–53, one of the most significant sociological phenomena in the Western Hemisphere during recent times.

A COLOMBIAN PIONEER

All over the world there seems to be a rural exodus, a kind of tidal wave of human beings leaving the land for urban agglomerations, large or small, that grow by accretion. However, a reversal of this process seems to be taking place in various parts of Colombia, particularly in the transition belt between the vast plains of alluvial deposition and the massive Andean wall. To be sure, many of the settlers entering this zone have been pushed off the land, either from large estates or from plots too small to support a family. However, a large part of this wave of migrants is made up of former urban dwellers, men who have made their living as artisans or as industrial workers. It can become so difficult to make a living in urban agglomerations that they cease to grow by accretion—indeed they may, and do, supply the recruits for pioneer fringe settlements. The pioneer settlers are to a great extent mountaineers, rural or urban, who hail from those regions of cold, rugged terrain that are feeling the effects of the continued and increasing pressure of population upon the land resource. Competition for jobs is extremely keen and the struggle for mere survival is grim.

In order to pinpoint this colonization and to hoist it out of the realm of mere statistics, detailed notes were taken on one family that might be considered typical.[10] Tiberio Valderama Gallo is an Antioqueño who, with his wife and family, is working out his salvation as a pioneer in the foothill area south of Sogamoso. As a young man, still a bachelor, he left his native province for the Chocó, where he worked as a mechanic, or at any work he could find, in connection with a mining enterprise. He saved little money but saw some of the country. In 1935, at age 25, he married María Sánchez, age 18, who had had some experience as a nurse. Then for eight years he worked as a carpenter in the province of Antioquia and in the cities of Zipaquirá and Sogamoso. His memories of the back-breaking, soul-depressing labor were still vivid. He kept longing to get out of this treadmill into something where he would be independent. The opportunity seemed to present itself when a "voluntary" contribution was asked from the workmen on the occasion of the marriage of the daughter of the owner of the small factory in which he was working. He spoke of the poverty of the workmen, of the relative affluence and economic security of the "patron," and he rebelled at the thought of having to pinch a contribution out of the bellies of his family, which by then (1942) consisted of five children, in order that the sleek, fat daughter

[10] Detailed studies by social anthropologists are yet to be made of social stratification and value systems in the pioneer zone and in the sectors from which the pioneers are coming. It is to be hoped that this virgin field will soon find workers.

of his "patron" might have a sumptuous wedding. He left Sogamoso with his family for the tiny hamlet of Pajarito, which is lost in the midst of the heavily forested, steep mountain slopes. He left his family in a one-room hut and went on without a cent to a plot of ground he was to clear, near Cupiagua. He had nothing, but *nothing*, he insisted, and this meant just that. For the first two weeks he lived on cooking bananas, boiled or baked, mixed with salt—these and nothing else. He planted small patches of corn, of bananas, and of yuca. Meanwhile, his wife and children were living on a diet barely able to hold body and soul together. When a temporary shelter was built on the clearing, she sold her stockings and ironing board to get enough to hire a pack mule on which to load her few belongings. Then she set out on foot for the clearing. The night she arrived they experienced the worst storm of her life and spent the whole night in fear and trembling. The roof held and it was clear on the morrow, and both she and her husband said that, in spite of storms, they were so glad to be here at the edge of the forest where one was independent. The dominant motive behind the move was the unquenchable desire for independence. He was determined to go forward, to migrate, without looking back. He knew that he had burned his bridges behind him and that it was on the frontier where he must make his living. To be sure, he might send his family away to be educated, but he would carve out of this wilderness the land that would support him and his family. He was here *para siempre* (forever) he said, but he mused awhile before adding, unless he found another area of colonization in a sector with a somewhat milder climate. He has given some thought to settlement possibilities in that sector of the mountain front between San Martín and Florencia, one of the most attractive areas yet to be settled in the whole country.

His wife María is just as determined to be independent as is her husband. Fortunately she enjoys good health and can work 14 to 16 hours a day. She now has excellent help in her two oldest daughters, who are up early and do a lot of the cooking, but while they were still small their mother did all the cooking, sewing, mending, bathing of children, and so on. Further, she did not hesitate when her husband was away from home or busy at other tasks to do the work herself in the small plots where yuca, plantains, and corn are grown, and to carry the produce home on her back.

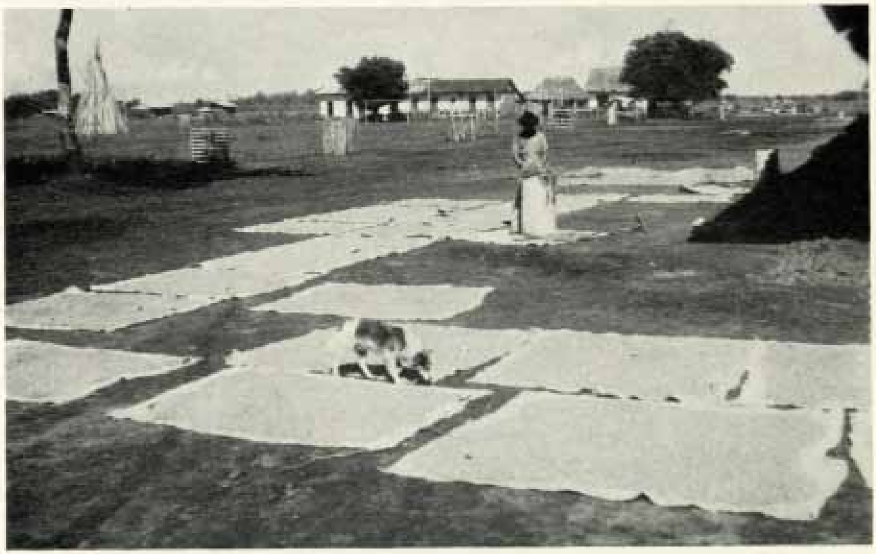
By February 1945 everyone was sick with intestinal upsets and malaria, but Tiberio had to go out, alternately shivering with chills and burning with fever, into the dark forest and the rocky grassy hills to hunt for game. It was the only protective food available. The whole family is aware of the importance to health of citrus fruits, and parents and children alike consumed quantities of lemons from several

1. One of the rice hullers in Villavicencio. The growing of rice is now commercially possible, as a result of the highway connecting it to Bogotá.

2. A former road worker, originally from Huila, who has settled near the Humadea River. He married a local girl. Later his sister and her husband, from Huila, joined the family group.

1. Transshipping cargo by hand across the Humadea River on the frail suspension bridge.

2. The sea of natural grass just north of Boca del Monte, a typical view of the llanos, or grassy plains.



1. Drying rice in the streets of Boca del Monte preparatory to shipment to Bogotá.

2. A bus held up by a landslide on the Garzón–Florencia road. Such occurrences mean hardships and loss of time for bus passengers, and may cause substantial losses for truckers with perishable produce.

1. Dug-out canoes from downriver being unloaded at Puerto Lara. The cargo in this case consisted of rice, plantains, two fattened hogs, and planks of hardwood. Each canoe is powered by an outboard motor.

2. The ranch house of Sr. Valderama Gallo in the distance, with his cornfield in the foreground and the pasture field this side of the house, both cut out of dense forest.

1. In Neiva a convoy of buses (mistos) and trucks unload rice, cooking bananas, and other produce from the llanos.

2. The Muñoz family at Montañita. The elderly couple on the left pioneered from Huila; all the rest were born in the hot country in or near Montañita and are leading happy lives there.

1. These children of settlers who originally came from the mountain province of Huila walk by the stalled station wagon on the way from their frontier farm to the market in Boca del Monte. Note the turkey on the boy's shoulder.

2. The rancher, his wife, and eight of his children as they stand between the house and the kitchen garden.

1. Newly constructed hut of a recent settler on the Pasto–Mocoa road, with sacks of charcoal ready for shipment to Pasto.

2. Sibundoy Indians at the Capuchin Mission of the same name, where they are taught Spanish, agricultural practices, and so on. Note the many strands of beads used as an adornment.

1. Home of a relatively prosperous rancher on the Mocoa road, cut out of what was originally dense tropical rain forest.

2. A crude sawmill at the end of the Pamplona–Río Frio road, with the hut in the upper left the only sign of human occupance.

old trees near the house that were bearing while I was there. For months it was impossible to get protein, except by hunting. There was no neighbor near enough from whom he might have obtained pork or beef. It was then that he became most keenly aware of the importance of an adequate diet to fortify the human body against the onslaught of disease. Everyone became infected with malaria when the mosquitoes got bad in the dry season, but he was able to send for plasmoquin through a friend and thus cure the sick.

The first year he cleared 1½ hectares of land during off time from his job on the road where he earned 1.80 pesos a day. With that money he could buy the barest essentials in Boquerón. By the end of the second year he had cleared 8 hectares of land, had bought a milk cow for 65 pesos, and had several pigs and 40 chickens. The cow had a calf in two months' time. By 1949 he had built a house and had acquired 6 cows and 8 calves, 3 hogs, and a sizable flock of chickens. Then came civil war, which rapidly created a social and political climate infinitely more difficult to cope with than the natural environment.

The scourge of the subsistence farmer or the pioneer in so many parts of Latin America has been the recurrent revolution or actual civil war. Colombia had been spared this curse for over two generations, but the hatred between conservatives and liberals had merely been smoldering, and in 1948 it was to burst into flame and destroy many thriving villages and properous farmsteads. Almost the entire valley on the eastern side of the Andes, with Pajarito as its center, was devastated as the bands of conservatives, the government forces, hunted down and destroyed the liberals, giving no quarter. Many people hid out in the forest with little shelter, almost no food, and in constant danger of being ambushed and destroyed. Their tales of living like hunted animals were heart-rending in the extreme. Others returned to the cities, where life and limb were more secure than in the villages or in the open countryside. It became unsafe in this sector even for a conservative Antioqueño, because as the fighting continued and the lust for blood increased in intensity government forces were apt to shoot first and inquire into political affiliations afterward.

So Tiberio was forced to sell the land that he had with such loving care cleared and made productive. He received 2,400 pesos for the cleared land and another 300 for the hogs, chickens, and corn. The fact that, starting with nothing at all, he had been able with 5 years' hard work, to accumulate 2,700 pesos was a great stimulus to him. But unfortunately he was caught again in the same urban treadmill. His earnings as a carpenter were not enough to keep up with inflation, and his savings dwindled rapidly. By the time the civil war was over he

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was again in desperate financial circumstances, leading a precarious existence in his struggle to support a growing family with wages lagging far behind soaring costs. By 1953 he was anxious either to return to his former holdings or to go somewhere else where settlement was active. His old farm was not for sale, and he had no money with which to buy it, so he was glad to enter into an agreement with the owner of 80 hectares of land near Cupiagua, whereby he could establish his home, clear land, and harvest crops on the halves.

He came out again in '53 to build a shelter and get his food crops—corn, yuca, and plantains—planted (pl. 4, fig. 2). He has a 4-year contract with the owner of the land. Everything produced on the farm, not including what is consumed by the family, is on the halves. However, one-third of the value of permanent improvements on the farm, such as coffee bushes and improved pastures, belong to the renter. He already has 20 acres or so of pastures cleared and has about five times that amount to clear. It is slow work because he and his brother-in-law, without money to hire men, must do it alone. Coffee will be planted next year. He talked the language of a poet and seer as he described the dense forest which he must first dominate in order that, a few years hence, fine, sleek cows could pasture where now grew only an impenetrable tangled mass of trees and vines and shrubs.

He had come out to this land without any previous knowledge of soils, rainfall conditions, or other physical factors he must cope with. He is experimenting steadily in his kitchen garden to find out what food crops will do best. He grows onions, lettuce, tomatoes, cabbage, squash, carrots, and other vegetables. Use is made of cow manure gathered in the nearby, recently cleared pasture. Around the house 40 mango trees are just coming up from seeds. This is the type of farmer who would and could benefit from technical assistance, preferably on a county agent basis. However, Colombians, like Latin Americans generally, have learned the hard way to distrust those who proffer assistance. Before farmers will be receptive to a technical aid program, even one of, by, and for Colombians, they would have to be convinced that it was really to their interest to cooperate. This might prove to be a formidable task.

An important factor in the success of this pioneering venture is family solidarity. Husband and wife and children form a closely knit unit working toward a common goal. Dora and Soe de la Cruz do the house cleaning and cooking. They are up at about 5 o'clock in the morning, to build the fire in the cook shed next to the house and start breakfast. Wood is brought in from the forest by the boys and is cut into usable lengths and split into smaller pieces by fond, easy-going Uncle Marco, brother of María, who also helps in clearing the forest. House-cleaning tasks are performed after the menfolk have gone to

work and while mother is busy with her sewing. Besides the two daughters mentioned, there are José Ceferino, Omar, Hairo Alonso, Waldemar, Lida de la Cruz, Tiberio Agusto, Gorge Enrique, and José Guillermo. They all have to be regularly bathed, fed, clothed and "minded," and those jobs take up all the available time of the mother and two oldest daughters. Each child asks and receives his mother's and father's blessing each night, and the family often reads the questions and responses of the *rosario*. Discipline is strict, punishment is swift. Certain precepts are instilled into the children at an early age. Parents must be obeyed without question; the older children do not tease the younger ones; food is never to be wasted. When one of the younger children, in a fit of temper, threw his food on the ground, he was soundly spanked.

Further, the Antioqueño has the tradition of individual initiative and of economic independence behind him. He has made his living at his trade or on his little plot of land and has unbounded confidence in his capacity to continue to earn his living at his own trade or on his own land. He has not, like the Santandereano, been tied to the land in debt bondage till he has lost the capacity to strike out on his own. He still has the will and the optimism to migrate, in the hope of finding something better. The Antioqueño is a rugged, hard-working realist, intent upon achieving his own independence, without government aid in any form.

PAMPLONA-RÍO FRIO

The population of the little mountain town of Pamplona and vicinity has in recent years been subjected to the economic pull of Cúcuta. This pull has counteracted the tendency to migrate southward and eastward toward the llanos of the Arauca River, the boundary between Venezuela and Colombia. The road from Pamplona to Labateca is mainly through the narrow gorge of the Chitagá River where the growing of crops is difficult, and even grazing does not prosper. However, Labateca and Toledo have been established on relatively fertile alluvial terraces. These are old settlements, and the cultural landscape between Labateca and Batá is mature—corn, yuca, plantains, beans, and squash are the food crops, and coffee and sugarcane are grown for cash. However, as soon as one crosses the high ridge south of Batá, on the Margua River, one is in wild, barely settled country. A few men are engaged in burning charcoal and in cutting trees for lumber. Along the last 20 kilometers of road before reaching Río Negro there were only six huts or thatch dwellings, two of which were uninhabited. A primitive sawmill was turning out logs (pl. 8, fig. 2). One wondered how the laborers operating them existed. There were no plots anywhere on which staple foodstuffs were being grown, and there were

no womenfolk in evidence. The sector is obviously being "mined" of its resources with no plan of permanent settlement, yet the area should be colonized for strategic if for no other reasons. The road should by all means be improved if settlers are to be attracted. As things now stand an oil strike south of the Arauca River would probably mean that that whole area would to a large extent be invaded by Venezuelans looking for work, rather than by Colombians.

Guanapalo and Pauto were thriving economic and cultural centers during colonial times, the epoch of greatest missionary activity. Because of their wealth and the number of their inhabitants they played an important role in the wars which have made Colombian history. This was a zone of great ranches and thriving towns when the rest of the llanos was still virgin territory.[11] Pore was the most important of these towns and, for colonial society, its influence was greater than that of any of the modern capitals. It is said that at one time Pore, extremely rich in cattle, had a larger population than Santa Fé, capital of the vice royalty.

After the wars of independence, missionary activity declined in the mountain-front sector for a hundred miles or more south of the largely unoccupied Colombia-Venezuela frontier zone, but whether it was the cause or the effect of lack of development it is difficult to determine. At present Colombian nationalism is demanding that this unoccupied area between the mountain heartland and the international boundary be filled in, in somewhat the same manner that a boy with a suit several sizes too large for him wants to grow up fast and fill out his clothes. But all growth requires time. Meanwhile the boundary between Colombia and Venezuela remains to a high degree an artificial line on a map, a broad buffer zone with little significance in reality.

PASTO-MOCOA

The road eastward from Pasto, the economic and administrative capital of highland Nariño, can take care of vehicles of 3 tons or less; the first 10 miles it climbs steeply through an intensively cultivated area of *minifundio* to the pass known as El Tábano (the horse fly), the continental divide, or *divorcio aquarum;* the road descends even more abruptly to the tiny village of El Encano on the shore of the picturesque Laguna de la Cocha—very probably of glacial origin; at present a rendezvous for hardy trout fisherman. Between El Encano and Santiago another extremely steep mountain must be crossed, on both slopes of which the felling of trees for timber, but particularly for the making of charcoal, is going on at a dizzy pace,

[11] Cf. Platt, Raye R., Opportunities for agricultural colonization in the eastern border valleys of the Andes, in Pioneer Settlement, Amer. Geogr. Soc. Spec. Publ. No. 14, pp. 87-92, New York, 1932.

with little thought of control measures to safeguard soil and water resources (pl. 7, fig. 1). Between Santiago and San Francisco, via the village of Sibundoy, seat of the Capuchin Mission, the road hugs the base of the steep north slope of a vast swampy basin, now drained by the Putumayo River, that must originally have been overdeepened by glacial action. Settlers have cleared the forest from the well-drained and fertile alluvial fans deposited by the streams that empty into the swamp, and have established thriving cattle ranches (pl. 8, fig. 1).

The San Francisco-Mocoa sector crosses still another high pass, the Páramo of Bichoy, before plunging eastward through many miles of wild, rocky country, completely inhospitable to human settlement. From the last defile, at about 6,500 feet, one can, in clear weather, discern the great valleys of the Putumayo and Caquetá Rivers with the tiny settlements along them; from there the road descends 1,000 meters in 25 kilometers to Pepino, 10 kilometers from Mocoa, long the capital of the Comisaría of Putumayo and the most important urban agglomeration of the region; it has three long streets cut by six short ones, wide and well marked out. The authorities work and live in relatively commodious municipal buildings.

Puerto Limón, Urcusique, and Puerto Umbria, all are tiny bridgeheads in the wilderness, settled mostly by hard-working people from Nariño, Antioquia, and Caldas.

The Comisaría of Putumayo is the home of three cultural, racial, and linguistic groups of Indians, the Ingano, Siona, and Kofán, who were well adjusted to their environment but whose economy and social organization were primitive. The settlers from the mountains made these primitive Indians work for them; they exploited them and took advantage of them in many ways, with the result that the Indians have fled to areas as yet untouched by the new settlers. The cultural inferiority of those few who remain, to be seen in the Sibundoy valley and around Mocoa, is reflected in their low social and economic standing in the community, where they are a prey to malaria, yellow fever, influenza, and water-borne diseases, as well as to their "civilized" fellows (pl. 7, fig. 2). These primitive people are given little help toward improving their agricultural techniques, although even now they supply many of the "spearheads of penetration" with yuca, plantain, corn, and vegetables. Nor is their artistry valued very highly, in the making of pottery, baskets, and textiles, some of the finer examples of which are veritable museum pieces.[12]

Some of the settlers who came as the Pasto–Mocoa road was opened up had a little capital and a small fund of experience in living and in

[12] Chavez Milciades, La colonizacion de la Comisaría del Putmayo: un problema etno-economico-geografico de importancia nacional, Bol. Arqueol., vol. 1, No. 6, pp. 567–598, 1945.

making a living in frontier zones, but the great majority were men whose only baggage consisted of their capacity for hard work. The settlers were a heterogeneous lot, poverty-stricken day laborers, sharecroppers, or renters from the large estates in the hot lowlands or temperate highlands; half-starved peasant proprietors of tiny, fragmented plots in the cold country. Here was a vast fertile country awaiting settlement, where land could be had for the taking, for no one owned it. All the settler had to do was to build a thatch hut, clear a piece of forest with his faithful machete, and plant corn, yuca, and plantains. But this was not enough to cope with the new environment. Weakened by a poor diet the settler became a ready prey to malaria, and to other diseases that still further undermined him. With no capital it was impossible to buy drugs, even if they had been available. Many of the early settlers died; in many settlements *all* the children died year after year. Once sick and ailing, a worker is no longer able to keep up the unequal struggle against the forest, to be sure, but there would be much less sickness if public health measures were systematically undertaken to kill the vectors of tropical fevers and to decrease the incidence of water-borne diseases. Further, cheap and easy credit should be available to the settler, without his having to go through endless red tape; thus he could bring his agricultural equipment and techniques up to date and take care of his seasonal needs without recourse to the usurer. Finally, improved roads would tie the settler more securely to his local market and thereby to the national economy.

The Pasto–Sibundoy–Mocoa–Urcusique–Puerto Umbría road should at the earliest moment possible be extended as far as Puerto Asís in order to tie in with navigation on the Putumayo.

The construction of this highway was especially pushed during the war with Peru, itself probably due in part to the neglect of this frontier zone. When the treaty of peace was signed, work on the road was abandoned; the last 25 miles of the Pasto-Puerto Asís road was not finished. Thus an extremely fertile area, the alluvial land along the Putumayo, does not have an outlet for its produce. Rice is reported to give prodigious yields here, but it cannot reach its market. At the same time there is a great demand for it in the mountains, and in Nariño a brisk contraband trade in Ecuadorean rice has grown up.

The mountainous area around Ipiales, near the border with Ecuador is also seeking a safety valve to the east, in the form of one road via La Victoria to connect with the San Miguel River, and another via Puerres, which crosses a pass in the cordillera and will connect with the Guamués River, which drains the Languna de la Cocha.

The state of Cauca has completed the road from El Bordo to Bolívar and every effort should be made to continue this on to San Sebastián and thence, crossing the divide, to Santa Rosa on the

Caquetá. Santa Rosa should then be tied to Mocoa and Puerto Limón. This accomplished, the road following the foot of the cordillera from Florencia to Puerto Limón, via Belén, would open up a vast fertile area to settlement.

CONCLUSIONS

Almost three decades ago F. O. Martin[13] felt that the three chief drawbacks to settlement and development of this vast region were the lack (a) of kept-up roads and trails; (b) of a good labor force, and (c) of community spirit. He felt keenly about the latter item, complaining that "there is no community spirit among the inhabitants in the matter of maintaining trails or in any other communal relations. Cooperation is unknown; rather, intense jealously among individuals prevails." It has been seen that, although in Colombia as elsewhere miracles are rare in the affairs of men, improvement has been steady: roads and trails *are* being kept up and improved, and the labor force is not only more numerous than when Martin wrote, but it is more efficient because of a better diet and a lower incidence of the so-called tropical diseases. The community spirit cannot be said to have become Utopian, but it has certainly changed for the better generally, in spite of the temporary setback resulting from the revolutionary outburst of 1950–53. Of fewer and fewer sectors can it be said, "settled but unexplored," for the reality is that population pressure in the mountain areas has built up to such an extent that a wave of migrants is actually crossing the eastern cordillera at many points to enter the tropical lowland. The physical climate is one that can the more readily be coped with if collective man surrounds himself with a favorable political, social, and economic climate.

In the words of Professor Bates, tropical forests are not unfriendly: they are merely disinterested. It is understandable why they do *seem* unfriendly when they are engaged in single combat by a lone individual armed only with a machete, who, besides being poorly fed and poorly housed, may be suffering from fever and intestinal ailments and parasites. The picture changes completely when man is in cultural control, as it were, and can create his own favorable habitat as he penetrates the forest or any other natural landscape he has decided to live in or change; a young army officer in Florencia pointed out that any place can be a pesthole if one eats poorly and takes none of the ordinary precautions to maintain health. He concluded that, by merely minimizing and guarding against the bad features of the tropical climate and taking advantage of the good ones, one could lead a very pleasant life there. And thousands of his compatriots are finding this to be true, no longer regarding the forces of

[13] Martin, F. O., Exploration in Colombia, Geogr. Rev., vol. 19, p. 628, 1929.

nature as terrors to be placated, but rather as beneficent powers with which man may cooperate.

There has been no steady pushing back of the frontier on a broad front; rather the forest has been encroached upon in widely scattered areas for the exploitation of whatever resource was most highly prized at the time. For centuries minerals, or forest products such as rubber and quinine, played that role. As the mountain population slowly began to recognize the soil of the rain forest as an important, valuable, exploitable resource, they were able to effect what might be termed a "break-through" into the Andean foothills and tropical lowlands in the Villavicencio and Florencia sectors, where they are rapidly consolidating their gains. The temporary break-through south from Sogamoso has been largely halted by an unfavorable political climate, while Pamplona is not yet successfully tied to the plains area to the south. Settlers from the mountain sectors of southwest Colombia are in the process of effecting their break-through to the east, along the highways mentioned, but thus far various factors have made it impossible for them to anchor themselves by permanent agriculture and grazing. New roads are being constructed only very slowly and roads already open have not been too well maintained, education and public health campaigns have been neglected, and the capacities of the indigenous Indian population have not been fully realized.

The tragedy of the llanos is the tragedy of a frontier zone that by its very nature is not yet able to live a life of its own, somewhat like our own Middle West a century ago. As long as the Middle West led a kind of colonial existence vis-a-vis the eastern seaboard it could not work out its own regional salvation. Once it was settled by an industrious, agricultural people, and was crisscrossed with railroads and motor roads for intraregional as well as interregional trade, it could and did develop its own complementary industrial society. With the introduction of adequate roads and transportation facilities, education and public health measures, and permanent rather than nomadic agriculture by a vigorous and hard-working people, the llanos may indeed experience an evolution similar in many respects to that of our Middle West during the first half of the nineteenth century.

The densely populated Andean heartland of the nation is being subjected to centrifugal forces that are already undermining its immemorial dominance. Although the center of gravity is still in the cool to cold mountain sectors, the frontier of settlement is actually on the march into the low-lying hot country.

The Sources of Animal Behavior[1]

By G. P. Wells
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For nearly 20 years now I have worked on various aspects of the biology of a group of marine worms—the polychaetes—mainly, though not exclusively, on the members of one family. An intensive study of that kind has its own fascination, and it becomes particularly rewarding if the investigator is lucky enough to find that his animals illustrate with exceptional clarity some principle of wide application in biology. I believe this can be said of the behavior of my worms, and although the belief may be merely the rosy illusion of a specialist (for I tend to see any biological problem in worm's-eye view), I shall try to develop the theme here. I shall start with the only species I know at all intimately—the common European lugworm, *Arenicola marina*, and go on to certain related species and then to quite different kinds of animals. My aim is to show that even a worm may have a useful contribution to make to our understanding of animal behavior in general.

I

The lugworm is commonly about the size of a fountain pen—though it may be rather larger, or very much smaller. It is found at low tide by digging in beaches of muddy sand. It lives in a fairly permanent burrow, eating the sand, digesting some of the organic content, and ejecting the unwanted residue on the surface. These residues collect as a heap of sandy cylinders; most of us have walked across a flat beach when the tide is out, and seen the little heaps in their thousands.

The lugworm's brain is very small and its nervous system is comparatively simple; it leads an extremely sheltered life, surrounded by the sand, which is at once its food and its protection from the hazards of the world: and one might reasonably expect, from these facts, to find that its behavior consists largely of simple responses to stimuli, most of which come from within. For example, one might expect it

[1] Inaugural lecture delivered at University College, London, May 5, 1955. Reprinted by permission.

to start eating when its stomach is empty, to go on till the stomach is full, and then stop; and to make the backward trip to the surface, to shoot out a sand cylinder, whenever its rectum fills up to a certain degree. But the facts are quite otherwise. Under natural conditions it feeds in little bursts, each lasting for a few minutes, with rests of a minute or so in between; and if you watch it in a glass tube of sea water, without any sand to eat, you often see a similar alternation of feeding movements and rest. The important point here is that each of the outbursts subsides although there has been no satisfaction by eating. Again, under natural conditions a lugworm moves backward to the surface and shoots out a sand cylinder at regular intervals which vary somewhat with the temperature and the size of the worm—commonly about once every 40 minutes—and the fasting worm in a glass tube can often be seen to make similar backward trips, as before, at regular intervals of about the normal length, even though it has no urge in the form of residues to discharge. It looks as if the worm had "physiological alarm clocks" in its organization which go off spontaneously every so often, irrespective of its needs, and compel it to make a burst of feeding movements, or a backward trip.[2]

In the case of the feeding rhythm, the analysis has been pressed further. The "alarm clock" has been located. If you remove the front part of the gut—the esophagus—put it in a dish of sea water and watch it carefully, you see that this little fragment of the worm has a complicated automatic rhythm of its own. For a few minutes it is vigorously active, with waves of contraction running along it in regular sequence from the front end to the back, then it becomes quiet for a couple of minutes, and so on. We can distinguish two rhythms here, of different levels—the first is that of the contraction waves themselves, and the second, superimposed upon it, the alternating appearance and disappearance of the first. It can be shown quite convincingly, by appropriate experiments, that this behavior of the esophagus is the cause of the intermittent feeding of the intact worm. When the esophagus is active, its activity spreads through the nervous system to most of the muscles of the body, affecting them in various ways and producing periodic feeding movements.

In writing these opening paragraphs, I tried above all to be clear, and the resulting picture is rather oversimplified. The behavior of the isolated esophagus is very regular and mechanical, but when it is part of the worm its rhythm and the extent to which its activity

[2] Under the conditions of the lecture, it was necessary to leave out a number of interesting points—such as the fact that each backward excursion to the surface is followed by a spell of vigorous water pumping, or the way in which the excursions can be exploited at low tide as a method of aerial respiration. Some of these points are mentioned in the subsequently added footnotes.

spreads through the body can be controlled to some degree. The general situation is roughly parallel to that of a vertebrate heart. The isolated heart will continue to beat and so will little shreds of heart muscle, but in the body its activity is modified by regulating nerves. So also with the lugworm esophagus; it has an inherent rhythm which can be regulated; but its pattern, being intermittent, is more complicated, and in this case the pattern can spread through the body and cause periodic movements of the whole animal.

These facts impressed me, when I first came across them, for the following reason. When I was a young man I was a mechanist of the most bone-headed type—believing that behavior was nothing more than a series of reflexes. The animal was stimulated by the presence of food, or an enemy, or a mate, or by some simple organic need, and it performed appropriate deeds. If it happened to be a very intelligent animal—as a man is, or an octopus—it could form conditioned reflexes, and then its reactions were more complicated. But always it was driven, and its life was patterned, by the incidence of stimuli of one kind or another. Presumably, as a corollary, a physiologically satisfied animal in a homogeneous environment would do nothing at all; but I do not remember that I worried very much about that. I think that if one did not know what it was that stimulated a particular act, one called it a drive. Be that as it may, in the lugworm we see something rather different. The characteristic activity pattern of the isolated esophagus is part of its organization—if you like, part of its structure. The rhythmic outbursts begin spontaneously, without any external stimulus or any biological need; they subside without any kind of satisfaction; and normally their rhythm plays an important part in patterning the life of the worm as a whole.[3]

[3] The basing of the lugworm's behavior on inherent rhythms, instead of on simple responses to its immediate needs as they arise, has definite survival value. The flat beaches frequented by these worms are often covered with puddles and sheets of water at low tide. On a sunny day this water may be several degrees hotter than the underlying sand, and well above the highest temperatures which the worms can tolerate. A sharp frost or a heavy downpour of rain could also make the surface water harmful to the worms. Normally, the worm drives water through its burrow to get a supply of oxygen; if the surface water became dangerously hot or dilute a reflex hyperpnoea in response to oxygen lack might be disastrous; it would be wiser for the worm to suspend its activities. When placed in a glass tube under unfavorable chemical conditions the worm becomes relatively inactive; but under the influence of its 40-minute rhythm it makes periodic backward trips toward the top of the tube and generally draws a little water along on these occasions, as if testing the surface water. We may guess that when unfavorable conditions develop in the field, it behaves in the same way; after the rising tide has covered the burrow again and so removed the danger, the fact will be detected at the next testing excursion, and the worm's full activities will then be resumed.

At this point an obvious question arises. I have spoken of the esophagus as a physiological alarm clock. How does the clock work? From what kind of cellular mechanisms does its regular intermittent pattern arise? The first step in trying to find an answer is to pull the clock to pieces. If you cut a lugworm esophagus into several bits, cutting either lengthways or across, you find that each of them shows the characteristic alteration of rhythmic activity and rest, from which it seems that the pattern is a general property of the esophageal wall. The fine structure of the wall was described by Dr. Whitear; it contains a diffuse network of nerves which may be responsible, but unfortunately the anatomical arrangement is not favorable to further attempts at identifying the active structures. On the purely physiological plane some light could perhaps be thrown on the nature of the mechanism by varying the temperature and composition of the surrounding fluid; and I have published some experiments along these lines in collaboration with Miss Ledingham. But the essential problem remains unsolved. The esophagus can be slowed down by increasing the amount of magnesium in the surrounding fluid, and it may then show its outbursts of activity at very regular intervals of over half an hour. The problem of how to construct a clock of cellular dimensions that will tick as slowly as this is indeed an intriguing one. It is presumably related to many of the problems with which the physiologist is concerned, such as the exact mechanism of the heartbeat. Under certain abnormal conditions a heart may beat in intermittent bursts, and its activity pattern is then very like that of an isolated lugworm esophagus. Perhaps when our physiologists have published all the answers to their problems the results may be applied to mine.

With that I shall leave the *Arenicola* esophagus and begin to broaden the picture, but first a word must be said about one of the experimental methods. We are going to consider the results you get, if you observe the behavior of a polychaete continuously for days or weeks on end, and this may sound a hard thing to do, particularly if the worm is burrowing, invisible, in sand, or living (as is the way of many species) in an opaque tube of its own construction. In practice, however, it is easy to persuade the worms to write down on paper what they are doing; and possible (although more difficult) to learn to read what they write. It all depends on the fact that they drive water through their tubes in order to get oxygen, and often for other reasons too. The method consists of three stages: (*a*) you set up a simple apparatus which traces on slowly moving smoked paper the speed and direction of the water currents, so that you can see how the currents vary with time; (*b*) you find, in many species at least, that certain characteristic

patterns appear over and over again on the tracings; (*c*) by special means (such as watching worms in glass tubes) you find out what particular activities these patterns accompany. This is the most laborious stage, and it must be confessed that one's knowledge of the script of any species is never complete. But even with partial understanding the method is useful. One can set up the apparatus, leave it to run for a very long period of time, and afterward read from the tracings what has happened and when. It is worth emphasizing that one's interference with the worms is minimal; they are perfectly free to move about in their tubes or burrows, and one only imposes an imperceptibly small resistance on their water currents. One finds out, in this way, how they behave when they are left alone.

One of the results of this method is to show that the lugworm is a creature of moods. It has several alternative patterns, any one of which it can write on the paper. It may behave as I have already described, feeding in little bursts and discharging a sand cylinder every 40 minutes; these acts affect the water movements, and gives the record a very characteristic appearance. Alternatively, it may lie still and do nothing; or it may trace violent chaotic wiggles that I cannot pretend to understand; or it may trace other rhythmic patterns, without feeding, that there is no time now to describe. A long-term record of its behavior always shows these "moods," each of them generally persisting for several hours and then passing suddenly into another. The patterns can of course be modified by external circumstances; but what I have just said is true of worms living, as far as one can judge, in very uniform and favorable conditions. It looks as if the lugworm's behavior is mainly governed by an elaborate inherent organization, perhaps even up to the level of the long-term changes of mood.

The same kind of thing can be seen in other marine worms. Their activities are patterned in time, sometimes with strikingly regular rhythms; and in some cases there are alternative rhythms and changes of mood. A point that comes out very clearly when the tracings of different kinds of worms are compared, is that the more regular patterns are characteristic of the species. There is, for example, a family of worms—the Sabellidae—that live in tubes of their own construction, spreading their crowns of feathered tentacles in the sea water, and eating the minute suspended particles which these tentacles entrap. Water-current records of two species of this family have already been published, and I have unpublished material on two more. All of them have complicated activity-time patterns, and—although they all live in very much the same way—the patterns are in part specific. Each species has its own characteristic kind of wiggle, which

it writes on the paper; just as each can be distinguished by certain anatomical characteristics.[4]

II

I turn from the polychaetes to a group of animals that has a wider appeal and is very much in the limelight nowadays—the birds. I am going to suggest that much of what I have said about worms is true in principle of birds too.

At this stage in the argument, I am reminded of a proverb that the shrewd old Russian peasants used to say in the days before the revolution. They would peck at their fields with primitive tools, as their fathers and grandfathers and great-grandfathers had done before them; and when one suggested that more modern methods might increase productivity, they would shake their heads and say: "If you make your strides too great, you tear the seat of your pants."

The step from worms to birds is a long one. I encourage myself with the thought that all animals, however different they may appear, are variations on a common theme. It is, of course, the aim of the comparative method to find out how much is variation and how much is theme.

Probably nearly all of us have been irritated at one time or another by the insistence with which our feathered songsters repeat their

[4] The "mood changes" are strikingly shown by *Chaetopterus variopedatus*, which has several very characteristic and clearly contrasted alternative activity patterns. The statement about the Sabellidae is based on published records got from *Sabella spallanzanii* at Naples and *Sabella pavonina* at Plymouth, and unpublished ones from *Branchiomma vesiculosum* at Plymouth and *Schizobranchia insignis* at Friday Harbor, the latter with the assistance of LeRoy B. Nydegger. In *Myxicola infundibulum*, which is referred on anatomical grounds to a separate subfamily, no water is driven through the tube, although there are other characteristic activity patterns.

Comparison of the two *Sabella* species is interesting. The tubes are found, either attached to such submerged objects as rocks, piles and buoys, or with their lower ends embedded in the material of the sea bottom. The ecological preference of the two species are not quite the same; *S. spallanzanii* occurs attached to submerged objects or embedded in coarse sand, while *S. pavonina*—though it also can occur in these situations—is especially frequent in muddy sand or in mud. The spontaneous irrigation patterns of the former involve the propulsion of water in both directions in turn, those of the latter in a tailward direction only. If *S. pavonina* draws an irritating substance into its tube with its water current, it can at once reverse the current and thereby take rejection action; it is therefore capable of reversal though it never reverses except in response to such occasional crises; the normal restriction of its behavior to tailward irrigation may be correlated with its habit of colonizing muddy situations, since a headward current, in such situations, would tend to draw in mud and clog the tube.

This is only one example of the fact that an inherent activity pattern can be adaptively modified, just as an anatomical pattern can.

songs. To hear the brilliant little song of a chaffinch, sung from a branch just outside one's window as one lies in bed on a sunny April morning, is delightful. To hear it again a second time, a few seconds later, is very well. But if the bird repeats the identical song phrase over and over again, at extremely regular intervals of about 10 seconds, as it often does at that season—and let us remember that 10 seconds is just long enough for one's thoughts to get nicely settled elsewhere—one begins to wish that it would stop.

Such an experience impresses upon us that the singing behavior of our common woodland and garden birds is rhythmically organized, and we can distinguish two levels in this organization.

First, is the pattern of the individual song phrase. This is highly specific. The biological function of song is above all to warn off other birds of the same species and sex, and to inform them that the singer has taken possession of the surrounding territory, which he is prepared to defend. Evidently, the phrase must be recognizable and distinctive of the species. There is of course a certain amount of variation from individual to individual and from moment to moment in any one bird, and in some cases (such as the chaffinch) there are well-marked local dialects. Nevertheless, the songs of any one species have enough in common to be readily identifiable as such, and a bird can be known by its song as surely as it can by its plumage.

To some extent these song phrases are learned from other birds, to some extent they are innate. The extent to which song has to be learned probably varies from species to species, but the innate contribution seems always to be substantial.

Dr. W. H. Thorpe has described the songs of chaffinches that were hand-reared in soundproof rooms at Cambridge and isolated from any contact with experienced birds since the first few days of nestling life. When such chaffinches grow up and sing, all the finer details of the adult song are lacking; there is, nevertheless, a rough framework of definite structure on which they could be hung. In his own words:

> The experiments with the hand-reared birds suggest that there is an inborn basis to the song but that it is extremely generalized. Innately these birds seem able to produce a song of about the normal length, 2–3 seconds, and showing a tendency to crescendo accompanied by a fairly steady fall in mean pitch . . . there is a clear tendency in some birds to conclude the song with a single, simple note of a higher pitch than the rest.

Such a framework is, in itself, quite a complicated thing to inherit. According to Dr. Sauer, of Freiburg, whitethroats reared in isolation from the egg produce the entire song when the right time comes, down to the finest detail.

The second level of organization is the distribution of the song phrases in time. Many birds, when in singing mood, will shoot off

a series of little song phrases at extremely regular intervals, often of about 10 seconds. The chaffinch is one of these, and there are many equally familiar examples—the hedge sparrow, the yellowhammer, the willow warbler, the robin, and so on. Even in those birds whose songs seem, at first hearing, to consist of long ramblings rather than compact phrases, the utterances show a more-or-less regular and characteristic punctuation. The spacing of bird song seems to have received less attention than the structure of the individual phrases. There is however a mine of exact information in E. M. Nicholson's admirable book, "Songs of Wild Birds," and the regularity of the rhythms which his timings reveal, in species after species, is indeed impressive.

One would expect such timing to be basically innate. Dr. Peter Marler tells me that the chaffinches reared in isolation at Cambridge sang at about the usual intervals. The rhythms are of course by no means inflexible. A chaffinch will sing at shorter intervals at one time than at another, and for many months in the year it hardly sings at all. Each bird has its preferred time of day, when it sings most frequently. In the great tit, as Dr. R. A. Hinde has recently shown, the frequency of singing may vary from minute to minute. But many plainly spontaneous rhythms in animals can fluctuate and be modified according to circumstances—the heartbeat, for example—and these variations do not exclude the view (which I think is inescapable) that the timing of bird song is based on an inherent, automatic rhythmicity.

The essential spontaneity of bird song is beautifully brought out in the following passage from Mr. Nicholson's book:

> A song, in fact, needs no immediate stimulus to set it in motion (such as fear, anger, hunger or isolation) nor does it call for any special reply. A cock bird may sing better if more cocks are singing within earshot, but on the other hand, he will go on singing for weeks at the right season with no other songsters within miles of him and without a mate. We might even say that any bird sound usually uttered in response to a specific and immediate stimulus is probably not true song.

As everybody knows, true song is only one item in a bird's vocabulary, and most species have a wide repertory of different calls. Some are brief outcries in response to a sudden stimulus—alarm calls at the approach of a hawk, for example—but many of them are repeated for considerable lengths of time in more-or-less regular rhythms, and indicate the mood of the bird. Dr. Sauer has illustrated this very beautifully in the case of the whitethroat, and gives many descriptions of the mood notes and of the manner of transition from one mood to another. He tells, for example, how a whitethroat in winter, sitting quietly and singing its subdued and nearly continuous subsong, may suddenly begin to interpolate among the song phrases the notes of mild alarm or mild hunger, often accompanied by appropriate move-

ments, and how the new mood can be heard to intensify and then fade away again—for all the world as if the bird were dreaming of fear or food as it sang.

There are lists of calls in Witherby's "Handbook of British Birds," and the reader can hardly fail to notice a strong positive correlation between the number of different notes assigned to each bird and the thoroughness with which that species has been investigated. In "The Wren," which is not only the name of a bird but also the name of a recent important book about it by E. A. Armstrong, that author enumerates 14 kinds of calls and 6 kinds of song, and he writes that his account "is over-simplified and includes only the commonest and most significant types of utterance." In the whitethroat, Dr. Sauer has tabulated 25 different calls and 5 types of song; and he finds that the whole of this tremendous vocabulary appears in whitethroats reared in isolation, in soundproof rooms, from the egg. In his own words, "A bird lacking all acoustical experience, utters all these sounds in exactly the same manner, in the same phases of its life cycle and in the same specific moods as birds in the field."

Dr. Marler tells me that his isolated chaffinches produced all the calls perfectly normally, except for a slight peculiarity of one note. According to Dr. Collias, the domestic chick can emit its usual distress and pleasure notes even before it hatches. Cool the "pipped" egg and you hear loud, protesting cheeps from inside; warm it again, and they are replaced by delighted twitterings.

I have talked at some length about the vocal behavior of birds because it is so easily observed. It is in fact meant to be observed, being a method of communication. But birds do other things besides emitting noises. They hunt for food, they fly about, they preen themselves and scratch, they continually interrupt whatever else they are doing to raise their heads and look around for possible danger. May it not be that the patterning of these activities is largely based, as the vocal behavior so clearly is, on complicated inherent rhythms?

It is not easy to get clear evidence on this question. One would expect an affirmative answer, for the following reason: the various notes are often accompanied by characteristic movements of the bird; and in many cases, what is characteristic is not so much a particular posture as a particular sequence of events which appear in other contexts—for example, an alternate raising and lowering of the head feathers, or a moving of the body from side to side. Voice and movement are intimately entangled, and it would be strange indeed if the type of organization that is shown by vocal behavior were strictly limited to that one activity. There are, in fact, several published descriptions of what appear to be inherent rhythms in nonvocal performances. Let us consider three examples.

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Dr. Hinde has recently described fluctuations in the frequency of various activities, of various birds, and he remarks: "It is characteristic of instinctive activities that they do not occur regularly but in complex patterns of bursts." Nest-building in the great tit, for example "occurs not in more-or-less evenly spaced visits, but in rather irregular bursts of visits with occasional visits between." Of outstanding interest are his observations on the food-begging calls of juvenile blue tits, which are accompanied by particular movements and attitudes. The birds were fed to capacity and then observed for more than half an hour as they gradually became hungry again.

> The record shows that the phrases come in bursts. Increased hunger results not in a gradual increase in the rate of calling, but in an increased frequency of bursts and an increase in the length of bursts. . . . The observations of begging . . . were made under controlled conditions which were very nearly constant throughout each experiment. It is thus certain that the fluctuations do not depend on environmental changes.

The next two examples are of rather longer cycles. Nearly 30 years ago, Professor Curt Richter described the behavior of a pigeon in a cage which automatically recorded its movements. Every 20 minutes or so, the bird left its perch, hopped around on the floor for a few minutes, and then returned to the perch again. If corn was available, the bird ate every time it jumped down, but the very regular rhythm persisted in the absence of food. The outbursts of restlessness apparently coincide with outbursts of contraction in the emptying crop; and the crop may in fact play a part comparable to that of the esophagus of *Arenicola*, and set the rhythm of the whole performance.

More recently Dr. Whitehouse and Mr. Armstrong, using an automatic recording device, studied how a wren divided her time between sitting on her eggs and other activities. Her day consisted of "sessions" and "recesses." The lower the temperature, the more time she spent on her eggs, as one might expect; but the sum of a session and the following recess was not affected. The two together occupied a time which fell steadily during the day (quite irrespective of temperature) from about 19 to 27 minutes; cold weather simply lengthened the sessions and correspondingly shortened the recesses. This looks like a clear case of an inherent rhythm with environmental temperature playing a secondary, modifying role. Every 20 minutes or so, some kind of "physiological alarm clock" goes off inside the wren, and she gets off her eggs; the colder it is, the sooner she comes back. Later in the season, when she is feeding her young, another rhythm appears; the frequency with which she visits the nest shows a well-marked peak every four or five hours.

The demonstration of these slow cycles would hardly have been possible without the use of the automatic recording devices, which wrote

on moving paper whenever the pigeon hopped on the floor of its cage, or the wren passed through the opening of her nest. Most bird activities would be difficult to register in this way. There are, however, plenty of hints to be found in the literature that inherent rhythms of quite long period are widespread in birds. Among the beautiful descriptions of the herring gull's behavior in Dr. Tinbergen's "The Herring Gull's World" there are several—such as the way in which an incubating bird will get up, as he says "spontaneously," at intervals of one or more hours, shift the eggs a little with its bill, and then sit down again.

These facts and hints encourage us to believe that a large part of a bird's behavior springs from within—not only in reflex response to physiological urgencies, but also in obedience to timing mechanisms that are essentially arbitrary. As in a polychaete worm, an activity may begin without an immediate need and subside without any satisfaction. This arbitrariness is evident in the detailed structure of the song. The song phrase, if it is to fulfill its biological purpose, must be audible to other birds, it must be sufficiently directional to inform them where the singer is located, and it must be distinct enough from that of other species (and perhaps of other individuals) to identify him. Beyond these requirements there is no reason why it should have one pattern rather than another; the great variety of songs that delight and sometimes irritate us in spring is largely the expression of a variety of types of innate organization. If we turn our attention to the other notes and calls, we can hear that an individual bird is equipped with a repertoire of alternative rhythmic patterns that modulate or replace each other as its mood changes. All of this is pretty obvious; the role of the more slowly moving rhythms is less so; and to myself, at least, it is an exciting idea that changes of activity or mood, occurring at intervals even of several hours, may often be due to the action of arbitrary internal "clocks." It may be that the further investigation of this aspect of behavior, by the continuous study over long periods of the way in which a bird's various acts are distributed in time, might help very materially to bridge the gulf between the province of the field observer on the one hand and that of the physiologist on the other.

Perhaps the average bird watcher is too much inclined to suppose that every act a bird performs is biologically useful in itself. There are, of course, a number of things the bird must do—eating, breeding, and so on; but on the other hand, like any living animal, it is in a state of organized instability, and can never be completely at rest or even completely steady. A motionless bird, sleeping, for example, while perched on a twig, breathes and stays upright—the latter performance involving feats of equilibration which are no less consider-

able for being apparently effortless—and for most of its time the bird does much more than that. It is so made that it must always do something, even if it has nothing special to do, and quite a lot of its behavior may be simply filling in time between one functionally directed act and the next. The unceasing flow of energy must be patterned and organized; not every element in the design need in itself be utilitarian.

I venture the opinion that we should diagrammatize the driving forces behind animal behavior, not so much in terms of the familiar tank in which water collects at ever-increasing pressure until it escapes through a spring-guarded outlet, as of a complicated system that can never rest but has to oscillate in one or another of a number of predetermined alternative rhythms. This approach might help our understanding of many phenomena, such as the appearance of "displacement activities" when a straightforward course of action is checked for one reason or another. It would indeed be surprising if the thwarted animal did absolutely nothing at all.

III

What we have learned from worms and birds is true of many other kinds of organisms too. More and more instances are appearing in the literature of the importance of inherent rhythms in behavior. The rhythms vary greatly in tempo and complexity. The organisms in which they have been demonstrated include sea anemones, bivalves, insects, sea squirts, sticklebacks, rats, and medical students—to mention only a few. The work on mammals is mainly concerned with long-period rhythms, correlated, for example, with the hunger contractions of the stomach or with oestrus; shorter rhythms would be harder to record automatically, and it is worth remembering that mammals have characteristic voice rhythms as have birds. So, of course, have many other animals, such as frogs and fishes, grasshoppers and cicadas. I thought it better in this lecture not to attempt a catalog of examples, but to make my point by concentrating on two contrasted groups. They are certainly not exceptional in basing their behavior to a large extent on inherent and often arbitrary timing mechanisms.

And now a word in praise of worms. For obvious reasons, spontaneous behavior is most easily studied in animals that live under sheltered and uniform conditions. The sense organs of my worms are comparatively simple, and their way of living in burrows or tubes restricts the number of disturbing stimuli which impinge on them from without. Moreover, their activities are easy to record by the water-current method, and they often show surprisingly normal behavior patterns after drastic surgical operations—decapitation for ex-

ample;[5] this facilitates a physiological approach. No doubt there are plenty of other subjects at least as favorable to be found among the invertebrates. The situation is vastly more complicated in a bird or a mammal. Its activities are harder to record, its body is less amenable to operation, and because of its restless habits and highly developed sense organs its behavior is interfered with by the environment more continually and in more varied ways than is that of a worm. Much of the underlying inherent structure of its behavior can be seen, but the experimental investigation of the timing mechanisms would be very difficult.

I cannot resist the temptation of adding a wild little fantasy about communication.

If you lie in a deck chair in your garden with your eyes shut and listen to a bird—and if you know your bird as well as Dr. Sauer knows his whitethroat—you can tell what is passing through its mind from its calls and from variations in the timing and structure of its song, and you can see in your own mind's eye nearly everything it does. Similarly, if you make a worm write its water currents on paper, and if you know your worm, you can tell from the patterns it traces what it is doing at any time. The two have this in common: in each case you study one aspect only of the animal's activities, but in each case the behavior of the animal is so closely integrated that nearly everything it does is reflected in that one. They differ in this: the voice of the bird is a method of communication; another bird can hear what the first one says. The usual effect of bird communication is to bring both into the same mood. Such moods as restlessness, alarm, or lazy contentment can spread by this means through a flock of birds so that all are in the same condition and prepared to act in the same way—this has been described by Professor Lorenz in jackdaws and geese, by Dr. Tinbergen in gulls, by Dr. Hinde in great tits, and by many others too. But take your bird and isolate it in a soundproof room and it still continues to call and sing. The parallel with the worm is now very close indeed, for in both cases you get the performance of intricate spontaneous rhythms, and in both you get changes of mood. Perhaps it is only 99 percent fantastic to say that the worm, though it is a dumb animal and has not yet invented a way of communicating

[5] *Sabella* generally whips its head back into its tube at the approach of a predator, such as a fish; but sometimes it fails to do so fast enough, and loses not only its head but also several segments from the front end of the body. It then grows a new head, which can be distinguished by minor anatomical characters from the old, and Professor N. J. Berrill has written: "In nature it would seem that about half the *Sabella* population suffers such mutilation at one time or another." I found that the normal activity-time patterns (as registered by the water currents) are hardly altered, if at all, by the loss of the front end of the body.

with its fellows, is talking to itself. One cannot help wondering what would happen if one could work some kind of magic spell and enable the lugworm to detect the water currents of its neighbors. It is not conceivable that the worms would resonate, as it were, to the same pattern—that moods would spread across a lugworm beach, just as they do through a flock of jackdaws? The mechanical effect on the beach of synchronizing the efforts of all these hundreds of thousands of little diggers might be formidable, but it would lead me too far astray to pursue that line of thought.

I have already wandered quite far enough since my lecture began—from worms to birds, from fact to the wildest speculation. On such an occasion as this the speaker may be allowed to relax that caution which normally characterizes a scientific address, and I have taken the opportunity to make what is really a declaration of faith. I believe that the innate morphology of animal behavior is of far wider importance than is generally realized—or, at least, generally stated—for the principles of what I have said are already familiar furniture in the minds of many of my hearers.

The zoologist is always concerned with organization. At whatever level he studies his animals, he finds intricate and fascinating patterns—in their gross anatomy, in their histology, even in their molecular structure. He learns also that the living body is in a state of ceaseless change—moving, growing, metabolizing, wearing out, attempting to repair itself. The cessation of these processes is death; life is their control; and just as the living animal patterns the molecules that constitute its body into a characteristic anatomy as exactly as the assaults and restraints of the environment will allow, it patterns the events that constitute its behavior. It organizes itself elaborately and beautifully—more so, I think, than has yet been revealed to us—not only in space but also in time.

NOTES ON THE LITERATURE

The first part of the lecture is based on the following original papers:

ARENICOLA

Feeding cycle: G. P. Wells, Journ. Exp. Biol., vol. 14, p. 117, 1937. Defecation cycle: G. P. Wells, Journ. Mar. Biol. Assoc. U. K., vol 28, pp. 447, 465, 1949.

Review: G. P. Wells, Symp. Soc. Exp. Biol., vol. 4, p. 127, 1950. Additional details: G. P. Wells and E. B. Albrecht, Journ. Exp. Biol., vol. 28, p. 41, 1951. G. P. Wells, Journ. Mar. Biol. Assoc. U. K., vol. 32, p. 51, 1953; Quart. Journ. Micr. Sci., vol. 95, p. 251, 1954.

Nervous system of the esophagus: M. Whitear, Quart. Journ. Micr. Sci., vol. 94, p. 293, 1953.

Action of changes in bathing medium on the esophagus: G. P. Wells and I. C. Ledingham, Journ. Exp. Biol., vol. 17, pp. 337, 353, 1940; vol. 19, p. 176, 1942.

OTHER WORMS

G. P. Wells and R. P. Dales, Journ. Mar. Biol. Assoc. U. K., vol. 29, p. 661, 1951.

G. P. Wells, Proc. Roy. Soc., B, vol. 138, p. 278, 1951; vol. 140, p. 70, 1952.

I am by no means expert on the other groups mentioned. The following references are to works that I happen to have encountered and enjoyed. I have deliberately avoided the complicated question of inherent rhythms synchronized with the tidal, diurnal, lunar, or annual cycles, on which there is an enormous literature.

BIRDS

E. M. Nicholson, Songs of wild birds (1936), with a chapter by Ludwig Koch. This was published with a "learner's set" of gramophone records. There have been subsequent issues of bird-song records; in my opinion, the first is still the best because of the excellence of the book.

Niko Tinbergen, The herring gull's world (1953).

A. E. Armstrong, The wren (1955).

Konrad Lorenz, Er Redete mit dem Vieh, den Voegeln und den Fischen (1949). Translated as King Solomon's Ring (1952). Jackdaws in both versions; geese in the German only.

Song-learning in chaffinches: W. H. Thorpe, Nature (London), vol. 173, p. 465, 1954.

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Domestic fowl: N. E. Collias, Auk, vol. 69, p. 127, 1952. N. E. Collias and M. Joos, Behaviour, vol. 5, p. 175, 1953.

OTHER ANIMALS

Sea anemones: E. J. Batham and C. F. A. Pantin, Journ. Exp. Biol., vol. 27, p. 290, 1950. C. F. A. Pantin, Symp. Soc. Exp. Biol., vol. 4, p. 175, 1950.

Sea squirts: Graham Hoyle, Journ. Mar. Biol. Assoc. U. K., vol. 31, p. 541, 1953.

Fresh-water mussels: G. E. Barnes, Journ. Exp. Biol., vol. 32, p. 158, 1955.

Cicadas: J. W. S. Pringle, Journ. Exp. Biol., vol. 31, p. 525, 1954.

Newts: H. Spurway and J. B. S. Haldane, Behaviour, vol. 6, p. 8, 1953.

Mammals (including medical students); also pigeons: Curt Richter, Quart. Rev. Biol., vol. 2, p. 307, 1927.

GENERAL

Review of biological rhythms: Nathaniel Kleitman, Physiol. Rev., vol. 29, No. 1, 1949.

The fourth volume in the series Symposia of the Society for Experimental Biology (1950) is an interesting and still useful collection of different approaches to the mechanisms of animal behavior.

Rivers in the Sea[1]

By F. G. Walton Smith

Vice President and Secretary
The International Oceanographic Foundation

[With 6 plates]

The passenger aboard ship, out of sight of land, sees only the motion of his vessel through the water. There is nothing visible about the sea surface to show whether the water itself is moving, either as a favorable current, helping the ship's progress, or, as an adverse current, retarding it. Yet currents do exist in the open sea, of such power as to make a substantial difference to the daily distance made good by the ship and so be important to the mariner as a factor in fuel economy as well as in his navigational estimates. It is important, then, to measure the speed of these rivers in the sea and to know how they vary from season to season, day to day, and even hour to hour. The ways of doing this are surprisingly varied and involve some of the most ingenious ideas and devices in the science of oceanography.

IMPORTANCE OF CURRENTS

There are other ways in which ocean currents are important. Near the Equator the surface of the sea gains heat from the sun, whereas there is a heat loss at the Poles. The action of such currents as the Gulf Stream, carrying warm water poleward, has a profound effect upon climate and weather. The distribution of fishes is dependent upon sea-water temperature, and is thus both directly and indirectly related to ocean currents. Currents not only carry food in the form of microscopic sea life or plankton but also help to distribute the fertilizer materials upon which they grow. There are numerous other problems both of scientific and practical importance which involve a knowledge of the pattern in water movement in the sea, and today there is the most recent one of disposing of radioactive wastes at the bottom of ocean deeps. This requires a knowledge of how long it

[1] Reprinted by permission from Bulletin of the International Oceanographic Foundation, vol. 2, No. 2, July 1956.

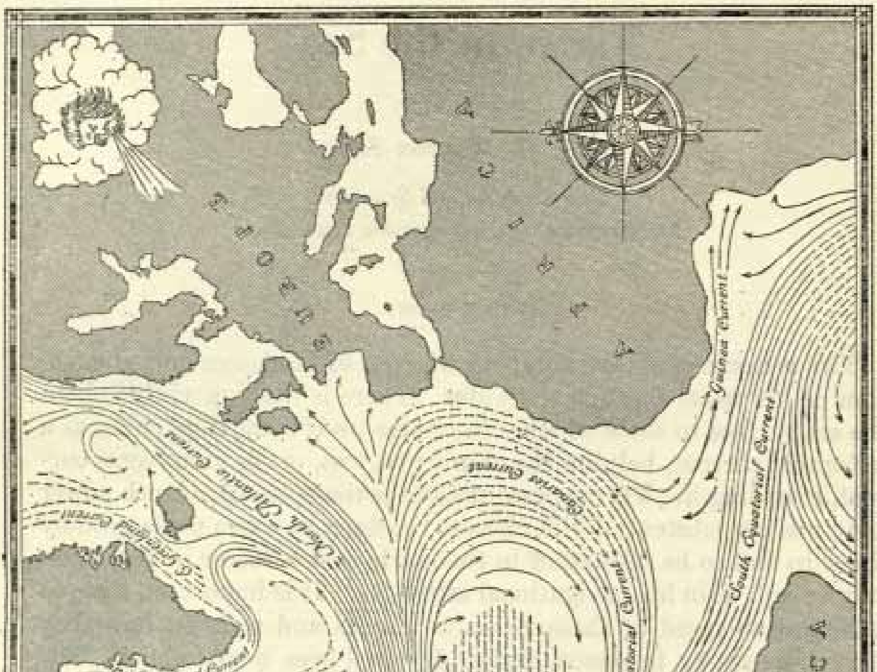


FIGURE 1.—Surface currents of the North Atlantic.

would take for deep bottom water at any given place to reach the surface. If the time is great enough, much of the radioactivity might be lost, otherwise it would become a hazard.

GIANT EDDIES

The major currents of the world, with some exceptions, run as part of a continuous circulation, completing a clockwise circuit in the northern oceans and a counterclockwise one in the southern oceans. In general, the current flowing toward the Pole on the western side of the ocean tends to be comparatively narrow and fast, whereas the corresponding current on the east, flowing toward the Equator, tends to be wide and slow. Thus the Gulf Stream, a flow of between 25 and 50 million tons of water per second, is concentrated into a fairly narrow stream in its most westerly part, and has a maximum velocity of over six knots at times. Having crossed the Atlantic Ocean, the stream veers south again, off the coast of Africa, to complete the circuit. Here, as the Canaries Current, its flow is very slow and is spread over a wide area. The counterpart of the Gulf Stream in the North Pacific is the Japanese Current, the Kuroshio, and in the Indian Ocean there is the strong Agulhas stream flowing south, off the coast of east Africa.

There are, of course, many other currents besides those which form the major circulations of each ocean. Some are tidal, others due to seasonal winds, to unequal heating of the water, or indirectly caused by winds which pile the water up against the coast, thereby bringing about a longshore current parallel to the coastline. And here it may be said that, as a rule, the currents caused by winds do not flow in the direction of the wind, but at an angle to it, with a right-hand twist in the Northern Hemisphere, left-hand in the Southern Hemisphere. Thus the trade wind of the southern North Atlantic blows from the northeast in a southwesterly direction toward the Equator but the north equatorial current which it drives across the Atlantic moves to the right of the wind, in a westerly direction toward the Windward Islands.

Although, for the most part, the ocean circulations of the two hemispheres do not directly intermingle, there is a current which branches off from the South Equatorial Current, flows across the Equator and joins the westerly movement into the Caribbean. This transports something like six million tons of water a second across the Equator. There is no compensating surface current in the opposite direction, and the North Atlantic and Polar Sea have no other outlet. Obviously there must be an accounting for this net gain of surface water by the North Atlantic, and equally obviously there must be a compensating return movement somewhere. Since it does not take place at

the surface there is, as might be expected, a flow of water deep below the surface, to the south. A number of compensating flows of deep water are found in all of the major oceans and they, in turn, are linked to vertical movements, the transfer of water back and forth between the surface and the deeper layers.

SINKING WATER

The net gain of surface water to the North Atlantic is balanced by water which leaves the surface and sinks below in areas between Greenland and Iceland, in the Labrador Sea, and to the west of where the Mediterranean communicates with the Atlantic. Each of these three downward movements removes from the surface about one-third of what the Southern Equatorial Current brings to the North Atlantic. There are reasons for these vertical movements, based upon unequal heating and cooling of sea water and upon evaporation and rainfall. The hotter sea water becomes, the lighter it is, so that it tends to rise to the surface. The cooling of sea water has the reverse effect and gives it a tendency to sink. Evaporation of sea water at the surface, due to winds and the heat of the sun, makes it saltier and heavier. The addition of fresh water by heavy rains has the effect of reducing the salinity and so causing surface water to become lighter.

SIX MILLION TONS PER SECOND

The surface of the Mediterranean Sea loses more fresh water by evaporation than it gains from river discharge and rainfall and therefore becomes heavier than the water in the adjacent Atlantic. The result is that in the Straits of Gibraltar there is a 2-knot inflow of lighter surface water from the Atlantic to the Mediterranean, and this is compensated for by a deep subsurface flow of the heavier Mediterranean water into the Atlantic. This continues to sink and joins the deep south-flowing stream on its way to cross the Equator. A similar amount of surface water joins the deep southward flow by sinking off Greenland and in the Labrador Sea at places where the cold Arctic water, meeting warmer, but saltier Atlantic waters, especially in winter, cools the latter by mixing until the surface waters become heavier than those below. The North Atlantic loses in this way a total of 6 million tons of surface water a second, but this amount returns to the surface in the South Atlantic, owing to other forces, where it exactly replaces the six million tons of water which originally crossed the Equator to enter the North Atlantic circulation.

SOURCES OF FERTILIZER

There is another type of vertical movement in the sea. When winds or other causes bring about a divergence of currents, water will well

up from below to fill the void. Similarly, when currents meet or converge, there is a net displacement of water in a downward direction. Winds blowing away from a coast may have most important effects since the water displaced offshore must be replaced from below. The lower layers of water are often better supplied with natural fertilizer than those at the surface so that upwellings of water are apt to be more productive of sea life, including commercial fishes. The west coast of Africa is a good example of such a situation. The reverse case, when water is piled up along the shore, may result in a sinking surface water which is replaced by less fertile surface water from offshore.

MEASURING CURRENTS

How is it possible to measure the rate of these various currents and to estimate the volume of water transported? There is a wide variety of methods available to oceanographers, some simple and some more complicated, but the simplest are those that are based upon the measurement of a drifting object. For instance, a line might be let down to the bottom with a weight for anchor and the ship allowed to drift, without power or sail. The rate at which the line is dragged out would provide an approximate measure of the ship's movement due to the current. When Columbus, halfway across the Atlantic on his first voyage, tried to sound for bottom he failed to find it, but the angle at which his leadline ran out from the becalmed ship gave clear indication that the ship was moving westward with the surface water layer while the weighted end of the line was in a deeper, relatively motionless layer. Today a ship may be moored to an ice flow and the current speed measured in a similar way by dropping a weighted line to the bottom and measuring the speed at which it has to be run out as the ship moves within the ice and current.

CURRENTS FROM SHIP'S LOGS

A great deal of information about currents has been obtained from the navigational records of ships, filed with the U. S. Navy Hydrographic Office. From this information the monthly averages of currents are charted. Using the known speed of the ship through the water a navigator is able to calculate what his position should be at the end of any given period of time, assuming that no currents are diverting the ship. At the end of this time he finds his actual position or fix by taking bearings of a stationary light or by observations of heavenly bodies. The difference between the predicted position and the actual position gives the direction and speed of the current. Today, there are more and more reliable methods of fixing a ship's position, even with an overcast sky, owing to the invention of Loran, radar, and radio direction finding. Even so, this method will only

give the average current speed over a more or less extended distance and gives no information about the actual speed of current at any one point or about its variations.

MEASURING THE SHIP'S SPEED

The speed of a ship is measured in a number of ways. The patent log, a propeller towed behind the vessel, clear of its wake, is attached by a cord to an instrument that records on dials the distance traversed. Another device, the pitot log, measures the pressure differences in tubes projecting from the ship's hull, and records this as speed, much as the air-speed indicator of a plane. The Kenyon log measures speed by the deflection of a blade projecting from the hull into the water. And the speed of revolution of the ship's engines and propellers may be used to judge her speed through the water when properly calibrated for various conditions. Most of these methods are designed for measuring the comparatively high speeds of ships through the water and are not accurate when used to measure the slower drift of ocean currents past the hull of an anchored vessel. Special instruments have therefore been designed for use from anchored vessels in order to measure currents, both at the surface and at various depths below. Lightships thus become of especial value to the oceanographer interested in currents at sea.

FLOWMETERS

Flowmeters used from stationary vessels or buoys are frequently driven by means of a propeller or by a set of cups similar to those of a wind gauge. These are set in motion by the water passing by. Their speed of rotation is proportional to the current, and they are so arranged as to register the number of revolutions on a dial. The Ekman type of meter, which has been used most frequently, also has an ingenious arrangement for showing the changing direction of the current. The propeller is geared so as to rotate a horizontal disk containing a single hole of the exact size to allow a small shot to pass through from a shot reservoir above it. Every 33 revolutions of the propeller the hole arrives in position and the shot drops through the disk. Beneath the hole in the disk is a pivoted magnet carrying a channel along which the shot rolls. Beneath the magnet is a box with 36 radially arranged compartments, each corresponding to a 10-degree sector of the compass. The whole instrument is suspended so that vertical fins will keep it alined with the direction of the current. Thus, each time a shot drops, the compartment to which the magnet directs it indicates the direction of the current.

Current meters of the Ekman type may be suspended at intervals on a long cable and in this way measurements may be made at various

depths from the surface to the bottom. Special weights sent down the cable will release trigger devices so as to start and stop the meters at precise times after lowering the cable and before hauling it back to the surface. Variations of this type of meter are also designed so as to make mechanical records, or to record current velocity and direction on the deck of the ship by electrical means.

Among the ingenious devices applied to current meters are those designed to keep the recording or electrical parts in a waterproof housing. One type of meter, designed to operate for long periods without attention, has the propeller outside of the main instrument. Instead of a shaft entering the instrument through a watertight seal, the propeller carries a magnet. As this rotates it actuates the recording mechanism within the watertight shell, so that no shaft need penetrate and the problem of a seal resistant to the high pressures of deep water is sidetracked. Some instruments of this type are designed so that at regular intervals of time part of a strip of photographic film is exposed, while a light illuminates the dials showing the time and the velocity and direction of current. In an instrument developed at Miami which can be left unattended on the bottom of bays and estuaries, the photographic record also includes the salinity of the sea water measured by its density, and the tidal depth of the water.

There are simpler devices that tell the speed of currents at the surface only. These depend usually upon the drag of a float upon a pendulum or cable, which is pulled at an angle from the vertical according to the speed of flow. For measuring current at various depths the more complicated meters are needed. Even here the problem arises of the back-and-forth motions of the vessel as it rides to its anchor, especially in deep water. Fortunately, the motion of the ship is rhythmical in nature and can be subtracted from the meter records by careful analysis.

DRIFT BOTTLES AND FLOATS

When measurements are needed over a wide area, anchored ships do not offer a practical solution and, instead, use is made of drifting bottles or floats. The simplest observation of this kind must have been the discovery of tropical woods or fruits on European shores, which indicated that currents reaching northern Europe must have originated in the Tropics and to the west. Perhaps this influenced the Norse explorations long before the time of Columbus. Today various types of floats are set free upon the water so that when recovered they may indicate something of the nature of the currents that carried them. Glass bottles with addressed postcards and directions for filling out details of time and place of recapture have long been used. Some types of bottles are weighted and have a wire trailer below so that

they will drift just clear of bottom obstructions and be carried by bottom currents.

RED TIDE

This is one of several hundred cards released along the West Coast of Florida for the study of currents in connection with the *Red Tide.* Your cooperation in giving accurate information and returning the postage-free card will be greatly appreciated, and will be very beneficial to you and your neighbors.

Date and Time found________________________________

Where found______________________________________

(Name of Beach, Key, Place on shore, near what city, or other prominent reference point. OR, if at sea, exact latitude and longitude.)

Name and Address of Finder ____________________________

The back of a prepaid postal card used in drift bottles and in pliofilm envelopes for investigating currents in their relation to Red Tide

DRIFT CARDS

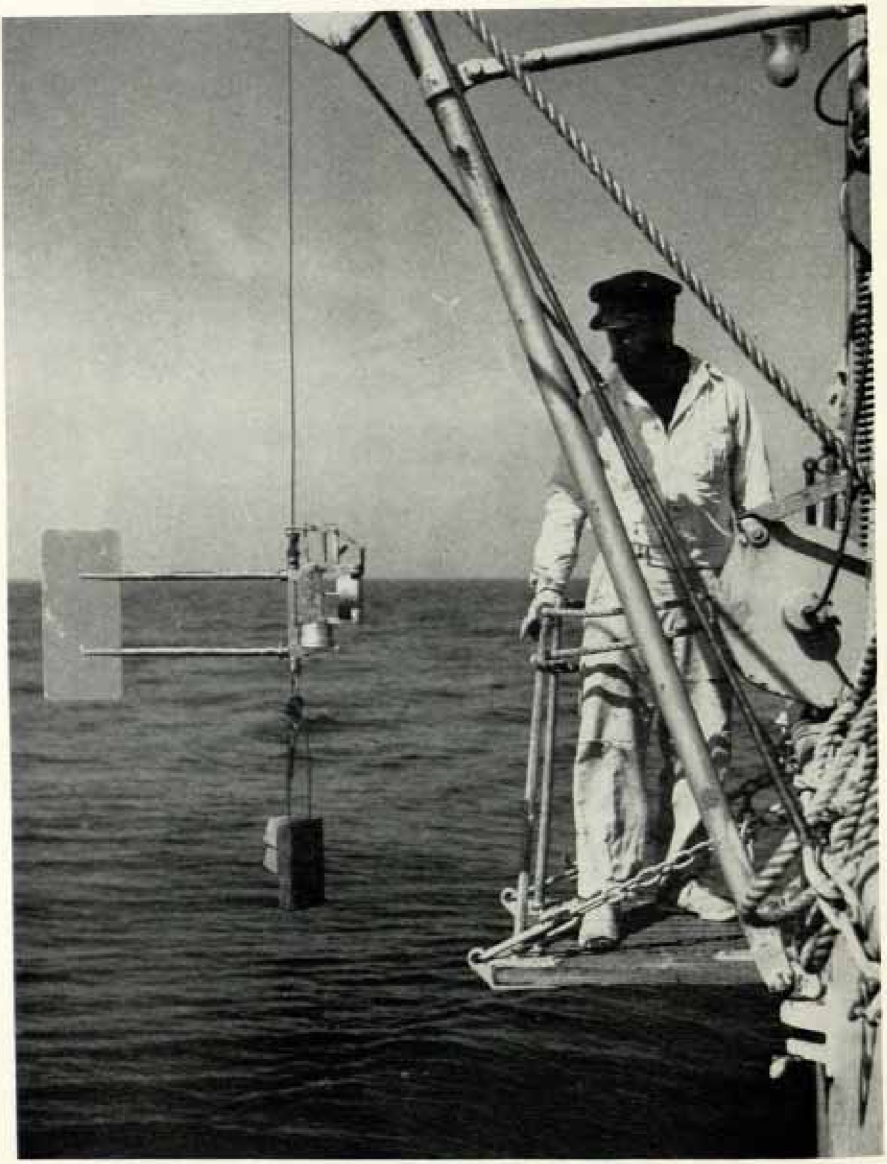
An interesting variation in the use of drifting floats is the drift card, which consists of the usual information postal card enclosed in a transparent pliofilm envelope so that it floats. During investigations of the Florida Red Tide, The Marine Laboratory of the University of Miami used thousands of these cards. They were distributed from a fleet of private motorboats in such a way that very large areas of water were covered, and when picked up by the same fleet some days later an unusually detailed picture of the complicated system of currents and eddies off the west coast of Florida was obtained.

The interpretation of float records is full of difficulties, since any one bottle, card, or float can only tell the beginning and end of its course and the time taken. It does not show whether the course was direct or indirect. An example of this was given by Dr. Tait in his study of the North Sea currents in relation to fisheries. Bottles released at one place were picked up near the coast of Jutland at various times. The times taken for them to reach the place where they were picked up were in multiples of 20 days. The explanation was that there is a big eddy off the Jutland coast and that the circulation time of the eddy is about 20 days. Some bottles completed the course once, but others went around twice or even more before being picked up.

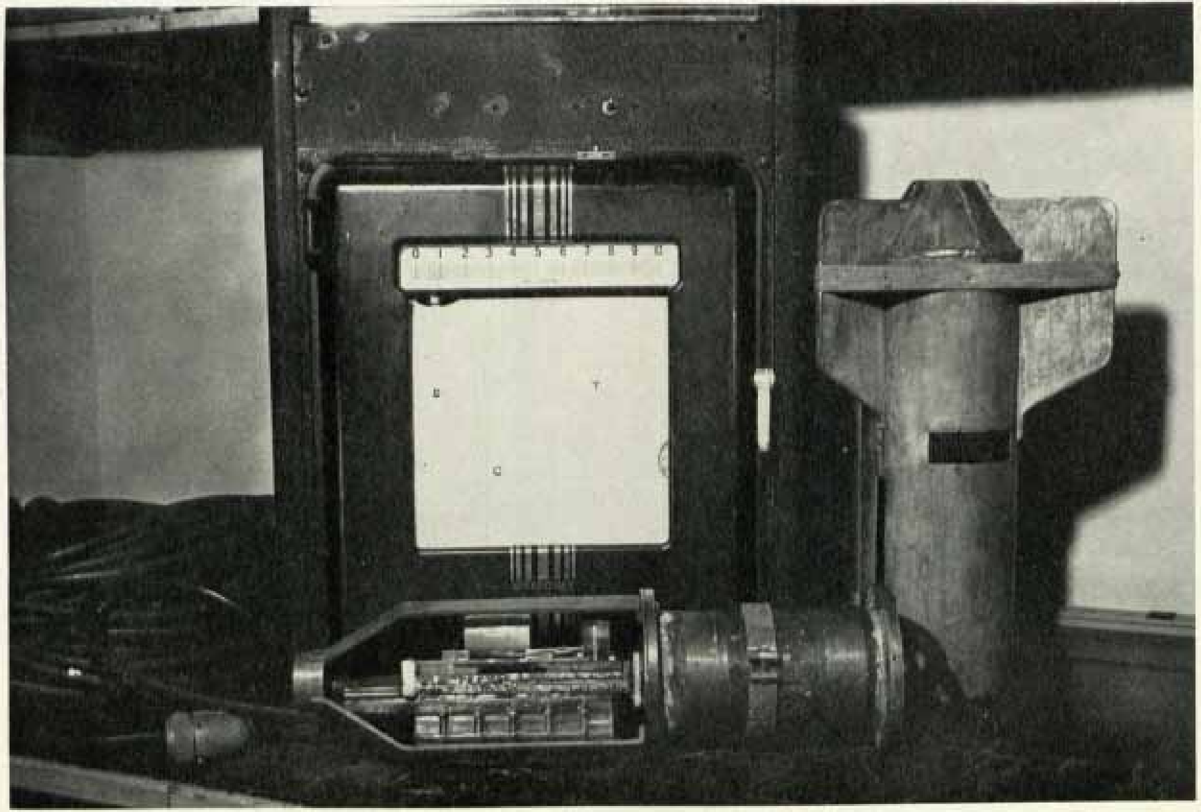
RADIO FLOATS

As electronic devices are being applied more and more to oceanographic problems and instruments today, it is not surprising to find the drift buoy or float undergoing its own kind of evolution. Floating

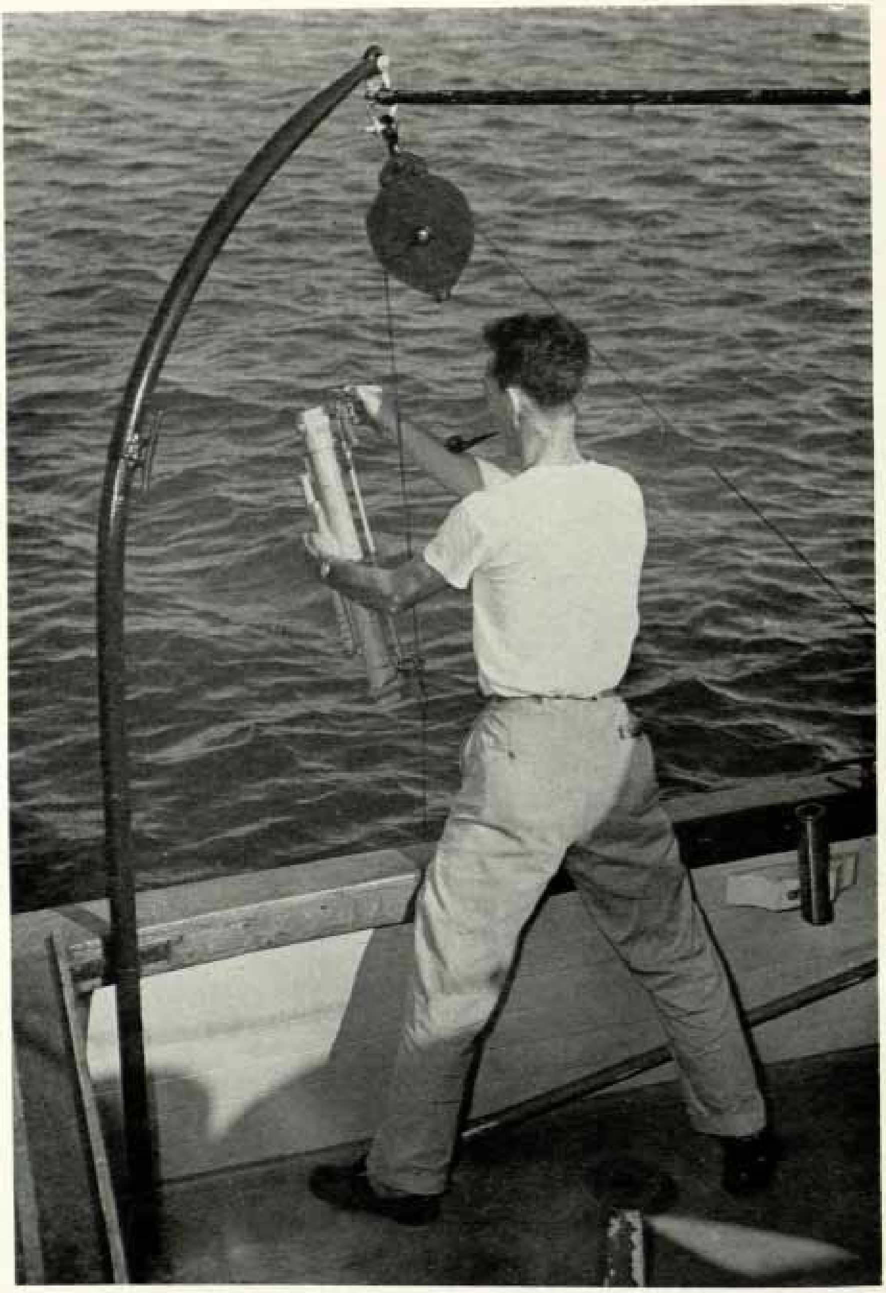
Ocean currents are important for many reasons. One of these is the distribution of temperature, salinity, and the fertilizer salts dissolved in sea water which play a large part in determining the fertility of any part of the ocean. The illustration shows large flocks of birds feeding upon a great concentration of fish in the sea off Iquique, Chile, where the Peru current and vertical movements of water account in part for unusual fertility of the sea.



Currents are measured directly by means of specially designed meters, similar in principle to wind recorders, which are lowered on cables to the required depth. The fins ensure that the propeller which is turned by the current always faces toward it.



THE C.T.D. is an instrument which measures temperature and electrical conductivity of sea water and the depth in which the instrument is working. The pressure, resistance, and temperature elements at the bottom of the illustration are enclosed in the short torpedolike housing at the right and towed at varying depths behind the vessel. An electric cable connects the elements to the measuring and recording instrument in the deckhouse, where the information appears as lines on a moving roll. This type of measurement is used mainly for investigating water movement in estuaries.



Samples of sea water used in the measurement of ocean currents are taken in special steel containers known as Nansen bottles. A series of these, open at each end, is lowered on a cable to the required depth. Weights are then sent down the cable which release one end of each bottle so that it turns upside down, at the same time closing each end so as to trap water from the required depths. Thermometers may be seen in metal tubes attached to the side of the bottles for measuring the temperature at each depth.

An important method of measuring ocean currents depends upon careful analysis of the salt content of the water, as explained in the text. The illustration shows an oceanographer removing samples of sea water from steel sample bottles for chemical analysis.

A heavy steel bottle crushed flat by the pressure in deep water. This Nansen bottle, shown by Dr. Luis Howell Rivero, Cuban oceanographer, was flattened when a technician accidentally attached it to the cable with the ends closed and lowered it to 1,000 fathoms. In normal use the bottle is open at both ends when the cable is lowered, so that the pressure is the same inside and out.

In ocean races today more and more yachtsmen are taking advantage of the fact that temperature changes take place at the sea surface in relation to the position of ocean currents. This has been especially true in the Newport-Bermuda race which crosses the Gulf Stream, variable in speed and position. The illustration shows *Comanche* leaving *Jubilee* at the start of the Lipton Race, sailed in the Florida Current, at the headwaters of the Gulf Stream.

buoys, with deep keels or weighted poles to minimize wind action, are now equipped to send out radio signals which carry information about water temperature as well as signaling their changing positions. Surface vessels are thus able to follow individual floats at their will, simply by "homing" on the radio signals. Another type of float works in reverse, as it were, by having a staff and metal flag that acts as a radar target, so that the research vessel may find its free floating buoys on its own radar screen. This system obviously suffers from being unduly subject to the effects of wind on the target. Still another type of free-floating buoy, developed at Miami, has a lightweight anchor and cable. At the end of a specified period, say 30 hours, a clockwork mechanism trips the anchor, thus mooring the float, and erects a radar target, previously folded down out of wind action.

So far we have considered the more or less direct ways of measuring ocean currents, but there are some interesting properties of sea water that make it possible to use indirect methods, involving, odd as it may seem, tide gages, thermometers, electric currents, and even chemical analysis. Only by means such as these is the oceanographer able to compute more or less accurately the volume of water flowing in the sea which, in the case of the Gulf Stream, is many hundred times that of River Mississippi in flood.

ELECTROMAGNETIC MEASUREMENT

An old principle has been recently applied to the measurement of currents. This is based upon the electromagnetic properties that underlie the dynamo from which we obtain our electricity for power and light. When an electrical conductor moves across a magnetic field, then an electric current is developed in the circuit containing the conductor. The faster the conductor moves the more electricity is produced. Pretty much the same thing happens when sea water, itself a conductor of electricity, moves across the earth's magnetic field. And so, by measuring the small amounts of electricity produced at sea, we have a means of measuring the rate of flow of the water. For this purpose two stationary electrodes may be placed at suitable distances apart and the electrical flow between them measured. Or they may be towed behind a ship. In each case they measure the water flow between and at right angles to the line joining the electrodes, independent of the ship's speed. The instrument used at sea today, including a potentiometer, which records the speed of water current continuously on paper, is known as the G. E. K., or to be more exact the geomagnetic electrokinetograph. When the method was originally tested in England by Faraday from a bridge over the River Thames the results were not satisfactory, but in more recent years Longuet-Higgins and subsequently Von Arx have developed

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a satisfactory system. A remarkable feature of this method is that under some conditions the measurement of water currents may be carried out without even leaving the shore. Since the electrical field caused by currents extends beyond the edge of the water the electrodes may be used on land where they measure the speed of water from the terrestrial part of the electrical field.

Water in the open sea is not exactly the same from top to bottom. As mentioned previously, sea water is lighter when it is warmer and fresher, and heavier when it becomes cooler and saltier. As might be expected, when undisturbed by currents or mixing processes, the surface layers of the sea will be lighter and successively deeper layers will be increasingly heavy. The exact density can be calculated from the temperature and salinity. When a current flows, however, there is a readjustment of the distribution of density in the water to compensate for the earth's rotation, which exercises an effect on moving bodies known as the Coriolis force. The effect of this is to shift the heavier water toward the left of the current when looking downstream in the Northern Hemisphere. The degree of this shift is proportional to the current. The oceanographer can therefore calculate the flow of a water current at sea provided he knows the way in which the water density is distributed.

For practical purposes, the research vessel steams at right angles to the current, stopping at intervals to make the necessary measurements. At each station a cable is sent down with a number of water-sampling bottles attached to it at appropriate intervals. The Nansen bottles, as they are called, are made of steel tube, and are sent down with both ends open so that the water runs through them. When each arrives at its proper depth, messenger weights are sent down the cable so as to trip a trigger mechanism that turns the bottle upside down on its hinged attachment to the cable, while at the same time closing it. The temperature is meanwhile measured by means of a sensitive thermometer, attached to the bottle, which automatically records the temperature registered at the time it is upended. The saltness of the water is measured by chemical analysis of the sample brought back in the bottle.

The thermometer used is guarded against the pressure of water by being enclosed in a protecting tube. A second thermometer is carried on the Nansen bottle for the surprising purpose of measuring the depth at which the sample is taken. In order to do this, this thermometer is not provided with a protecting tube. As a result, the water pressure causes the bulb to be slightly compressed and so the thermometer registers higher than it should. The amount of pressure and therefore the depth of water can be calculated from the difference in reading of the two thermometers.

Another consequence of the way in which the Coriolis force causes a redistribution of water density enables changes in the flow of ocean currents to be measured by means of tide gauges. Since the heavier water shifts to the left of the stream, the water surface tilts in order to maintain equilibrium so that the right-hand edge of the stream is higher than the left. For instance, the Atlantic circulation, including the Gulf Stream, flows in a circuit with the Sargasso Sea near the center. On all sides, therefore, there is a downward slope of water from the Sargasso Sea outward. In the Florida Straits this means that the water level at Miami on the coast of Florida is around two feet lower than it is at Gun Cay on the Bahamas side of the Straits. This downhill gradient increases when the current increases, so that comparison of tide-gage records at the two places enables the oceanographer to detect changes in the pace of the Gulf Stream, after averaging out the tidal movements, of course.

AID TO YACHTSMEN

Yachtsmen in the Newport-Bermuda ocean race go to sea equipped with water thermometers, not through an enduring interest in oceanographic science, but for navigational reasons, since they are able to judge when they enter the Gulf Stream by changes in the surface temperature. Since there is relatively less change in saltness than in temperature in the open ocean it follows that the density distribution is more noticeably reflected in the temperature of the water. For this reason there is a rise of temperature as a ship enters the Gulf Stream from the American side.

VERTICAL CURRENTS

Mention has been made of vertical currents and the huge slow movements of water deep below the surface. The measurement of these presents a different kind of problem to that of surface currents and so other methods must be used. An obvious approach, of course, is to add up the volume of water flowing into and out of any particular ocean or body of water. When the surface currents are known and hence reliable estimates can be made of the vertical movements, then a balance may be struck and the residual amount of flow must take place below the surface. A water budget, in fact, is set up. Other methods are used, involving the measurement of carbon isotopes in the sea. The ratio of the carbon-12 and carbon-14 atoms in the water varies according to the length of time it has been away from the surface so that isotope measurements provide a measurement of the water movement. Other approaches involving changes in oxygen concentration, temperature, and salinity have been used and will be described, it is hoped, in a future article.

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WITHIN THE WATER [illegible]

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A Narrative of the Smithsonian-Bredin Caribbean Expedition, 1956

By Waldo L. Schmitt

Head Curator of Zoology, U. S. National Museum
Smithsonian Institution

[With 8 plates]

The Caribees, the Lesser Antilles, the Windward and Leeward Islands!—names to conjure with. This cradle of many of our hurricanes and much of American history is equally fascinating from a purely scientific point of view. It is still a happy and a fruitful hunting ground for the naturalist, and so it proved to be during the recent Smithsonian-Bredin Expedition to the Caribbean, sponsored and led by J. Bruce Bredin,[1] of Wilmington, Del. The Smithsonian has long been interested in these islands "adjacent" to our continent and has welcomed all opportunities such as the present one to learn more about them and their inhabitants—animal, plant, and human, present and past, recent and fossil.

In 1947 Ernest May financed explorations along the historic route of Columbus so that Dr. Herbert Krieger, Smithsonian ethnologist, might reconnoiter the native village sites reported by the discoverer of the New World in the course of his four voyages of exploration, and so that Conrad Morton, Smithsonian botanist, could spend six weeks on the Island of St. Vincent sampling the flora of its little-investigated higher levels and mountains. Earlier, in 1937, the writer, as marine biologist to the Smithsonian-Hartford Expedition on the *Joseph Conrad*, visited a number of the islands of the West Indies, including some in the current itinerary, and others in the Greater Antilles, and in 1938 as a member of the Hancock Atlantic Expedition to the north coast of South America he was enabled to collect on the island of Tobago, not reached during the Bredin Expedition.

[1] An Honorary Fellow of the Smithsonian Institution, Mr. Bredin sponsored the Smithsonian-Bredin Expedition to the Belgian Congo in 1955 and another expedition to the Society Islands in 1957. Previously he had actively participated in the Smithsonian-Hartford Expedition.

The Smithsonian's earliest collections for the area are recorded in the National Museum's fish and invertebrate divisions as having been received from Theodore N. Gill, who collected extensively in Trinidad and Barbados in 1857–58.

These expeditions, undertaken and underwritten for the purpose of broadening the Institution's coverage of the animal and plant life of the world, do much to increase its knowledge of their kinds and distribution and their representation in the study and reference collections of the U. S. National Museum.

The Smithsonian-Bredin party, besides Mr. Bredin and the writer, included Dr. Fenner A. Chace, Jr., carcinologist and marine biologist; Dr. J. F. Gates Clarke,[2] entomologist and microlepidopterist; and Dr. Albert C. Smith, botanist and specialist on the flowering plants—all then members of the professional staff of the U. S. National Museum.

Desmond Nicholson captained our chartered yacht, the *Freelance*, out of Antigua, which served as our floating laboratory. His schooldays acquaintance with the seashore life of the British Isles, his skill and experience with the underwater face mask and snorkel, and his untiring efforts afloat, ashore, and under water materially enhanced the collections of marine animals taken in the course of the expedition. Supporting the captain was the *Freelance's* cooperative, able crew of native Antiguans, all five experienced sailors—"Kennet" Potter, cook, a man who commanded universal respect and who also took over as first mate in the captain's absence or whenever his services were needed; Smith, the engineer, who saw to it that the yacht's twin auxiliaries, the generator, motorboat, and outboard functioned properly and when wanted; Danny Thomson and Miguel, deck hands; and Thomas, cabin boy. Among them, all our wants were well attended, even to trudging miles overland, assisting the botanist with his plant collecting. Hauling seines or cracking rocks and coral heads for the contained borers and other life harbored in their crevices and interstices was all in the day's work for the crew. No matter what other work was being carried on, there was always a line, hook, and spinner or two trolling off either quarter while the ship was under way. The cry of "fish" always called forth speedy action. Everyone but the man at the wheel dropped what he was doing and ran aft either to take a look or to lend a hand getting the line aboard. Most of these interim catches of fish were eaten, if not wanted for specimens or for the parasites attached to them.

[2] Desirous of spending more time on the island of Dominica than the planned itinerary of the expedition would have permitted, Dr. Clarke flew to Dominica while the rest of the party proceeded to Port of Spain, Trinidad. Dr. Clarke joined the expedition at Roseau. Pertinent notes on insects and plants were supplied by Drs. Clarke and Smith, respectively.

The *Freelance* herself, a twin diesel schooner, measured 86 feet over-all. She had a 19-foot beam and 11-foot draft and was equipped with motorboat, sailing dinghy, electric generator, electric fans and refrigeration, with hot and cold running water in each stateroom. Two single and two double cabins provided ample accommodation for our party.

To keep our rendezvous with the *Freelance* in Trinidad we obtained passage for ourselves and our bulky outfit and collecting gear aboard the cruise ship *Ile de France* to Port-of-Spain. A one-day's stop in Barbados made it possible to visit the Bellairs Research Institute of McGill University and the Barbados Museum.

The Institute, at St. James, a short distance out of Bridgetown, is being set up primarily as a marine laboratory. The director, Dr. John B. Lewis, had visited us previously at the National Museum, and we were anxious to learn more of the scientific work of his laboratory. He showed us through the Institute's newly acquired quarters, a former private residence located on a lovely beach with a variety of marine habitats, including a flourishing coral reef close at hand. At the time of our visit the residence was in the throes of renovation and conversion into a well-appointed laboratory for marine study, with all facilities, including, of course, aquaria and running salt water.

The Museum, under the directorship of Neville C. Connell, is maintained by the Barbados Museum and Historical Society. Of marine invertebrates, in which two of our party were especially interested, there is a fair display of the commoner species of Crustacea and coelenterates, a habitat group showing a section of a local coral reef with associated fauna, and a rather comprehensive and well-prepared series of colored casts of the commoner fishes as found or taken about the island. Most of the exhibits in the Museum, however, pertain to the early history of the island, its inhabitants, their lives, local manufactures, and importations. Very pertinent and of most interest were the objects and the models relating to the early days and development of the sugar industry in Barbados.

In Trinidad, the following day, March 7, we were met at the Customs House dock by Jocelyn Crane and Henry Fleming of the New York Zoological Society's staff working with Dr. William Beebe at the Society's Tropical Research Station at Simla. Miss Crane, well-known authority on fiddler crabs, is associate director of the station. Her cordial invitation to Simla was accepted forthwith by Dr. Smith who wished to botanize the area and by the rest of us for several days later, as we wished first to undertake shore collecting at Maracas Bay, one of the island's many beauty spots. We went to Simla on March 11, it so happened in time for the dedication of the station's new butterfly flight cage. This was erected so that the species then under investiga-

tion could be closely followed and observed under virtually normal, natural, yet controlled conditions.

During the entire period of our stay in Trinidad, Dr. Smith made headquarters at Simla, which is located at an elevation of about 800 feet on the inland (southern) slope of the Northern Range of Trinidad. This Range comprises the island's highest and most heavily forested land, reaching an elevation of more than 3,000 feet; its third highest peak, Morne Bleu (2,781 feet) lies some miles northeast of Simla. Botanical collecting along the crest of the Range toward Morne Bleu provided Dr. Smith with excellent material; the low crest forest bears a heavy growth of epiphytic ferns and bryophytes, with many species of orchids, aroids, and bromeliads. Among the interesting trees and shrubs of this rain-drenched forest are species of the melastome, madder, and pepper families, while among the undergrowth of ferns is to be found the beautiful white-flowered succulent *Begonia glandulifera*, one of a group that ranges throughout the Lesser Antilles in wet areas.

In Port-of-Spain we paid our respects to the American Consul, and fortuitously, through a misdirected telephone call, we became acquainted with Frank Ambard, customs official, who has a very fine and complete representation of the butterflies of Trinidad. Nearly every species in his collection is represented by a pristine pair—with few exceptions reared by himself.

We also visited the Royal Victoria Museum, of which Arthur N. Greenhall is the director. This museum possesses a number of zoological rarities, including the giant tadpole of a relatively small frog, *Pseudis paradoxis*. The adult is under 4 inches long, whereas the tadpole may reach 7½ inches in length.

On March 12, at 5 p. m., we were under way on the first leg of our 40 days' and 40 nights' cruise through the islands. This last day in Trinidad had been a busy one getting our stores aboard, filling the water and the fuel tanks, and our collecting chests with alcohol needed for the preservation of zoological specimens. It was a rolling first night at sea. The next morning was one of busy preparation organizing gear and containers, fitting together our water glass, and assembling the bottom sampler. By lunch time we were tied up off the sea wall in St. George Harbor, Grenada, just across the roadway from the ship chandlers and the wholesale district, a busy harbor indeed, teeming with the loading and unloading of cargoes from the interisland schooners. We took time to make a number of purchases essential for our collecting work, particularly a small kerosene heater for Dr. Smith's plants in their presses below deck, where the plant specimens had to be dried because of the wind, the occasional rain or spray, and the lack of space topside; and a wooden shovel for screening beach sand for its contained macroscopic organisms.

I was told that this type of shovel was ordinarily used for shoveling cocoa pods and beans about. Before us, atop the sea wall, we saw another step in the journey of the cocoa beans on their way from the parent tree to the tin of commerce in which cocoa is sold. Along the harbor road square yards of pods were spread out on tarpaulins to dry in the sun. Over them a buxom, heavy-weighted native woman strode in endless measured tread back and forth, crunching the pods to free the beans.

Grenada, the southernmost of the British Windward Islands, 97 miles to the north of Trinidad, and only 133 square miles in extent, is a veritable "Spice Island," for, aside from cocoa beans, of which over 5 million pounds are exported each year, nutmegs are the largest item in the island's economy. Before the well-nigh disastrous hurricane of 1955 more than 6 million pounds of nutmegs and mace were shipped out of Grenada. Most of these two spices are exported to the United States, where, according to local reports, the nutmegs are used chiefly to flavor sausage meats. Included in the island's spice exports are cinnamon and cloves; considerable cotton is also grown here.

The morning after our arrival in Grenada, Mr. Bredin and Dr. Smith headed for the hills and Grand Etang, a beautiful crater lake 2 miles in circumference situated in the heart of a tropical rain forest which covers most of this island. The volcanic depression in which the lake is located at an elevation of about 1,600 feet is reached by a steep, much-contorted, yet exceedingly picturesque road. It is often—as it was this day—overhung with curtains of moist fog, while hard showers of rain fell intermittently. The forest that fills the inner valleys of Grenada shows the effects of the recent hurricane violence, in that the trees, often too thickly growing to fall, stand broken and leafless in eerie ranks. The region is not high enough to support the "elfin woodland" that characterizes high portions of the Antilles, but nevertheless the predominant trees do not much exceed a height of 30 or 40 feet. The immediate shores of the lake are low and swampy, and here the botanist found excellent collecting, obtaining many herbaceous plants such as sedges and the pretty yellow-flowered *Utricularia obtusa.* On the slopes farther from the lake, in the debris of the ruined forest, were found the coarse large-flowered *Lobelia cirsifolia*, masses of the little prostrate shrub *Sauvagesia erecta*, and many small-flowered orchids and ferns on the fallen branches of trees.

It is the luxuriant vegetation of the moister islands among the West Indies that have merited them the name Isles of Paradise. Certainly those who live on Grenada, Martinique, Dominica, and Guadeloupe—and many who visit them—feel this way about them. While Dr. Smith was sampling the flora, Dr. Chace and I, with our paraphernalia, took a taxicab out to Point Saline, for here the rocky

shores, sea caves, and interspersed sandy beaches held promise of good collecting of marine invertebrates.

We spent the afternoon collecting on a rocky reef between the ship and the farther shore in a bight called St. Martin's Bay. A few dredge hauls were also made off Grenada's famed swimming beach, Grand Anse, just outside the harbor proper.

Although we planned an early morning start for Carriacou, 30 or 40 miles to the northward according to the strength of the wind, a case of dysentery on board led us to seek advice and a prescription from a local doctor. He refused payment for his services, considering us as guests of the city, but finally he was persuaded to accept something toward the cost of the local hospital's charity patients.

The delayed sailing made it possible for us to extend the courtesies of the *Freelance* to Dr. Slominsky, the resident physician on Carriacou, sparing him a 4-day wait for the next boat returning there. In turn he was of service to us in locating a good and convenient anchorage in Tyrrell Bay. The bay is ringed with conical "peaked-cap" shaped hills, all seemingly a little slumped over to the right. This gnomelike setting was one of the richest collecting grounds of the cruise: *Porites* beds with turtle-grass patches, rocky reefs, mangrove swamps, and a wooden wreck thickly encrusted with animal and plant growths. In a few hours, over the flats, along shore, and in the wreck, this well-populated littoral area yielded such a profusion of specimens representative of all groups of invertebrates that we could not properly preserve all of them before sailing the next day at noon. Nevertheless, that night we put over an electric light at the gangway. Under it the captain wielded a busy dipnet. This routine was a regular thing for the captain almost every evening, and it always brought in a host of the "finer things" of life, from Protozoa and copepods to pelagic mollusks, little squids, and small octopuses, and now and then an unexpected fish and many bizarre larval forms of them and no end of large olive-green and blue-black sea-hares that were drifting or swimming by. At this time of the year they were spawning in the grass patches in shallow water, and evidently Tyrrell Bay was one of their favored habitats.

That afternoon the weather began kicking up, and by 4 o'clock we were driven to seek shelter in Chatham Bay on the lee side of Union Island. This was the only really bad spell of weather encountered during the 5½-week cruise. The wind screeched and whistled all night, and for a time both anchors with all available chain threatened to drag. The clearing sky the next morning was ushered in with a light breeze. Before long we reached the idyllic anchorage among the Tobago Cays for which we had been headed the afternoon before. Except for the utter lack of water ashore, one would be tempted to

spend a lot of time here. The botanist and a helper from the crew ascended the little islet of Petit Batteau to its high point of only 140 feet. Petit Batteau is a rough island composed largely of stony debris, covered by a thick and thorny growth of low shrubs and cacti. While the plants of this area represent widespread and common elements of the Antillean flora, the region is so seldom visited by botanists that it seemed worthwhile to obtain representative specimens of even well-known plants. Diving inside the reef, Captain Nicholson brought us our first living crinoid of the trip. It was with sincere regret that we left this beautiful anchorage for Mustique on the way to St. Lucia by way of Bequia. Mustique is one of the few remaining "feudal" holdings among the islands. It has been in the hands of one family from the time of the original grant to the present day, and on it is a village of several hundred of the descendants of the original slave laborers on its plantations, who today work as tenants for the owners of the island, whose responsibility they are for life. As one might say, they are an integral part of the land—they neither know nor have any other home. Seining was attempted off one of the better looking beaches, but the effort was not worthwhile because the many scattered coral heads made it impossible successfully to complete a single haul. Skin diving saved the day for us, as cracked-up coral clumps and the sponges so retrieved were alive with small animals of all kinds.

A 4-hour run brought us to Bequia. Its harbor, Admiralty Bay, is a quiet, out-of-the-way, withal very beautiful place, unspoiled by tourists except for the few who may go there for no more than a dip in the sea, a sunning on the beach, and a sleep in the shade. It was there that we saw some of the neatest sailing ever. It is marvelous how some of the stolid looking island schooners, with nothing but their sails to power them, can make their anchorages in a light breeze among other craft as easily as the best of motor sailers. True enough, it takes them a bit longer to tack back and forth across the bay, but the consummate skill and the certitude with which it is accomplished are a thrill to watch. We witnessed just such a performance during the heavily overcast afternoon that we were in Bequia; then, as the schooner came to anchor, the sun broke through the clouds to highlight the previously shaded white sails, a brilliantly scarlet hull against the azure sea, the green hills in back, and the white-flecked blue sky above. It was a seacape unsurpassed.

In passing on the way to Castries, St. Lucia, we stopped briefly at Soufrière. Through intermittent showers we beheld one of the most impressive harbor entrances in all the Lesser Antilles, guarded as it is to the east by the Pitons, Petit and Gros. Here, warm sulfur baths were enjoyed. History has it that the Empress Josephine spent her

childhood days on this island and bathed in the sulfur waters of these self-same springs. Soufrière is almost as French as English, in its place names at least. It changed hands a dozen times or more in the days the French were harassing the English during our own Revolution. Castries is big and bustling, having staged a most remarkable comeback following the disastrous fire of 1949. For the most part, it can now boast of new, clean, and modern shops, office buildings, and warehouses. We found it an excellent place for replenishing our stores and fuel and water supplies.

The next morning we dropped back a few miles to Marigot Bay—a most intriguing locality for the collector. The entrance to this secluded, sheltered place is scarcely to be marked from offshore, yet within it is a typical buccaneer's hideaway. On one shore the channel is so steep-to that one can tie up to the palm trees and literally step ashore. The ship's masts were completely hidden in the tops of the trees. All that the black-hulled *Freelance* lacked to complete the picture was a "Jolly Roger" emblazoned with skull and crossbones.

Some of our most successful seine hauls were made in this lovely spot. Our botanist, Dr. Smith, returned with ample booty from the hill above our mooring place, despite the warning posted near our landing place that "any trespass done under this woodland will be arrested & deal with arcording to the law." Captain Nicholson, with his expert diving, found something quite new to him, and to me also—a pair of plump brownish white-spotted snapping shrimps (*Alpheus armatus*) that find themselves at home in the shelter of the tentacles of the large fleshy sea-anemone *Bartholomea annulata*, which lives almost buried on sandy bottoms. These shrimps clambered over and among the tentacles of the anemone with impunity where other species of shrimps quickly became entangled in the mucus given off by the tentacles and perhaps also stunned by their nematocysts and were forthwith ingested. Though similar associations are known in zoological literature, it had not before been observed by any of us. Later, in an aquarium, the captain held two anemones and two pairs of these shrimps alive for several weeks with only an occasional small freshly killed fish for sustenance.

From Marigot Bay the course was set for Pigeon Island, which in 1782 was garrisoned by the English under Rodney in order to keep watch on the French West Indian fleet based on Martinique. Remains of the old fortifications and several of the cannon were noted by Mr. Bredin and Dr. Smith while exploring the heights above the landing place. Mr. Bredin brought back a much-corroded uniform button that must have been dropped in the fort during its occupation in Rodney's day. Now the island sports a beach club with overnight cottages run by a retired former member of the D'Oyly Carte Opera Co.

Captain Nicholson had told us of the great seine hauls made in favorable weather by the natives of the adjacent villages on the beach fronting Pigeon Island. The net is dropped and the haul begins far out in the bay at the very break of dawn. We went ashore an hour and a half or two hours later—nearer 6 o'clock. Even then there was scarcely light enough for regular color film—all that we had along. More of interest to us than the seine haul was the sight that greeted us as we struck the beach—as far as we could see in either direction—a conspicuous pink windrow of crab larvae in the megalops stage, and as we looked more closely the lapping wavelets and the waters of the receding tide were "peppered" with more of these larvae, three or four or more to every cubic foot of water. The natives said they had never seen anything like it before. Meanwhile the wings of the seine were coming closer and closer to shore. One of the lines, the left one looking at the shoreward moving seine, was manned by the womenfolk, with one lone man in the lead at the water's edge. The other line was being pulled in by an all-man crew. Natives in dugouts or canoes off either end of the net beat the water with their paddles and oars or threw stones to frighten back any fish that might try to escape the net. After three or four hours of labor the net was ashore. The catch was pitifully small—just not enough fish to go around. Which of the many native families participating got what and how much, we were unable to determine. It certainly looked as if the place was being overfished, too regularly and too thoroughly. Specimens representative of the catch were bought for the Museum. Elsewhere in the Lesser Antilles, the seine hauls do not appear to be any more productive, perhaps for the same reasons. At least in Martinique in the French West Indies, and in St. Kitts in the Leewards, this seems to hold true. In Martinique, where we drove along the shore for a considerable distance from St. Pierre to Fort-de-France, more than in any other island there were numerous large seines drying on every suitable beach. One haul that we witnessed not far from St. Pierre was most scanty. Certainly something should be done to rehabilitate the shore or seine fisheries of these islands.

At 5 o'clock on March 22 we made Fort-de-France, which must be a popular port of call, for we found several yachts there from the States, including the *Maverick*, another of the Nicholson charter yachts, and one from South Africa hailing from Hong Kong and on a trip around the world. Early the next morning we paid our respects to our American Consul, William B. Cobb, Jr., whose introductions enabled us to make a number of valuable contacts and to arrange for Dr. Smith to meet, at Guadeloupe, Dr. Henri Stehlé, a botanist colleague with whom he had long beeen in correspondence. This last was attended to by Dr. Blanche, Directeur du Service de

Protection des Vegetaux, Service de l'Agriculture, who also took us to meet J. Morice, Directeur de l'Office de Pêches. A further courtesy was the gift of a complete set of the bulletin issued by the local natural history society, a periodical not otherwise available in Washington that will be very welcome to our systematic biologists. Mr. Cobb also kindly conducted us on an extended all-day tour of the island, first inland through rain-forested valleys to the sulfur baths, and then over the hills to St. Pierre.

St. Pierre is the now famous city where on Ascension Day, May 9, 1902, 30,000 inhabitants lost their lives in a matter of moments in that fearsome cloud of incandescent gas that rolled down Mount Pelée. Parts of the city today are strongly reminiscent of Pompeii, except where some of the new, though not always modern, buildings are being erected among the old. Some protection is now being accorded the more significant ruins, and continued excavation is opening up more of the important structures and the streets of old St. Pierre. The vulcanological museum, with its host of "relics" and photographs taken shortly after that fatal eruption, furnishes a sad and moving visual commentary on what was that once flourishing town and what happened to it. It was perhaps the Creole Paris of the New World and is memorialized in Lafcadio Hearn's "Two Years in the French West Indies," written long before the disaster.

Later that day we received an invitation to meet M. Morice at the local yacht club with Dr. Blanche, where we were shown a number of interesting preserved specimens of Crustacea, including the three species of spiny lobsters known from Martinique. Then he mentioned a special zoologist's treat he had in store for us—a bottle full of red megalopa from Pigeon Island! Although they were picked up on the beach 30 hours after our visit, they were little the worse for wear. Morice assured us, too, that it was the first time the phenomenon had come to the attention of any observant person and that he was as anxious as we were to determine the species of crab represented. Dr. Chace has since determined these as probably previously unknown larval forms of an oxystome crab of the family Raninidae.

An urgent cablegram recalled Mr. Bredin to the States. His going left a gap in our ranks, which he promised to fill at the first opportunity with his brother-in-law, Ernest N. May. It was Mr. May who sponsored the Smithsonian-May Expedition of 1947, also to the West Indies, mentioned on the first page of this article.

Dominica is a beautiful high island, as attractive in many ways as equally verdant Martinique, with its majestic and destructive Mount Pelée. Our sails, with an assist in the lee of the island from our twin diesels, brought us from Fort-de-France to Roseau in about 9 hours. Greeting us on the dock was Dr. Clarke, who had already spent 17

days on the island thoroughly sampling the microlepidopteran fauna. In this brief span, in a rather restricted area, nearly 100 species of Microlepidoptera were taken. In this material are many species formerly unknown to science, many of which appear to be endemic. Other species such as *Brachyacma palpigera*, and the notorious pink bollworm (*Pectinophora gossypiella*) were formerly unrecorded from the island. Extensive collecting revealed the presence of both of the above species on many of the islands to the north. Preliminary examination indicates that the microlepidopterous family Blastobasidae, the larvae of which feed in dead and decaying vegetable matter, finds its greatest development in the New World Tropics where it replaces the Lyonetiidae of the Old World Tropics. The Blastobasidae were formerly considered a largely temperate zone family.

Dr. Clarke wished to make a final trip to the fresh-water lake that lies some miles inland, near the main ridge of the island at the head of the Roseau River. He and Dr. Smith spent a very profitable day in the vicinity of the little lake, which lies in a forest-surrounded valley at an elevation of about 1,700 feet. Along the swampy shores of the lake are found several species of grasses and sedges, behind which occur the usual genera of tropical trees and shrubs. Collecting along the trail back toward the coast, the botanist obtained many epiphytes in the wet moss-covered forest, while an endemic West Indian ericaceous plant, *Hornemannia racemosa*, was noted as abundant. A little trailside raspberry, *Rubus rosaefolius*, was appreciated by the collectors for its excellent edible qualities. This was Dr. Smith's best day of the trip from the viewpoint of quantity of material, as he prepared 92 numbers of specimens with about eight duplicates of each. In general he obtained this number of duplicate sets, so that the Museum's Department of Botany will have available seven sets of the expedition's plant collections to use for exchange purposes.

We anchored in Woodbridge Bay, a few miles up the coast, a somewhat better roadstead than at Roseau. Here there was a pier for lightering bananas out to the English-bound *Martha Reuter*. The loading was done with expedition, for here, as everywhere else, time was money. All day long the trucks were discharging heavy loads of bananas alongside natives from the hills, who brought in their one or two stalks upon their heads. In the same fashion the stalks were taken from the storage shed down to the pier to the lighters. All this carrying was done by the women—one stalk to a head and at a rapid walk, often a half trot, because they got so much for each one carried. Returning "empty headed," the more ambitious ones came on a run—the more trips the more earned. The steamer was in for only a day and had to leave at midnight. Except for brief pauses for snacks at noon and midafternoon there was no cessation of the work.

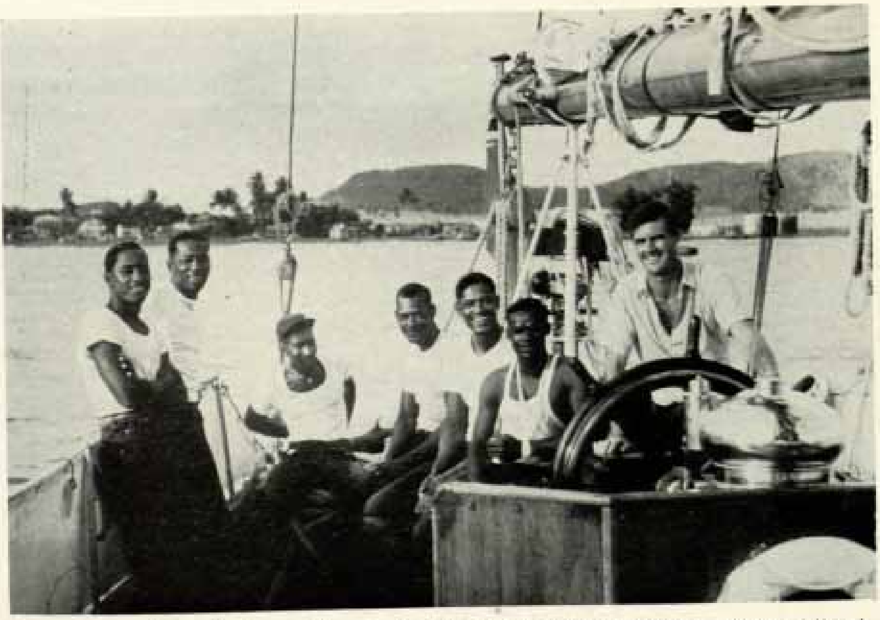
As each woman passed a checker on the way down to the pier she was given a metal token, for each of which she collected the equivalent of about 2 cents (U. S.). The minimum weight of any stalks accepted by the buyer, who pays the grower about 6 cents a pound for them, is 18 pounds, but the heaviest of these stalks easily weighed twice this. A woman might well carry nearly a ton of bananas from morning to midnight, when the steamer sailed, if she worked the entire time.

Here too we met Stephen Haweis, longtime resident artist of Dominica, who painted several of the color plates for Hildebrand's account of fishes in the Smithsonian Scientific Series. Among other things, Haweis is interested in the conservation of "mountain chickens," a delicacy much sought after by natives and Europeans alike, so much so that they are becoming scarcer by the year. The mountain chicken is neither bird nor fowl, but a large frog, *Leptodactylus fallax*, found now only in the mountain streams of Dominica. A specimen as much as 6½ inches long may weigh as much as a pound. Tasting like breast of chicken, the flesh is firmer than that of the frog's legs served in the States.

On March 28 we moved up the coast hoping to explore the Layou River Valley, a surprisingly beautiful place according to the captain, but, to our disappointment, the surf on the river bar was impassably high. Instead, we cast anchor in Prince Rupert Bay off the town of Portsmouth, where we were able to secure an additional length of stout tow line needed for contemplated dredging on the Saba Bank later during the cruise. We got another crinoid here off Portsmouth, and at night with the electric light lured two myctophids, fishes with rows of small luminous spots on each side.

On our way in to Pointe à Pitre, Guadeloupe, we passed just the type of reef over which we wanted to collect. It looked so good and was so close in that Dr. Chace remarked that it could well be the type locality for a number of the crustaceans first described from this island. On the natural history of their West Indies the French zoologists in the early days published a number of fine papers, but very little has appeared since. On the quay we met Dr. Blanche again. He had made a direct and quicker trip up from Fort-de-France. With him was Dr. Stehlé, the now resident French botanist. An all-day field trip to the uplands had been arranged for Drs. Smith and Clarke. But the pleasure of the meeting of two longtime friends who had only known each other through correspondence rather overshadowed the fieldwork this day. Nevertheless, Dr. Smith obtained some specimens of remarkable interest in the forest adjacent to the Institute for Agronomic Researches, as a result of Dr. Stehlé's intimate knowledge of the flora. Of particular interest were the little yellow-flowered iridaceous *Trimezia martinicensis* and a species of *Polygala* which has an odd known distribution of only Guadeloupe and Cuba.

1. The *Freelance*, the 86-foot auxiliary schooner which served the expedition as a floating laboratory during the 40-day cruise from Trinidad to St. Croix.

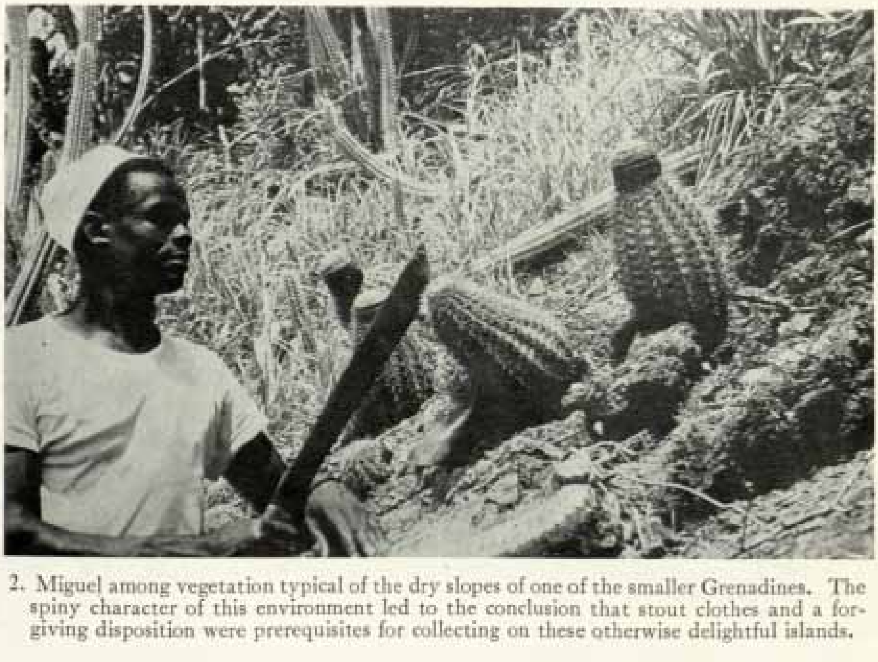


2. The crew of the *Freelance:* Thomas, Kennet, Potter, Edmund, Smith, Danny, Miguel, and Captain Nicholson. This picture was made at Basseterre, St. Kitts, where Edmund replaced Miguel who had injured his hand.

1. The anchorage at Tobago Cays, Grenadines, from the summit of Petit Batteau. This was one of the most beautiful localities visited by the expedition. The reefs, where the surf is breaking in the background, merit further investigation by marine biologists.

2. Hauling the seine in Marigot Bay, St. Lucia. It was in this spot that Captain Nicholson found the first of the striking snapping shrimps, *Alpheus armatus*, associated with the sea anemones, *Bartholomea annulata*.

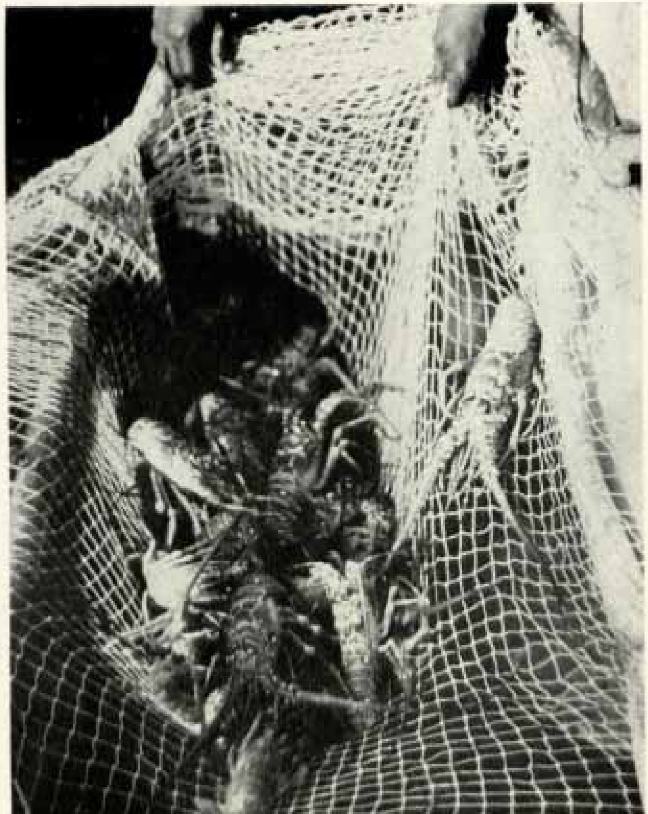
1. Dr. Clarke collecting insects from a bromeliad on Dominica. The boy on the left trudged 10 miles over the mountains to sell his bunch of bananas, only to have his crop rejected.



2. Miguel among vegetation typical of the dry slopes of one of the smaller Grenadines. The spiny character of this environment led to the conclusion that stout clothes and a forgiving disposition were prerequisites for collecting on these otherwise delightful islands.

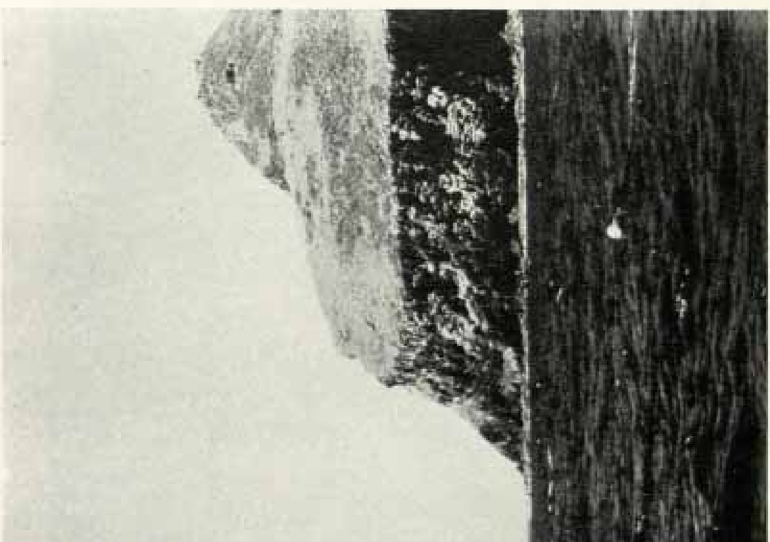
1. The *Caribee*. This yacht, once owned by Ernest N. May, was encountered in Sir Francis Drake Channel while Mr. May was aboard the *Freelance*.

2. Faggot fishing in the Barbuda lagoon. The three fishermen are moving the stack of waterlogged sticks outside of the net before pursing the latter and gathering the spiny lobsters trapped inside.

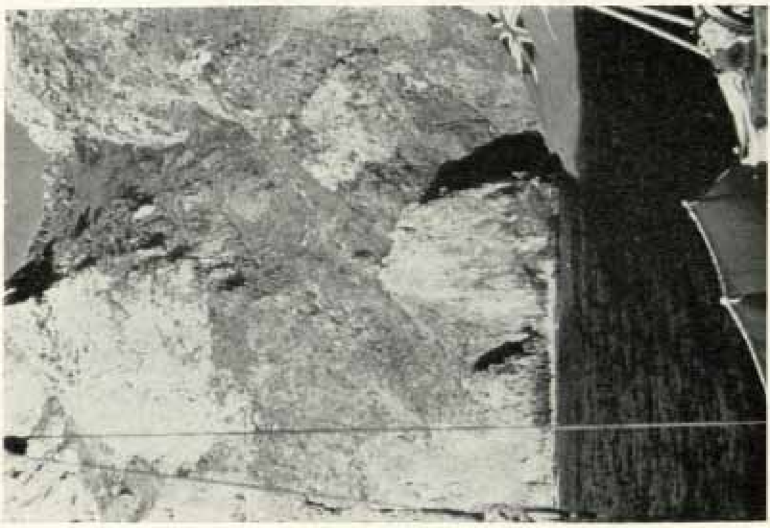


1. The catch from the faggot pile at Barbuda. There were 26 spiny lobsters in the net after the sticks had been removed.

2. Kennet with a barracuda caught on the trolling wire. Most of the fishes obtained in this way ended up on the mess table.



1. The forbidding cliffs of Redonda Island and the sloping grassy plateau above. Phosphate mines were once located on this volcanic rock.

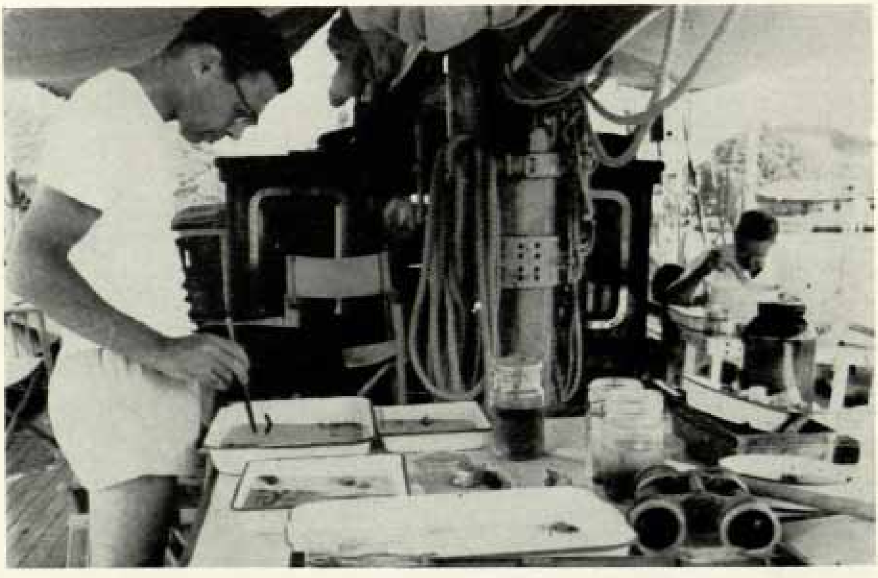


2. The landing place and gully on Redonda which gave Dr. Clarke access to the plateau and down which he descended more rapidly than planned.

1. Dr. Clarke pinning Microlepidoptera in the *Freelance's* saloon. After a successful light-trap station, this operation sometimes lasted most of the following night in order to obtain good study specimens of each of the species caught.

2. Dr. Smith stacks his plant presses around a lantern in his cabin. Because of unpredictable drying conditions on deck, all the botanical specimens had to be dried by this improvised method.

1. Pickling the catch. One of the less pleasant chores of a marine biologist is injecting the larger fishes to insure proper preservation.



2. After a good day on the reef. Dr. Chace and the author segregating the fragile and unusual invertebrates before preservation.

The reef we spotted on the way in was centered about Rat Island. It was indeed rich collecting, reminiscent of Carriacou. Roundabout were mud flats, sand flats, weedy patches rather than turtle-grass shoals, *Porites* clumps again, and, on the little island itself, much honeycombed and fissured sandy limestone alive with shrimps, crabs, and barnacles, boring, stalked, and sessile, and all manner of other invertebrates. On the other hand, the electric light over the ship's side within the harbor that evening lured virtually nothing to our dip net, probably because the waters here are too polluted.

Recalling that a longtime friend and correspondent of the National Museum lived in Pointe à Pitre, we undertook to look him up—Adrian Questal, now in his 80's and confined to his third-floor elevatorless apartment. He is very proud of the several papers he published on the island's flora, helped with identifications made for him in Washington. While looking for the Questal residence, we encountered a Mr. Halley who was anxious to have a strange crab identified. He said it had been taken in a fish pot or trap, locally. This we could not believe, for what he had was a beautifully mounted and varnished *Birgus latro*, the coconut "robber crab" known to us only from the mid and south Pacific. We were most skeptical of his claim that this crab came from the offshore waters of this Atlantic island, yet as we were preparing to leave Pointe à Pitre, we spied in the curio shop just within the customs house gates three identically mounted specimens in a case with a lot of West Indian shells, sea fans, and corals. Could it be that the robber crab has become an "acclimatized" inhabitant of the coconut groves of Guadeloupe? I shall always regret that a tight schedule did not permit us to check his information. We are still inclined seriously to doubt it. However, the rufus-tailed guan, a pheasant which was introduced into the islands of Bequia and Union in the 1800's, has become well established there; and monkeys said to have been brought over in the slave-trading days are at home in the forests of Grenada, according to Fredric Fenger (1926).

The night's run northward in the lee of Guadeloupe was uneventful. Our tries on the 40-fathom bank off Antigua for red snappers were futile; all we got was one black crevalle. It was midafternoon before we tied up at English Harbour and were received by Cmdr. and Mrs. V. D. B. Nicholson, Desmond's father and mother, from whom we had chartered the *Freelance*. Here, roundabout, were what was left of the buildings of Nelson's day, many of which were still in good repair when used in part as the shore laboratory of the Barbados-Antigua expedition of the University of Iowa in 1918. It was from English Harbour that Nelson sailed with his 12 ships to victory at Trafalgar over the French fleet which greatly outnumbered his small fleet.

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The old sea wall of Nelson's day, still standing, is a marvelous place for collecting invertebrates, mobile as well as sessile, and many small fishes, too. At night, with flashlight and long-handled dip net, night prowlers, which seldom if ever leave the crevices in which they hide by day, fall easy prey to the collector. Here the long-clawed, red-banded *Stenopus* can be caught in quantity, one specimen at a time. While Chace and the writer worked over the seashore, the reefs, the harbor piling, and an old wreck, the captain successfully dived for more of the sandy, bottom-dwelling anemones and their associated crustaceans. In addition to the snapping shrimp, *Alpheus armatus*, that he had discovered lurking among the tentacles of the sea anemones at Marigot Bay, he found here another species with similar habits, a hippolytid shrimp, *Thor floridanus*, and also a small red mysid shrimp of which he got several specimens under the same conditions.

The botanist and entomologist were otherwise engaged. They always sought out the higher elevations of most of the islands visited, for the higher one got, and the farther from civilization, the more natural and unspoiled the flora and fauna. The main range of hills on Antigua bears an imposing name—the Shekerley Mountains—although only in a few places does the elevation exceed 1,000 feet. There remain a few patches of native vegetation on these hills, but in the main the whole of the island has been cleared at one time or another. On Boggy Peake, the highest on Antigua, 1,314 feet, and later on Falmouth Peak ("Sugarloaf"), the collecting was varied. Much of the hill area is clothed with a thorny evergreen bush consisting of many species of the legume family; such genera of other families as *Guettarda*, *Capparis*, *Cordia*, and *Rapanea* are represented among the small trees. Several species of epiphytic bromeliads and peperomias thrive in spite of the scanty precipitation. At lower elevations, and especially on the dry hills near English Harbour, a predominant plant is the tall yellow-flowered *Agave obducta*, endemic to Antigua and the nearby island of Barbuda. This lowland vegetation is characterized by a preponderance of thorny plants, not only such horrendous cacti as *Opuntia triacantha* and *O. dillenii*, but thorny legumes, thorny Verbenaceae, thorny Rubiaceae, and thorny Euphorbiaceae. Dr. Clarke and Dr. Smith agreed that, in pursuit of their specialties on the hills near English Harbour, stout clothes and a forgiving disposition were prerequisites.

The low-lying, seldom visited, reef-girt island of Barbuda was next on our itinerary because we wanted to see there the spiny lobster faggot fishery, about which the captain had told us. To the island's treacherous reefs are credited perhaps more wrecks than any other island in the West Indies. But the island is nevertheless blessed with a large, almost landlocked lagoon. An opening to the north permits the shallow draft, usually Antigua-bound, sloops to make their way

from and to the town of Codrington on the eastern shore of the lagoon. It is in this relatively quiet inland sea that the faggot fishery is carried on. For the spiny lobsters, *Panulirus argus*, called crawfish in Florida, and crawfish or langouste in the West Indies generally, the lagoon seems to constitute a huge nursery. It is this circumstance, coupled with the relatively shallow water in much of the lagoon, that makes this unique method of fishing possible. In suitable parts of the lagoon, in about half to three-quarters of a fathom of water, the natives build up piles of waterlogged brush, tree limbs, and small stumps. This pile of "faggots" is usually about 4½ feet high and roughly 6 or more feet in diameter. Left to soak undisturbed for some weeks, it becomes a well-populated refuge or shelter for young lobsters. These are then secured by surrounding the pile of faggots with a seine or gill net of sufficiently small mesh. Then the fishermen stand within the encircling net and toss over the faggots to form a new pile just outside the net. Thus the faggot fishery is a continuing one. When all the faggots have been removed, the net is pursed at the bottom and the catch dumped into the sloop in which the natives travel about the lagoon. In the haul described there were 26 sizable lobsters. The three fisherman who put on the "performance" for us maintain seven of these faggot piles, in addition to whatever other fishing or agricultural work they may do.

Ashore with his light-trap set overnight, Dr. Clarke secured no less than 3,000 specimens of the tiny moths, Microlepidoptera, that he especially sought. Also, in the course of a hike to the so-called south landing, from the reefs there, additional forms of marine life were collected, and on the road to and through the brush from the landing Dr. Clarke got many other unexpected insects from bromeliads and other vegetation that he hacked to pieces on the way.

From Barbuda we returned to Antigua, but our stopover this second time was scarcely longer than necessary to stock up for the last lap of the cruise, and to await Mr. May's arrival by plane. This was his first opportunity to "sign on" following Mr. Bredin's return to the States from Martinique.

Nevis was our next destination. On the way, early in the afternoon, we found ourselves passing close to that isolated volcanic "extrusion" from the bottom of the sea, Redonda. About 20 years ago I had hoped to land on this small uninhabited island, but was thwarted by the high seas beating against its precipitous cliffs and boulder-strewn shores. For all these years I had wanted to get back to secure a few specimens of the "phosphate rock" formerly "mined" here for our late chief geologist, Dr. William F. Foshag, who had always wanted some of it. This year I was able to gratify that ambition; the sea was calmer, and the surf ashore far less forbidding. The captain

assenting, Dr. Clarke and I made it for a few hours, with Danny Thomson as boatman. While I worked the shore among the boulders, Clarke scaled the heights up a steep, narrow gully or rift. He retraced his steps a bit faster than he went up, riding a rock slide that he started in his descent. Though neither of our collections was at all extensive, we must have set up a number of records. Both of us got samples of the desired phosphate "ore," Clarke at the upper end of a former cableway that brought down the rock to the long-demolished pier, and I from the dump at the lower end, where remained still a lot of rock and debris.

Nevis is the island on which Alexander Hamilton was born, but all that remains of the reputed site of his home are bits of foundation walls and a few stone steps. On this day Dr. Chace and I were pitied by the entomologist and botanist, who, as usual, headed for the high point; on Nevis this is the precipitous truncated cone that dominates the island, Nevis Peak, with an elevation indicated (perhaps optimistically) on the charts as 3,596 feet. Marine biologists cannot always understand the exhilaration reserved for the mountaineering biologist, but on this clear and beautiful day we could indeed envy our colleagues "up the hill." They circled the peak to its eastern base by road, and then, with a local guide, struck up the unrelenting slope, following a single ridge to the summit. The cleared land gives way to forest at about 1,000 feet, and from that point the ascent was a scramble over boulders, roots, and saturated tangles of vegetation. Occasionally the climbers came to an open shoulder from which the cultivated fields and the shore line of Nevis could be seen far below. After three hours of climbing the party reached the summit ridge, above an old breached crater, which they followed to a surveyor's tripod on the actual summit. Several hours were spent here and on a slower return trip. Here is one of the most spectacular views available in the Antilles, as the whole of the adjacent island of St. Kitts, culminating in Mount Misery, spreads northward under piled white clouds. The summit ridge of Nevis bears an excellent sample of Antillean "elfin woodland," a dwarfed type of forest of which the component trees are bent and gnarled by the wind. Epiphytic ferns, mosses, bromeliads, and orchids abound in this cool, wet realm, and collecting for the botanist was excellent.

Inasmuch as marine collecting at Nevis was poor, we decided to move over to Frigate Bay near the southern end of St. Kitts and investigate what appeared on the chart to be a promising reef on the windward side of that island. A walk of about half a mile across the narrow neck of St. Kitts, past a pond where natives in festive mood were sacking blocks of salt that had crystallized on the surface, brought us to one of the most interesting reefs encountered on the

trip. A steep, sandy beach provided an underwater grandstand from which to view the activities of reef fishes about the bases of colonies of *Acropora palmata*. While we were there two native fishermen, with spear guns and goggles, wended their way across the flat tops of these coral growths to the outer edge of the reef a couple of hundred yards away as confidently as a woodsman might follow a forest trail.

As the long haul to Tortola would take us over the Saba Bank, we had planned a few dredge hauls on it. For us fortunately the great underwater plateau in some places reaches to within 6 to 9 fathoms of the surface. The ground fishing attempted by the crew drew a blank for reasons unknown to us, but the dredging exceeded all expectations—it was the best of the cruise.

Farther along and much nearer Tortola, we stopped briefly on Virgin Gorda to work over another rich littoral fauna in Gorda Sound, and to permit Drs. Clarke and Smith to ascend Virgin Peak (1,379 feet). They found no part of this hill with its original vegetation cover, but nevertheless the second-growth thickets and woods disclosed botanical and entomological components of considerable interest. A further stop was made near the western extremity of Virgin Gorda to visit the locally famous "Baths." These are veritable indoor pools open to the sea but sheltered in "chambers" formed by the most gigantic boulders any of us had ever seen. Tortola is another of those islands, like Barbuda, that few people ever visit unless they have special business there. Here the last mountain, Mount Sage, 1,780 feet high, was climbed by Clarke on his last hunt for insects on this expedition.

It *is* a small world after all. Mr. May, in 1947, was the proud owner of a very fine yacht, the *Caribee*, which he later sold, but this very day of April 18, as we were bowling along with a fair breeze through the beautiful, blue, island-studded water, Sir Francis Drake Channel, bound for St. Croix, Mr. May, who was watching sails on the horizon, exclaimed, "There's the *Caribee!*" "How do you know?" "I sailed her too long not to know the cut of her sails anywhere." It was the *Caribee!* In response to a radiotelephone request the present owner kindly brought her over so that we might photograph her under full sail. A once-in-a-lifetime happenstance—our boat being there and for a brief spell sailing the same course in the same direction.

It was with sincere regret that we had to pass up St. Thomas and St. John of the American Virgin Islands, but time was running out, as did our charter of the *Freelance*, too, in Christiansted, St. Croix, on April 19, 1956. Captain Nicholson most kindly granted us several days' grace to get our specimens packed as the expeditionary party scattered. Mr. May enplaned for Puerto Rico and Drs. Clarke and Smith for the States and the Museum, to which Dr. Chace and I were

also returning with the collecting gear and pickled specimens by slower transport, the *Alcoa Runner*.

All in all, the Smithsonian-Bredin Expedition on the *Freelance* covered, as a ship sails into the wind, perhaps a thousand miles between Trinidad and St. Croix, and from one to another of some 28 islands or islets, rocks, or reefs on the way. Biological collections were made on or about most of them, bottom samples were taken at 15 different anchorages, and samples of soil for biotic assay at 38 localities. The entomological aspects of the expedition were concerned primarily with obtaining material from an area that is rather weakly represented in the national collection. Much information on distribution and ecology, and some on habits and life histories were obtained, but the distributional data were by far the most important.

The various materials collected at this writing are still far from being completely sorted and critically identified. Included are over 4,000 specimens of plants, more than 18,000 individual specimens of Microlepidoptera and other insects, over 27,000 marine invertebrates of various kinds, sea anemones, corals, polychaete worms, shrimps, and crabs, and their smaller relatives, and many mollusks, squids, and octopuses. Among this material are many little-known or undescribed species. The fishes saved for the Museum's ichthyological collections numbered 1,700—a not insignificant showing for five "collectors" for a 5½-week period.

The Institution is again immeasurably indebted to Mr. and Mrs. Bredin for underwriting this second of their recent scientific expeditions undertaken for the enhancement of the study collections of the United States National Museum.

Of course, there was much more to the trip than is, or can be, recounted in these few pages. We have set forth, briefly annotated, the greater part of our itinerary and a few of our experiences. I cannot refrain from citing one quotation quite typical of the natives' philosophy throughout the islands, lifted, with apologies, from a little real-estate folder distributed in Christiansted: "Only so many dollars on St. Croix—mon kill heself try get more'n he share."

Man as a Maker of New Plants and New Plant Communities[1]

By EDGAR ANDERSON

Curator of Useful Plants, Missouri Botanical Garden
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St. Louis, Mo.

THAT MAN changes the face of nature may be noted by any casual observer; not even the ablest and most experienced scholar can yet estimate just how far this has reclothed the world. Whole landscapes are now occupied by man-dominated (and in part by man-created) faunas and floras. This process began so long ago (its beginnings being certainly as old as *Homo sapiens*) and has produced results of such complexity that its accurate interpretation must await research as yet scarcely begun. Though answers to many basic questions remain unknown, they are by no means unknowable.

The average thoughtful person has little inkling of this reclothing of the world; even professional biologists have been tardy in recognizing that in the last analysis a significant portion of the plants and animals which accompany man is directly or indirectly of his own making. The ordinary American supposes that Kentucky bluegrass is native to Kentucky and Canada bluegrass native to Canada. A few historians and biologists know that these grasses (along with much of our meadow and pasture vegetation) came to us from Europe. The research scholar inquiring critically into the question realizes that some of this vegetation was as much a Neolithic immigration into Europe as it was a later immigration into the New World. Like Kentucky mountaineers, this vegetation has its ultimate roots in Asia, and spread into central and western Europe at times which, biologically speaking, were not very long ago.

It is obvious that landscapes such as the American Corn Belt have been transformed by man. Other man-dominated landscapes do not

[1] Reprinted by permission from Man's Role in Changing the Face of the Earth, published and copyrighted by the University of Chicago Press for the Wenner-Gren Foundation for Anthropological Research, 1956.

betray their origin to the casual observer. Take the grasslands of California, the rolling hills back from the coast, the oak-dotted savannas of the Great Valley. Here are stretches of what look like indigenous vegetation. Much of this mantle is not obviously tended by man; it has the look of something that has been in California as long as the oaks it grows among, yet the bulk of it came, all uninvited, from the Old World along with the Spaniards. Most of it had a long history of association with man when it made the trip. Wild oats, wild mustards, wild radishes, wild fennel—all of these spread in from the Mediterranean, yet over much of the California cattle country they dominate the landscape. Native plants are there, even some native grasses, but it takes a well-informed botanist going over the vegetation item by item to show how small a percentage of the range is made up of indigenous California plants.

For those parts of the Tropics where plants grow rapidly it will take careful research before we can have an informed opinion about such questions. Thorn scrub, savannas, bamboo thickets, weedy tangles of quick-growing trees and shrubs are known to have covered vast areas in the last two or three millenniums. Yet Standley, our greatest authority on the vegetation of Central America, digging up a small tree in what appeared to him to be a truly indigenous forest in the Lancetilla Valley, came upon a layer of potsherds (Standley, 1931). What is the relation between the supposedly wild avocados of such a forest and the avocados eaten in the village that once covered that site? We now have various techniques (pollen profiles, carbon-14 datings, chromosome analysis, extrapolated correlates) which can give critical answers, but they are time-consuming, and their application to such problems has just begun.

The total number of plants and animals that have moved in with man to any one spot on the earth's surface is way beyond what even a biologist would estimate until he looked into the problem. There are the cultivated plants both for use and for display, the domesticated animals, the weeds, and their animal equivalents such as houseflies, clothes moths, rats, and mice. A much larger class comprises organisms not purposely introduced by man, which are neither eyesores nor plagues, but which, like weeds, have the capacity to get along in man's vicinity. Such are the daisies and yarrows and buttercups of our meadows. Such, in a sense, are even those native species that spread under man's influence. Take, for example, the sunflowers of Wyoming. They are certainly native to North America and may possibly in part be prehuman in Wyoming. They line the roadways yet seldom are elsewhere prominent in the native landscape. They appeared along with the road, even though they may have moved in from not so far away. But how did they get into the spot from which they

spread, and did pioneers or primitive man have anything to do with making this previous niche? This is the sort of question we are now making the subject of decisive experiments; we do not yet have enough results for decisive answers.

For micro-organisms the problem of the species that travel about with man staggers the imagination. Micro-organisms seemingly fall into the same general categories as macro-organisms. Brewers' yeasts are as much cultivated plants as the barleys and wheats with which they have so long been associated for brewing and baking. The germs of typhoid and cholera are quite as much weeds as are dandelions or Canada thistles. The micro-organisms of our garden soil are apparently the same mixture of mongrel immigrants and adapted natives as our meadow and pasture plants. Soils are good or bad quite as much because of the microcommunities they contain as because of their composition. Man's unconscious creation of new kinds of micro-organisms is an important part of his total effect on the landscapes of the world. Think, then, of this total composite mantle of living things which accompanies man: the crops, the weeds, the domesticated animals, the garden escapes such as Japanese honeysuckle and orange day lily, the thorn scrub, the bamboo thickets, the English sparrows, the starlings, the insect pests. Think of the great clouds of algae, protozoa, bacteria, and fungi—complex communities of micro-organisms that inhabit our soils, our beverages, our crops, our domesticated animals, and our very bodies.

If we turn to the scientific literature for an orderly summary of where these species came from and how, there is a depressing lack of information. The crop plants and domesticated animals have been somewhat studied, the ornamentals and the weeds scarcely investigated. Even for the crop plants one notes that for those that have been the most carefully studied—wheat (Aase, 1946), cotton (Hutchinson et al., 1947), maize (Mangelsdorf and Reeves, 1938)—there is now general recognition that their origins, relationships, and exact histories are much more complex problems than they were thought to be a generation ago. In spite of these wide gaps in our knowledge, I believe the following generalizations will stand:

1. All the major crops and most of the minor ones were domesticated in prehistoric times. *Modern agriculture, classified solely by the plants it uses, is Neolithic agriculture.*

2. For none of the major crops can we point with certainty to the exact species (or combination of species) from which it was derived: for some we can make guesses; for a number we can point to closely related weeds. This merely complicates the problem. We then have to determine the origin of the crop, the origin of the weed, and the history of their relationships.

The world's knowledge of crop plants, in other words, does not tell us very much. All we know is that we are dealing with man's effects on certain plants in the Neolithic or before. Yet for weeds and ornamental plants even less is known. A few general observations may be offered, parenthetically, about their origins.

1. We can now point to crops that are definitely known to have been derived from weeds. For instance, rye as a crop originated from a grainfield weed (Vavilov, 1926). As barley and wheat spread farther north onto the sandy Baltic plain, the weed gradually replaced the crop. The origin of rye as a weed is a far older and more complex problem. Stebbins and his students are far enough into it to tell us that it is a story with several chapters, most of them unsuspected until recently.

2. We can point to weeds that originated from crop plants. The bamboo thickets that cover whole mountainsides in the Caribbean came from cultivated bamboos. It now seems much more probable that teosinte the weed was derived from maize the crop than that maize was derived from teosinte.

3. Crop plants and their related weeds frequently have a continuing effect upon each other. We have documented evidence of weeds increasing their variability by hybridizing with crop plants and of crop plants consciously or unconsciously improved through hybridization with weeds. These processes recur repeatedly in the histories of weeds and crop plants. For wheat it is clear that a minor grain was in very early times built up into one of the world's great cereals through the unconscious incorporation of several weeds from its own fields (Anderson, 1952, pp. 57–64).

As a whole, ornamentals (though little studied as yet) provide the simplest keys and the clearest insights into the basic problems of domestication of any class of plants or animals. Some have been domesticated within the last century—the African violet, for instance—but are already distinct from the species from which they arose. Such recent domesticates provide unparalleled experimental material for determining what happens to the germ plasm of an organism when it is domesticated. Others of our garden flowers originated in prehistoric times. They seem to have been associated with magic and ceremony; some of them may have been with us for as long as or even longer than our crop plants. Take woad, *Isatis tinctoria*, now known only as a garden flower, though it persisted as a commercial dye plant until Victorian times (Hurry, 1930). When Caesar came to Britain, he found our semisavage ancestors using it to paint their bodies. There are various other ornamentals (*Bixa*, *Amaranthus*, *Helianthus*) whose earlier associations were with dyes and body paints. Which is older, agriculture or body painting?

The cultivated grain amaranths (known to the Western world mainly through such bizarre late-summer annuals as love-lies-bleeding) demonstrate that we shall be in for some rude shocks when we make serious studies of these apparently trivial plants. J. D. Sauer found (1950) that this whole group was domesticates, divisible into several different species, none of which could be equated to any wild amaranth; that the whole group was of American origin; and that the varieties cultivated since ancient times in Kashmir, China, and Tibet were not (as had previously been taken for granted) derived from Asiatic amaranths. They are instead identical with those cultivated by the Aztecs and the Incas.

It is now becoming increasingly clear that the domestication of weeds and cultivated plants is usually a process rather than an event. None of them rose in one leap from the brain of Ceres, so to speak. The domestication of each crop or weed went on at various times and places, though by bursts rather than at a regular rate. For many it still continues. Our common weed sunflowers, for example, are at the moment being bred into superweeds. In California, by hybridization with a rare native sunflower, these weeds are increasing their ability to colonize the Great Valley (Heiser, 1949). In Texas (Heiser, 1951), by similar mongrelizations with two native species, they are adapting themselves to life on the sandy lands of the Gulf Coast (see figs. 1, 2, and 3).

The story of the American sunflower is significant because it demonstates the kinds of processes that went on in the Stone Age and before, when our major crops were domesticated. It is because the domestication of weeds and cultivated plants (using the word "domestication" in its broadest sense) is a continuing process that it came to my professional attention. Thirty years ago I started out to study (and if possible to measure) such evolution as was still going on. As I analyzed example after example, the fact became increasingly clear that evolutionary activity is concentrated in (though by no means confined to) disturbed habitats—to times and places where man's interference with the prehuman order of things has been particularly severe. Post-Pleistocene evolution, it seems, has been very largely the elaboration of weedlike plants and animals.

Now why should this be? What is there about the presence of man that stimulates his plant and animal companions into increased evolutionary activity? A growing body of observational and experimental data bears directly upon that question; rather than summarizing it, let me describe in considerable detail one particularly illuminating example. It concernes the hybridization of two California species of wild sage, *Salvia apiana* and *S. mellifera*. They have been meticulously studied by Epling—in the field (1947), the herbarium (1938),

FIGURE 1.—(For explanation, see opposite page.)

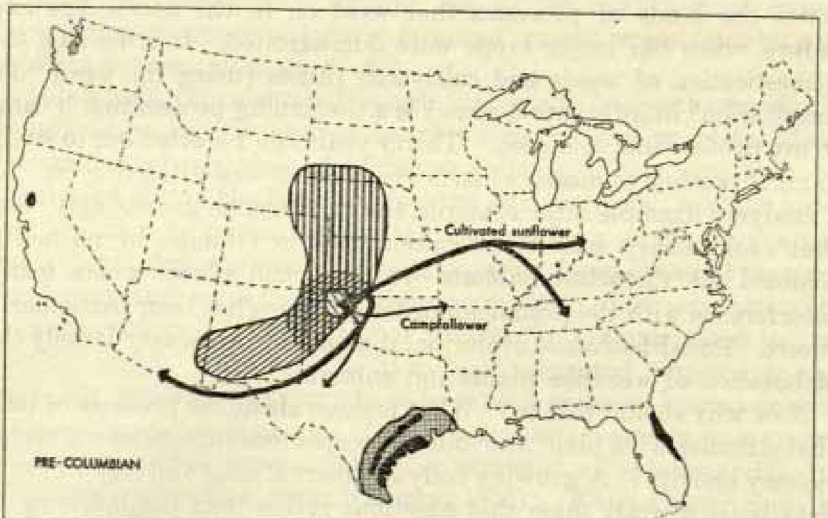

FIGURE 2.—(For explanation, see opposite page.)

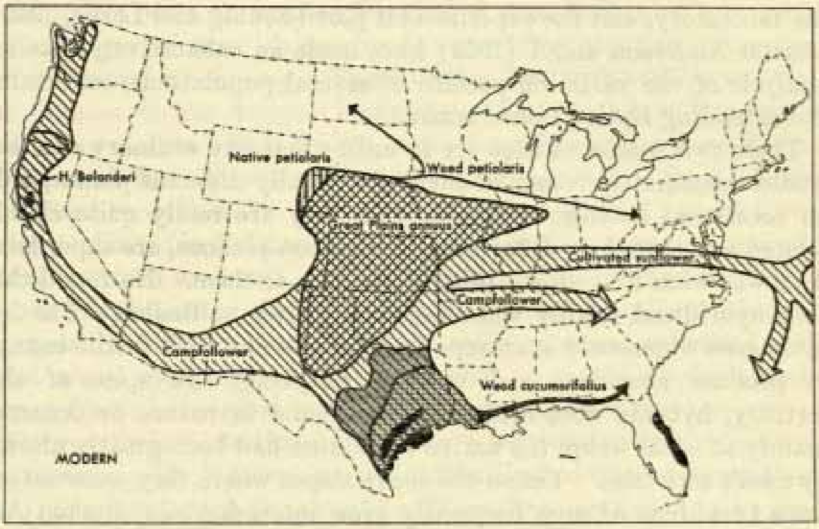

FIGURE 3.

FIGURES 1, 2, and 3.—A diagrammatic and greatly simplified demonstration of the extent to which the domestication of the sunflower as a cultivated plant and its development as a weed are processes rather than events. Data from Heiser (1949, 1951) and personal communications, and from my own observations. The history of the cultivated sunflower, complicated though it is shown to be, will be simpler than that of most cultivated plants when these histories have been worked out in accurate and documented detail. Various complications have been ignored altogether to keep the diagram intelligible, as, for instance, the continuing intercrossing between the "camp-follower" weed and the cultivated ornamental and field-crop sunflowers.

FIGURE 1.—Annual species of North American sunflowers as presumed to have existed in prehuman times: (*1*) *Helianthus exilis*, a highly localized endemic in the serpentine areas of California; (*2*) *H. petiolaris* on bare sandy areas in the western Great Plains; (*3*) *H. annuus* in playas and other raw-soil habitats of the southwestern deserts; (*4*) *H. argophyllus* on the sands of the Texas coastal plain; and (*5*) *H. debilis* in Florida and Texas.

FIGURE 2.—Hypothetical origin of the North American sunflower as a weed and as a cultivated annual in pre-Columbian times. In the areas where *annuus* and *petiolaris* had begun to introgress, this process is being unconsciously accelerated by the activities of early man.

FIGURE 3.—Spread of annual species of North American sunflowers in modern times. In the Great Plains extensive introgression of *annuus* and *petiolaris* produced the Great Plains race of *Helianthus annuus*, which has spread eastward through the prairies as a somewhat weedy native. The camp-follower weed (sometimes mixed with Great Plains *annuus*) has spread as a weed throughout the East and to irrigated lands in the West. In California, by extensive and continuing introgression with *exilis*, it has created the semiweedy *H. bolanderi*, which is still actively spreading. Similarly on the sands of the Texas coast and the Carrizo ridge, *H. argophyllus* is introgressing actively with *H. annuus* to produce weedier strains. Over an even wider area in Texas extensive introgression of *annuus*, *petiolaris*, and *cucumerifolius* is producing a coastal-plain weed sunflower which is actively spreading along the coast. In spots it has already reached the North Carolina coastal plain. Eventually this will react actively with *H. debilis* var. *debilis*, breeding a superweed for the American Southeast but, fortunately, a not unattractive one. The Texas and California phenomena have already been documented by Heiser (1949, 1951), and research on other facets of the problem is going forward rapidly.

the laboratory, and the experimental plot (Epling and Lewis, 1942). Burton Anderson and I (1954) have made an exhaustively detailed analysis of the variation pattern of several populations, confirming and extending Epling's conclusions.

These two species of sage are so unlike that any ordinary amateur would immediately recognize them as radically different plants; only an occasional botanist would see that they are really quite closely related and that their differences, though conspicuous, are superficial. This was what first drew Epling's attention to them. He found that they hybridized readily when artificially cross-pollinated. The hybrids grew vigorously in an experimental plot and were fertile enough to produce abundant and variable offspring. In spite of this fertility, hybrids were ordinarily not found in nature or occurred mainly at spots where the native vegetation had been greatly altered by man's activities. Yet on the rocky slopes where they were native, these two kinds of sage frequently grew intermingled. Burton Anderson and I worked with samples of wild populations of both species so intensively that eventually we could distinguish between mongrels, seven of whose great-grandparents were from one species and one from the other, and plants with all eight grandparents from one species. With this yardstick we learned that, though the plants on the mountainside were prevailingly of one species or the other, yet along the pathway from which we collected them we could find a few mongrels. These were mostly plants closely resembling typical *Salvia mellifera* but showing slight indications of *S. apiana* in one character or another. Apparently the very rare hybrids which Epling had found were not completely without issue. Some of them had crossed back to *S. mellifera*, and, of these three-quarter bloods, a few of those similar to the recurrent parent had been able to fend for themselves.

At one point along the path we found conspicuous hybrids resembling those produced by Epling; careful investigation of this area gave us new understanding. With repeated visits we gradually realized that these bizarre mongrels were limited to a definitely circumscribed plot having a greatly altered habitat. It was at a point where the trail swung down along the slope. Originally a forest of live oaks had abutted on the rocky, sunny slopes where the salvias grow. The oaks had been cut and a small olive orchard planted and then abandoned—abandoned so long ago that native plants had flowed in and the whole site looked quite natural. A collection of salvias made exclusively from among the olives was almost entirely hybrids and hybrid descendants. Though the bulk of the plants looked somewhat like *Salvia apiana*, there was not a single plant which in all its characters agreed exactly with the *apiana* outside this plot. Furthermore, they resembled artificial backcrosses in that their differences

from *apiana* were all in the direction of *S. mellifera.* These "sub-*apianas*" graded into plants closely resembling the first-generation hybrids raised by Epling. There were a few "sub-*melliferas*" similar to those we had detected along the pathway on the mountainside and a few plants which on our index scored as typical *melliferas.* However, in the field *none* of them looked quite average. Dr. Anderson and I had to work in St. Louis on pressed and pickled material previously collected in California. Had we been able to go back and add characters such as flower color and flower pattern to our battery of measurable differences between *S. mellifera* and *S. apiana*, I believe we could have demonstrated that the entire plot was colonized with hybrids and mongrels, most of them first or second or third backcrosses from the original hybrids to one or the other species.

The results indicate that hybrids are being constantly produced on this mountainside, but one does not ordinarily find them, because there is no niche into which they can fit. The native vegetation had a long evolutionary history of mutual adaptation. Plants and animals have gradually been selected which are adapted to life with each other like pieces of a multidimensional jigsaw puzzle. It is only when man, or some other disruptive agent, upsets the whole puzzle that there is any place where something new and different can fit in. If a radical variant arises, it is shouldered out of the way before it reaches maturity. In a radically new environment, however, there may be a chance for something new to succeed. Furthermore, the hybrids and their mongrel descendants were not only something new; they varied greatly among themselves. If one of them would not fit into the strange new habitat, another might. Though virtually all of them had been at a selective disadvantage on the mountainside, a few of them (aided and abetted no doubt by the vigor which is characteristic of these and many other hybrids) were now at a selective advantage. They consequently flowed in and occupied the old olive orchard to the virtual exclusion of the two original species.

Furthermore, to take up an important fact about which biology as yet knows very little, the habitat among the olives was not only something new; it was *open.* It was not full of organisms which had been selected to fit together. Remember that for the mountainside, on those rare occasions where a first-generation hybrid plant had been able to find a foothold, virtually none of its highly variable descendants was able to persist. Such species crosses can father hundreds if not thousands of distinguishably different types of mongrel descendants. Only along the pathway had *any* of these been able to find a place for themselves and then only those that differed but slightly from *Salvia mellifera.* Hybridization does not advance in closed habitats.

The plants in the olive orchard had no such history of long association. The olives were new to California. The societies of microorganisms in the soil were originally those that go with live oaks, not those accompanying the salvias on the sunny slopes. These must have been greatly changed during the time the olives were cultivated. Furthermore, the olives, being planted at considerable distances from each other, did not re-create either the fairly continuous shade of the oaks or the open sunshine of the upper slopes. The orchard became the site for evolutionary catch-as-catch-can, and under these circumstances, as we have seen, the new and variable had a decisive advantage.

Now that we know this much about these salvias, it would be interesting to work experimentally with them and the species with which they are associated to determine just what factors allow two different but closely related species to fit together with their associates so perfectly that all hybrid intermediates are excluded. From experience with other similar problems I would predict that among the most important factors would be fairly specific reactions between some of the other associated plants and these two sages. In our experimental work with sunflowers we have discovered that one of the strongest factors in determining where weed sunflowers may or may not grow is their reaction to grass. Many grasses apparently give off a substance highly toxic to weed sunflowers. The various species of weed sunflowers differ in their sensitivity to this poison. When two such sunflowers hybridize, one of the factors affecting the outcome is the grassiness of the site. Such relationships seem to be very general among plants. On the whole, many species grow where they do, not because they really prefer the physical conditions of such a site, but because they can tolerate it and many other organisms cannot.

Generally speaking, the plants which follow man around the world might be said to do so, not because they relish what man has done to the environment, but because they can stand it and most other plants cannot.

Are these salvias weeds? I would put forward the working hypothesis that those in the abandoned olive orchard are on the way to becoming weeds. The small exceptional communities of hybridizing colonies similar to this one, which can be found here and there over southern California, are worth considerably more attention than they have hitherto received. They demonstrate the way in which man, the great weed breeder, the great upsetter, catalyzes the formation of new biological entities by producing new and open habitats.

The *Salvia* case is not unique. We now have over a score of similar well-documented studies of the connection between hybridization and weedy, disturbed habitats. This relationship had long been known to observant naturalists, though not until the last few decades was

its significance stressed or experimental work undertaken. One other example demonstrates the role of man's operations on the habitat. Riley (1938) studied the hybridization of two species of *Iris* on the lower delta of the Mississippi in a neighborhood where the land-use pattern had produced something as demonstrable and convincing as a laboratory experiment (Anderson, 1949; see fig. 4). Property lines ran straight back from the river; the farms were small, only a few hundred yards wide, and very narrow. Under these conditions it was easy to see that the hybrids between these two irises were virtually

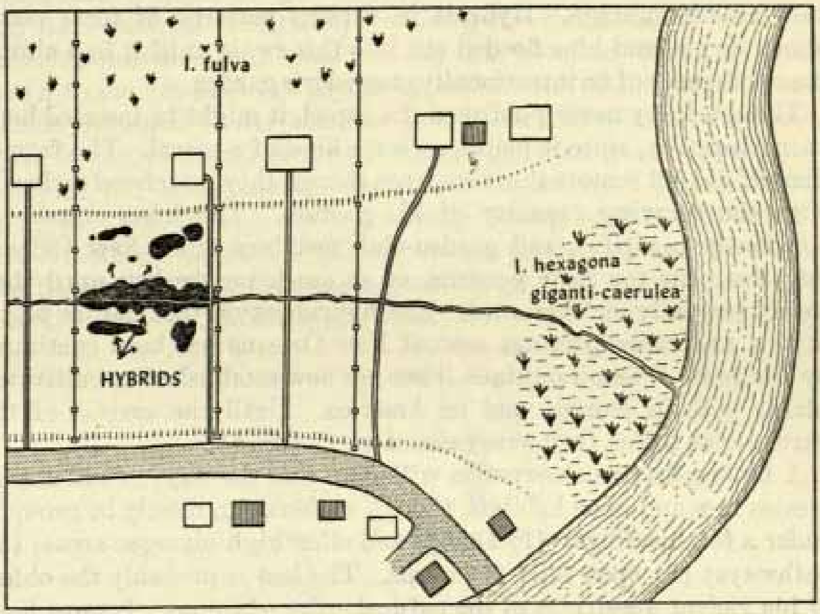

FIGURE 4.—A demonstration of man's unconscious role in creating new plants. (From Riley, 1938.) At the far right one of the minor bayous of the lower Mississippi Delta. At right angles to it and running nearly across the figure is the abandoned channel of a former stream, now drained by a ditch. The natural levees of the stream are slightly higher than the surrounding country. Their sharp inner edges are indicated on the map by hachures. The road has been run along the lower levee, and houses have been built along the opposite one. The property lines (as in many old French settlements) produce a series of long narrow farms, which for our purposes serve as so many experimental plots. Each farm has its house on a low ridge with a long entrance drive connecting it across a swale to the public road on the opposite ridge. The farms (including a score of others which are out of sight to the left of the figure) were originally essentially similar. At the point where the ditch joins the bayou is a large population of *Iris hexagona giganti-caerulea*. Behind the levee on which the houses were built, *I. fulva* grows on the lower ground as well as farther upstream along the ditch. The key fact to be noted is that the hybrids are on only one farm, that they are abundant there, and that they go up to the very borders of the property on either side. Nature is evidently capable of spawning such hybrids throughout this area, but not until one farmer unconsciously created the new and more or less open habitat in which they could survive did any appear in this part of the delta. (See Anderson, 1949, pp. 1–11, 94–98, for a more complete discussion.)

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limited to one farm. They grew in a swale which crossed several of the farms, yet were nearly all on one man's property. On his farm they went right up to the fences and stopped, and this could be demonstrated at either side of his property. Unlike his neighbors, he had kept the swale heavily pastured. His cattle had held in check the grasses which are serious competitors of swamp irises. They had also, tramping about in wet weather, turned the swale into more of a quagmire than existed on any of the neighboring farms. They had at length produced an open environment in which the pasture grasses were at a disadvantage and the resulting hybrid swarm of irises at a very real advantage. Hybrids in various patterns of terra cotta, wine, purple, and blue flooded out into this swale until it had almost the appearance of an intentionally created iris garden.

Though Riley never published the sequel, it might be inserted here, parenthetically, since it points up some kind of a moral. The farmer himself did not remove the irises, even though they interfered seriously with the carrying capacity of his pasture. The irises were conspicuously beautiful, and garden-club members from New Orleans dug them up for their gardens, at so much per basket, until they were eventually exterminated. The hybridization that nature began in this and other pastures around New Orleans has been continued by iris fans. These Louisiana irises are now established as cultivated plants both in Europe and in America. Until the arrival of the garden-club ladies, they were nascent weeds (fig. 5).

A little reflective observation will show that the ways in which man creates new and open habitats, though various, can mostly be grouped under a few headings: (1) Dumps and other high-nitrogen areas; (2) pathways; (3) open soil; (4) burns. The last is probably the oldest of his violent upsettings of the natural order of things. It must have stimulated evolutionary activity very early—whole floras or certainly whole associations must have come to a new adjustment with it here and there; fire should be, of all man's effects upon evolution, the most difficult to analyze. Until valid experimental and exact historical methods deal with this problem, it inevitably must spawn more polemic activity than scientific analysis.

In contrast to fire, the creation of open-soil habitats as a really major human activity belongs much more to the age of agriculture and industry than to prehistory. It may be that is why it seems to be the simplest to analyze. In Europe and eastern North America, in the humid Tropics and sub-Tropics, open soil—bare exposed earth—is scarcely part of the normal nature of things. Most of the flora truly native to these areas cannot germinate in open soil or, having germinated, cannot thrive to maturity. Make a series of seed collections from wild flowers and forest trees and plant them in your garden just

like radishes or lettuce. You will be amazed to learn how small a percentage of them ever comes up at all. Make similar collections from the weeds in a vacant lot or from the plants (wanted and unwanted) of your garden. Nearly all of them will come up promptly and grow readily. Where did these open-soil organisms come from in the first place, these weeds of gardens and fields, these fellow travelers which rush in after the bulldozer, which flourish in the rubble of bombed cities? Well, they must have come mostly from prehuman open-soil sites. River valleys did not supply all of them, but rivers are certainly, next to man, the greatest of weed breeders. Our large rivers plow their banks at flood times, producing raw-soil areas. Every river system is provided with plants to fill this peculiar niche; all those known to me act as weeds in the uplands. One of the simplest and clearest examples is our common pokeweed, *Phytolacca americana*, native to eastern North America. It will be found growing up abundantly in the immediate valleys of our major rivers (Sauer, 1952; see fig 6). On the uplands it is strictly limited to raw soil, though, once established in such a habitat, it can persist vegetatively for a long time while other kinds of vegetation grow up around it. Being attractive to birds, its seeds are widely scattered. I remember, from

FIGURE 5.—Sepals and petals of some hybrids of *Iris hexagona giganti-caerulea* and *I. fulva*, somewhat diagrammatic but accurately to scale. In each case the sepal (the so-called "fall" of iris fanciers) is shown to the left; the petal, "standard," to the right. *I. fulva* has small lax terra cotta sepals and petals. *I. hexagona giganti-caerulea* has large crisp petals and sepals of bright blue. The sepal has a brilliant yellow signal patch (shown in black) surrounded by a white area (shown by stipples) shading off into the blue. Note that in the various hybrids the small-sized flowers (characteristic of *I. fulva*) tend to be associated with the lack of a white area (another *fulva* characteristic). Note the variability of the hybrids. In color they varied from deep wine to very pale light blue.

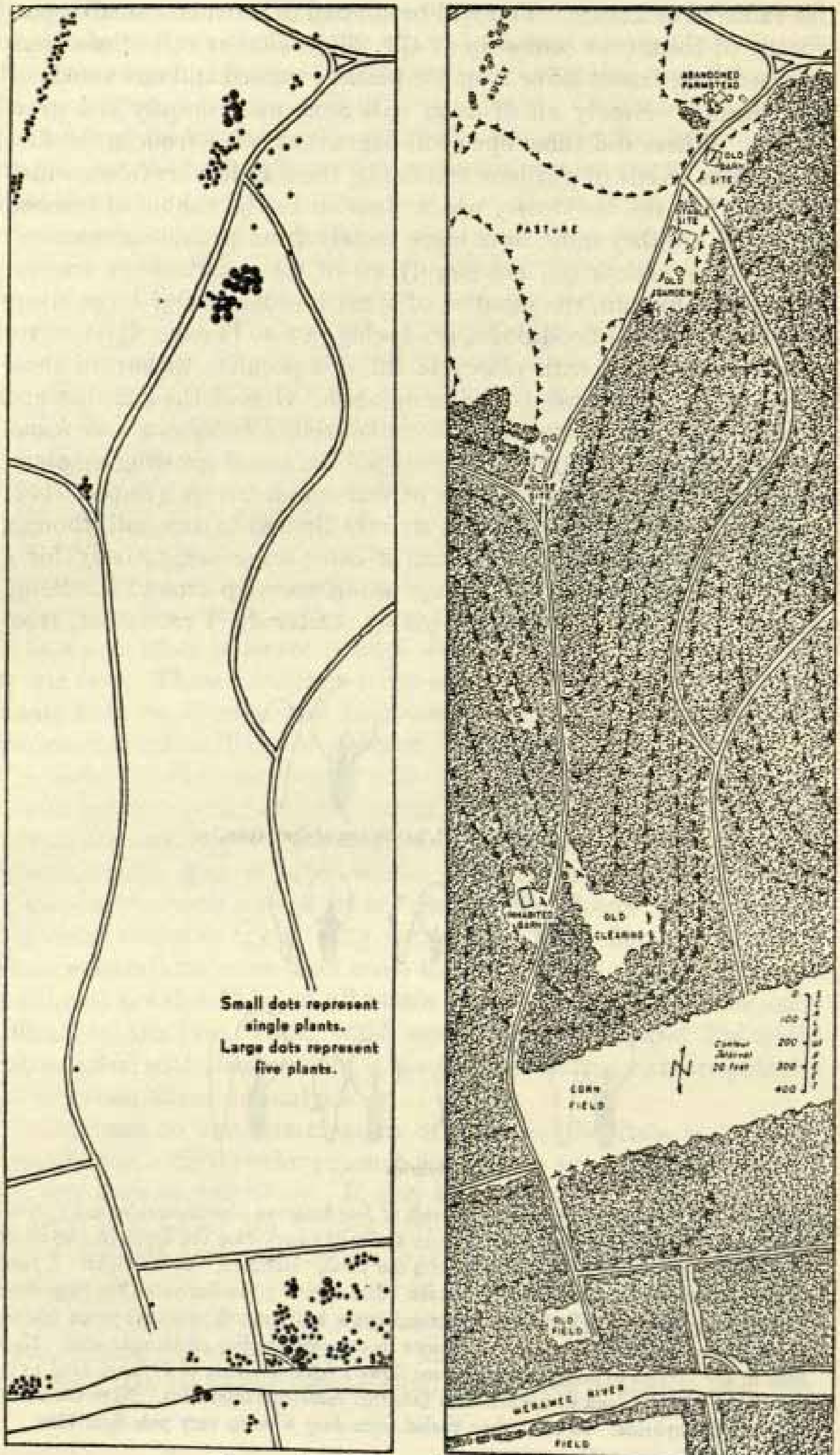

Figure 6.—(See legend on opposite page)

my Michigan boyhood, how pokeweed came in when a woodland near our home was lumbered over. We had never noticed this weed in that community, but the birds had been planting it wherever they roosted. When the felling of the big oaks tore lesser trees up by the roots, pokeweed plants appeared as if by magic for the next few years in the new craters of raw soil. Man and the great rivers are in partnership. Both of them are upsetters. Both of them breed weeds and suchlike organisms. The prehuman beginnings of many of our pests and fellow travelers are to be sought in river valleys. River valleys also must have been the ultimate source of some of the plants by which we live: gourds, squashes, beans, hemp, rice, and maize.

The examples of the salvias and irises show how quickly evolution through hybridization can breed out something new and different under man's catalytic influence. What we should most like to know is the extent to which weeds and similar organisms, created or at least extensively modified through man's influence, are built up into whole associations. It is clear that such things can happen; the *maqui* vegetation of the Mediterranean, the *shiblyak* and *karst* vegetation of the Balkans, the *carbón* scrub of Central America, are obviously very directly the results of man's interference. One would like to analyze the dynamics of these associations. We must do so if man is to understand his own past or to be the master of his own future. For such purposes we need ways of studying vegetation which are analytical as well as merely descriptive—methods not based upon preconceived dogmas. I should like to suggest that the methods used in analyzing the *Iris* hybrids and the *Salvia* hybrids, if combined with other experimental techniques, would allow us to get a long way into these problems. Let me illustrate what I mean by describing some recent studies of *Adenostoma*, a fire-resistant shrub, which is a common component of the California chaparral (Anderson, 1954).

Between the Great Valley and the Pacific Coast, *Adenostoma fasciculatum* is one of the commonest shrubs in the California landscape. Noting that it varied conspicuously from one plant to the next, I made collections of it near Palo Alto and applied to them the methods of pictorialized scatter diagrams and extrapolated correlates. The details of these techniques need not concern us here, since they have been adequately published elsewhere, both in technical

FIGURE 6.—Occurrence of pokeweed in two different habitats. Pokeweed (*Phytolacca americana*) is an example of a species which is apparently native in the open soil along American rivers but a weed in the open soil of disturbed habitats. (Map from Sauer, 1952.) Small dots represent single plants. Large dots represent five plants. It will be seen that the pokeweed is occurring in two quite different kinds of habitats: in the raw soil of repeatedly flooded woodlands on the immediate banks of the river and as a weed around farm buildings, gardens, and the like. (See Sauer, 1952, for further details and discussion.)

journals and in books for the intelligent public. They allow us (through a meticulous examination of variability in such mongrel complexes as the salvias of the abandoned olive orchard) to determine precisely the good species (or subspecies or varieties) from which these complexes must ultimately have arisen. Furthermore, though it takes considerable hard work, these methods can be used successfully by one with no previous knowledge of the organisms or of the faunas and floras from which they may have come.

Using these methods, I have shown that the common *Adenostoma fasciculatum* of coastal California arose from the hybridization of two very different adenostomas. One of these was *A. fasciculatum* var. *obtusifolium*, a low-growing shrub of the headlands and islands along the California coast. The other is now found in its purest form in the Mother Lode country of the Sierra foothills, a tall, branching shrub which, when in flower, somewhat resembles a small-leaved white lilac. Each of these had its own contributions to make to life in coastal California. The coastal shrub brought in a tolerance of brilliant sunlight and the ability to grow in thin, rocky soil. However, it was accustomed to fog and drizzle even during the dry season. The inland form could go months without a drop of water, but it is used to deeper soil and to less extreme radiation. When these two centers of variation had been identified, it was easy to demonstrate that the common *Adenostoma* is a great, plastic, hybrid swarm, including approaches to these two extremes and many intermediates between them. On dry, rocky ridges in sites that are frequently foggy, one finds plants very close to the island extreme. On deeper soils and in the shade of small oaks are bushes scarcely different from those of the Mother Lode country. Around old ranch buildings and in other peculiar habitats one finds strange and bizarre recombinations of various sorts.

Just as these studies came to a close and it was time for me to leave California, I realized that many of the other plants in the chaparral association were similarly variable. There were swarms of hybrid oaks and hybrid ceanothus and hybrid manzanitas. The entire association seemed to be in a state of flux. Unlike the coastal sages which I had studied in southern California, there was room for hybrid recombinations within the association itself. The entire chaparral seemed to be ecologically in the same general class of disturbed habitat as the abandoned olive orchard.

I do not wish to jump to conclusions from one small experiment. I would merely suggest that these methods are appropriate for the analysis of such problems, particularly if combined with experimental work (for instance, the removal of a single species or species complex from a small area using modern herbicides followed by measurement of the effect of this removal on the other complexes in the association).

Here is a field in which we could very rapidly get down to some of the basic principles concerning closed versus open habitats. In my opinion, the degree to which such associations as the California chaparral are manmade is a better subject for study than for debate. They have certainly been greatly affected by man. To learn to what degree, I should prefer to look for more facts rather than to listen to more opinions.

Even among biologists there has been a strong tendency to avoid such problems—to study the plants and plant association of mountaintops and jungles rather than those of dooryards and gardens, to think of plant and animal communities as they must have been in some blissfully innocent era before the advent of man. It seems to me far healthier and far more logical to accept man as a part of nature, to concentrate one's attention as a naturalist on man's activities, since he is the one species in the world we most nearly understand. It is because we know from inside ourselves the problems in which man is deeply involved that we appreciate their bewildering complexity; experiments with laboratory insects would not seem so beautifully simple if we knew as much about them as we do about man. The population genetics of garbage-pail flies (Dobzhansky, 1949) would appear more complex if we understood from within what it is like to be a *Drosophila*. The apparently standardized environment of flour in a bottle (Park, 1938) would not seem undifferentiated to any investigator who had once been a flour beetle and who knew at firsthand the complexities of flour-beetle existence. Imagine a nonhuman investigator of human populations recently arrived from Mars. What could he understand of the relationships of Catholics and Protestants? How long would it take him to discover that, though most of the shortest girls in New York City get married, the very tallest seldom do? Having discovered this phenomenon, how much longer would it take him to understand it? When we attempt to work with laboratory insects, our ignorance of their social complexities makes them seem far simpler material than they really are.

I must confess that when, from being a student of variation in natural populations, I was of necessity led to being a student of man's upsetting effects on his environment, my own thinking was too much colored by this attitude. Only gradually did I come to realize that, though man is now the world's great upsetter, he is not the first. There were others before him, and they played a similar role in evolution. Stebbins and I have recently suggested (1954) that the great bursts of evolutionary activity in the past, the times of adaptive radiation, were caused by such upsets. The formation *de novo* of a great fresh-water lake such as Lake Baikal produced a new and open habitat in which the organisms from various river systems could meet and

mongrelize and, under the hand of selection, evolve as rapidly into new paths as did the salvias in the abandoned olive orchard. What must have happened when the first land vertebrates at last arrived on continents whose vegetation had no experience of such beasts? What occurred when the giant reptiles of the Mesozoic churned like gigantic bulldozers through the ferny swamps of that period? Must not the plants of those periods have gone through the same general experiences as are now facing the adenostomas of the California chaparral?

Man has been a major force in the evolution of the plants and animals that accompany him around the world, in the midst of which he largely spends his days. The detailed study of this process (1) should illuminate for us the course of evolution in prehuman times; (2) should be as well one of our truest guides to the history of prehistoric man; and (3), most importantly, should enable us at last to understand and eventually to control the living world around us.

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Project Coral Fish Looks at Palau

By Frederick M. Bayer

United States National Museum
Smithsonian Institution

and

Robert R. Harry-Rofen

The George Vanderbilt Foundation

[With 20 plates]

We who live on continents can rarely appreciate the vastness of the world's oceans. Those of us who may be prompted by business or pleasure to traverse them learn of their two-dimensional magnitude, but there are a few of us who are privileged to investigate the secrets of the seas first-hand, by living among them. We look upon the seas in their role as an environment and seek to unravel the interwoven facts of life within them. One of the first facts we learn is the complexity of their many-faceted wonders, and we consider ourselves fortunate when we are able, as it were, to polish a few of these facets so as to see more clearly into them.

Of all the seas, the one with the greatest area, greatest depth, and most to tell us is that restless giant, the Pacific. Even before we begin to study it we must concede, if not defeat, at best a draw, for it is practically axiomatic that one solution leads to another problem. When our words are as antiquated as those of the Renaissance pioneers Belon and Rondelet and Marsigli now seem to us, people will still be learning new things about this watery one-third of our planet.

When we look upon the Pacific, or any ocean for that matter, as an environment, the central problem deals with the physical and chemical properties of the fluid medium that make it adequate to support life. This is a vast field of investigation to which many people in many laboratories are devoting tireless efforts. We, however, as biologists, can devote time to such problems only when they have direct and immediate bearing upon some question involving the organisms with which we are concerned, and even then we must rely upon specialists in those restricted fields for most of the information we need. The

next problem is a qualitative one regarding the population of the sea: what are these creatures that populate the waters? This is a basic problem in marine biology; upon it depend the solutions to problems of economic, or ecologic, or purely biologic interest. We must know what organisms we are working with before we can determine how they live together in communities, how they depend upon one another, and how they affect us.

Creatures of the sea do, in fact, affect the affairs of man in many ways. Many of them have served us for food since the beginning of mankind. When we build structures in the sea for our own purposes, certain of the animals and plants whose domain we have invaded use those structures to their own ends and thus either destroy what man has made or so befoul and beclog it as to render it worthless. When we sail in tropic waters, other marine life—corals and algae—has been there long before us and raised up an edifice that passively awaits the unwary navigator and his fragile keel. If we are thrown into the sea, or when we voluntarily venture into it, still others may unintentionally do us bodily damage or even deliberately seek us out as a meal. Most "dangerous" of all, to marine biologists anyway, are those that have such bizarre or complicated ways of life that they entice us to devote most of our lives to learning of them and solving their riddles.

Since the close of World War II, interest in the Pacific Ocean has been increasing steadily. A number of expeditions were sent out to study the tropical Pacific, among which were those of the Pacific Science Board (National Academy of Sciences–National Research Council) and the George Vanderbilt Foundation. Among the expeditions of the Pacific Science Board were those comprising the 5-year Coral Atoll Program, in some of which the present authors participated.

The expeditions of the Coral Atoll Program did much to broaden our knowledge of life on the coral atolls of the Marshalls, Gilberts, Carolines, and Tuamotus. But field team studies came to a close before the most interesting part of the Pacific could be studied: the western rim, the faunal gateway to that vast coral world that reaches to Hawaii, the Galápagos, and even our own western shores. Moving eastward from the Malay Archipelago and its wonderfully rich fauna, we find no depletion through the Philippines, but what of the westernmost islands of Micronesia? They are a scant 600 miles east of the Philippine Islands (see map, fig. 1), no journey at all for sea creatures with free-swimming young stages. However, between the Philippines and the Palau Archipelago lies one of the greatest deeps in all the seas. How many of the East Indian species have been able to span this deep? Even the submarine ridge upon which the Palaus are situated, extending northeastward from the Moluccas, is covered by

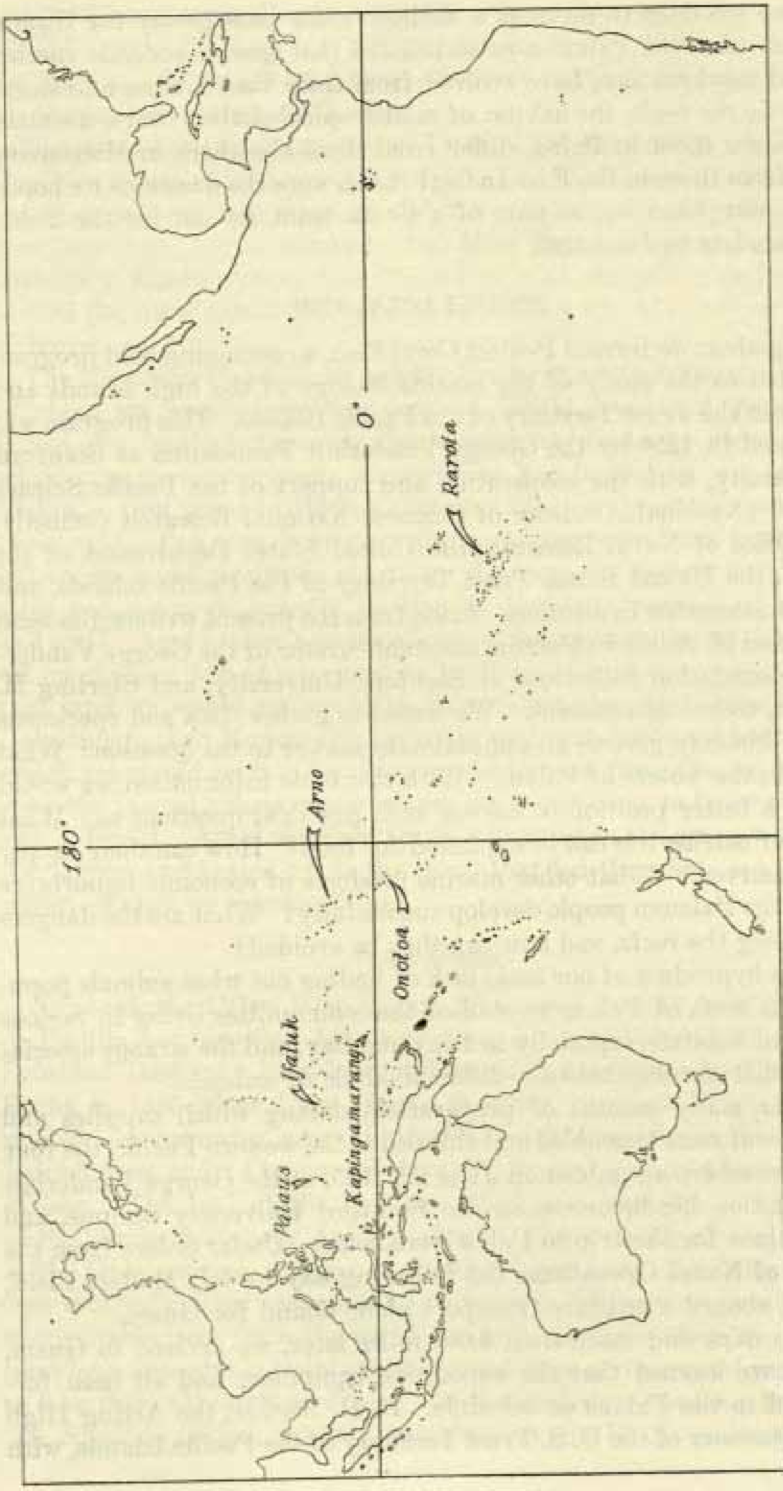


FIGURE 1.—Outline map of the central Pacific showing the location of Palau and the five atolls studied by the Pacific Science Board.

waters too deep to serve as a shallow-water passageway for littoral forms. Are the Palaus now so isolated that special endemic species, found nowhere else, have evolved from their East Indian ancestors? How do the reefs, the habitat of most tropical shallow-water animals, as we see them in Palau, differ from those elsewhere in Micronesia, and from those in the East Indies? Such were the questions we hoped to answer when we, as part of a 4-man team, set out for the Palau Islands late in June 1955.

PROJECT CORAL FISH

Together, we formed Project Coral Fish, a continuing field program devoted to the study of the marine biology of the high islands and atolls in the Trust Territory of the Pacific Islands. This program was initiated in 1954 by the George Vanderbilt Foundation at Stanford University, with the cooperation and support of the Pacific Science Board (National Academy of Sciences-National Research Council), the Office of Naval Research, the United States Department of the Navy, the United States Trust Territory of the Pacific Islands, and the Smithsonian Institution. Aside from the present writers, the team included H. Adair Fehlmann, assistant curator of the George Vanderbilt Foundation collections at Stanford University, and Sterling H. Pierce, technical assistant. We hoped to gather data and specimens of all kinds to give us an approximate answer to the question: What lives in the waters of Palau? With this basic information we would be in a better position to answer such practical questions as: What kind of marine life can be exploited for food? How can their supply be conserved? What other marine products of economic importance could the Palauan people develop successfully? What are the dangers in fishing the reefs, and how can they be avoided?

As a byproduct of our basic task of finding out what animals populate the reefs of Palau, we studied the communities living in various kinds of habitats, especially in Iwayama Bay, and the strange associations that develop between different kinds of animals.

After many months of preparation, during which supplies and equipment were assembled and shipped to the western Pacific, the four team members assembled on June 22, 1955, at the George Vanderbilt Foundation headquarters on the Stanford University campus, and final plans for the trip to Palau were made. Under orders from the Chief of Naval Operations, the following day we left Moffett Field, Calif., aboard a military transport plane bound for Guam.

Two days and more than 6,000 miles later, we arrived in Guam, where we learned that the expedition equipment had all been forwarded to the Palaus on schedule. D. H. Nucker, the Acting High Commissioner of the U. S. Trust Territory of the Pacific Islands, with

whom arrangements for the expedition had been made months previously, issued the permits necessary for our travel and fieldwork in the islands. All was in readiness. We were in the Tropics again, and our destination was almost in sight.

It was an impatient group that awaited the next weekly flight of the Transocean Airliner to Koror, but at last Thursday came and we were at the air terminal in the Naval Air Station, Agaña, early that morning. A few moments after Miss Thelma Gorman, of Trust Territory Headquarters, had bustled us and the other passengers aboard the Albatross amphibian and breathed a sigh of relief, we were airborne.

The islands of Palau lie some 800 miles southwest of Guam, a flight of about six hours, including stops at Ulithi Atoll and Yap. At Ulithi, we touched down on the airstrip to discharge passengers, where two years previously we ourselves had landed on our way to Ifaluk, a tiny jewel in the sea that captured our hearts as could no other spot. But that is another story, and we were back in the air before we could reminisce about it. At Yap, the lagoon is the airstrip and we made a water landing to discharge passengers, cargo, and mail. Again, after a pause of only a few minutes, we were taking off on the last leg of our journey halfway around the world. The next land we would see would be Palau—first the great, hilly island Babelthuap, then Koror with its settlement and the broad harbor on which we would land. Reaching up toward us from the sea below, were the jagged ridges of the islands we would come to know so well (pl. 1, fig. 1). Amid sheets of spray we settled in the green water of the lagoon and taxied up to the ramp that led the plane out of the water. At last we were in Palau.

THE PALAUS

Although the Palau Islands were discovered in 1710 by Francisco de Padilla and his pilot, Joseph Somera, on the galleon *La Santísima Trinidad* (and may have been sighted earlier, perhaps by Diego de Rocha in 1525–26 or Lope Martin in 1566), the first Europeans to publish an extensive account of their visit were the crew of the British East India Company's *Antelope* in command of Capt. Henry Wilson. The keel of the luckless *Antelope* struck the coral rocks of the barrier reefs near Aulong Island on the morning of August 10, 1783. Only one man was lost in the disaster, and the remainder of the crew escaped safely to set up camp on Aulong. The castaways salvaged every usable item from the wreck and, although the *Antelope* was a total loss, were able to build another vessel large and seaworthy enough to take them all safely to Macao. This vessel, the *Oroolong*, brought 700 Spanish dollars (about equivalent to the U. S. dollar of the

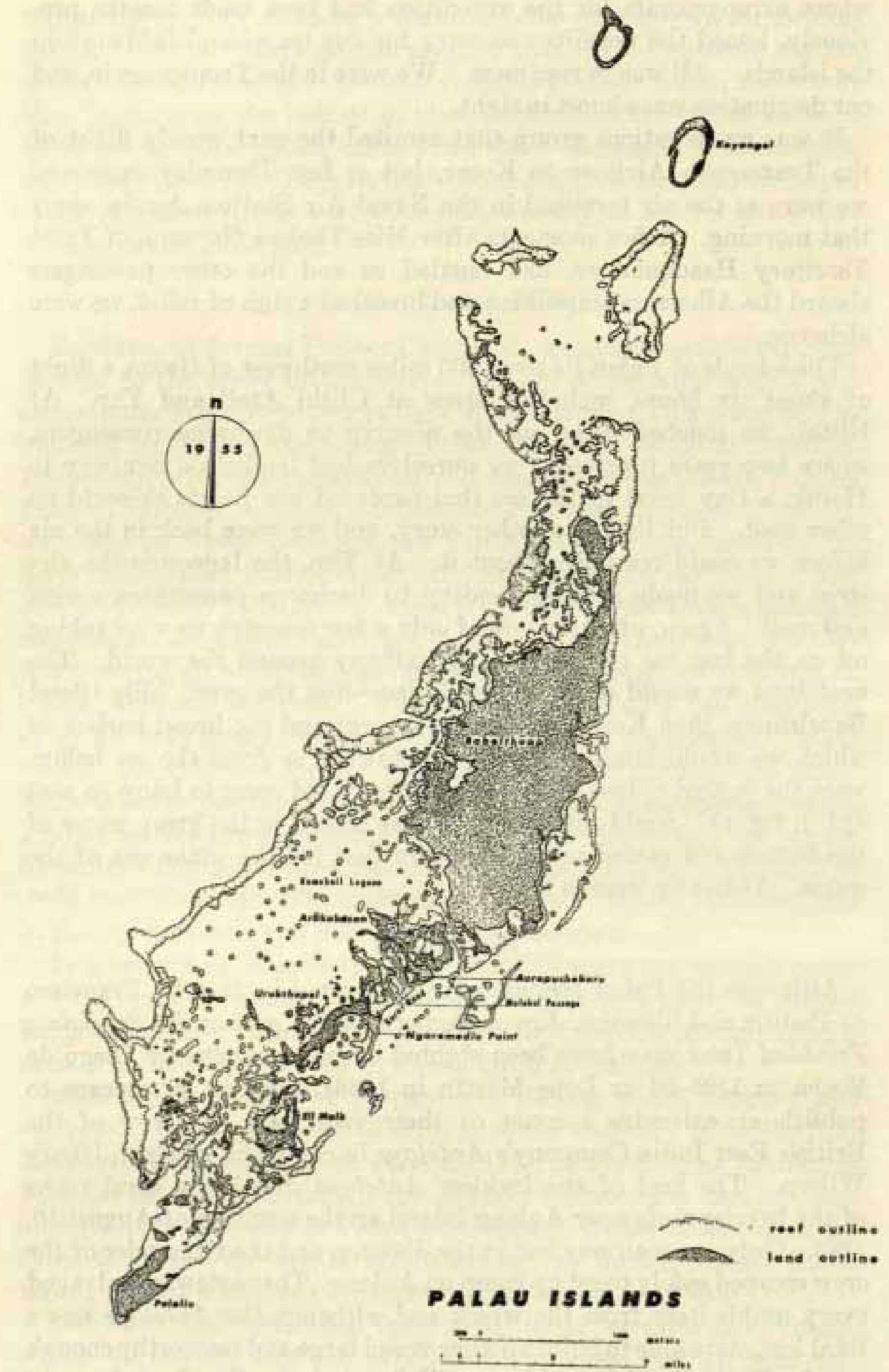
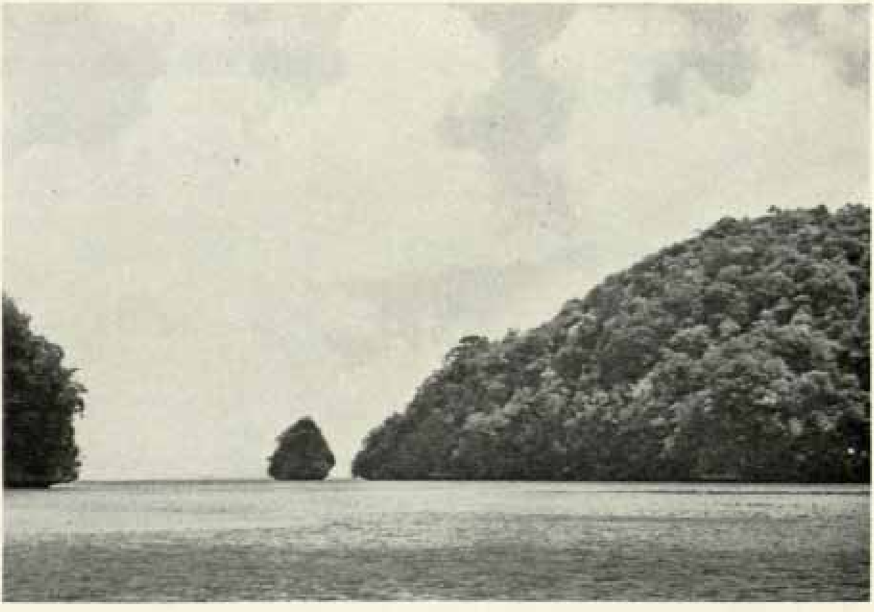


FIGURE 2.—The Palau Islands. Adapted from U. S. H. O. chart 6073.

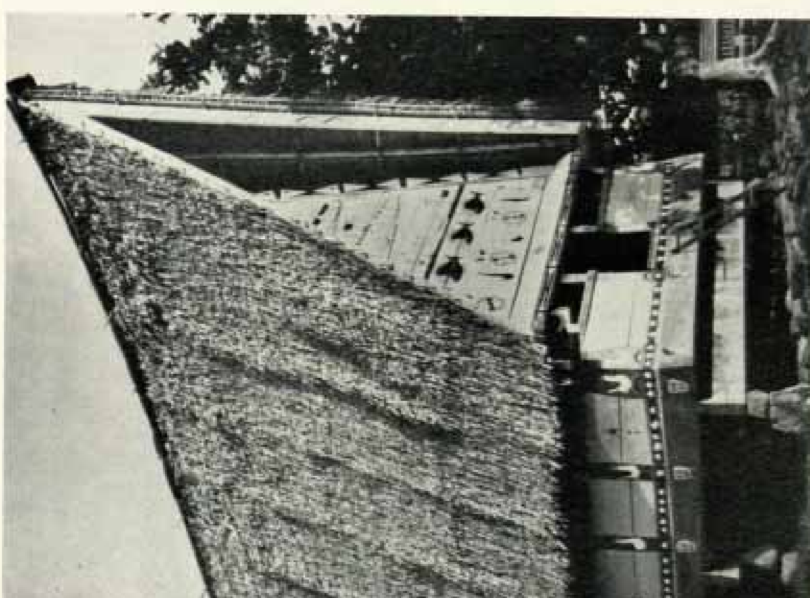
1. Koror from the air, with Iwayama Bay and the limestone islands in the distance. The abrupt headland on the horizon at right is Ngaremediu Point on Urukthapel.



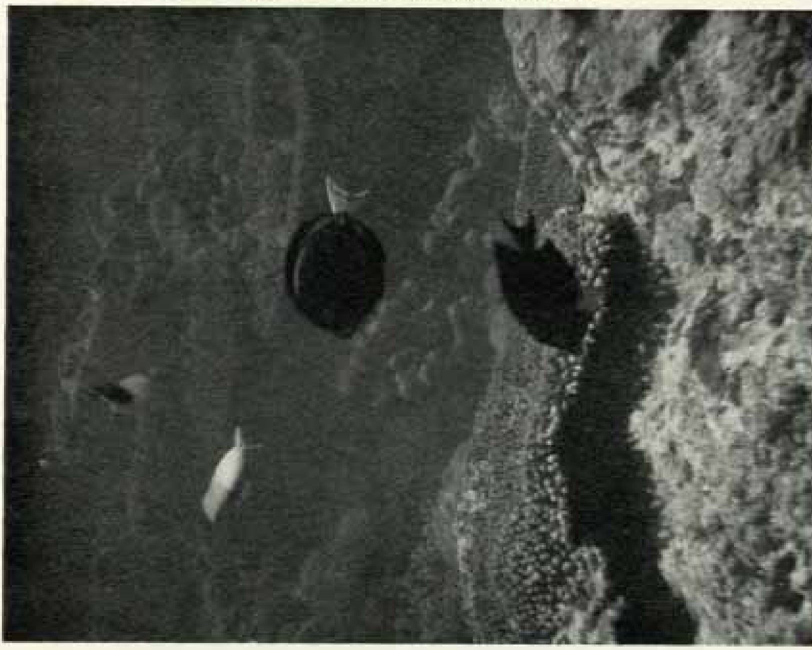
2. Looking east through Ngasaksao Pass, the eastern entrance to Iwayama Bay. To the left is Ngalap region of Koror, and to the right Kwannon (Ugeliungs) Island, with conical Ngaraglbukl (Ngergelbakl) Rock in the pass.

1. The *Lenore* in Lebugol Passage, the narrow western entrance to Iwayama Bay. This boat was used by field parties to reach the more remote localities investigated in the Palaus.

2. A building that was once part of the Japanese meterological station on Koror now accommodates biological activities in the Palau District of the U. S. Trust Territory. The ground-floor laboratory to the left of the main entrance is occupied by the George Vanderbilt Foundation, and the apartment above (now remodeled) provides living quarters for members of its field parties.

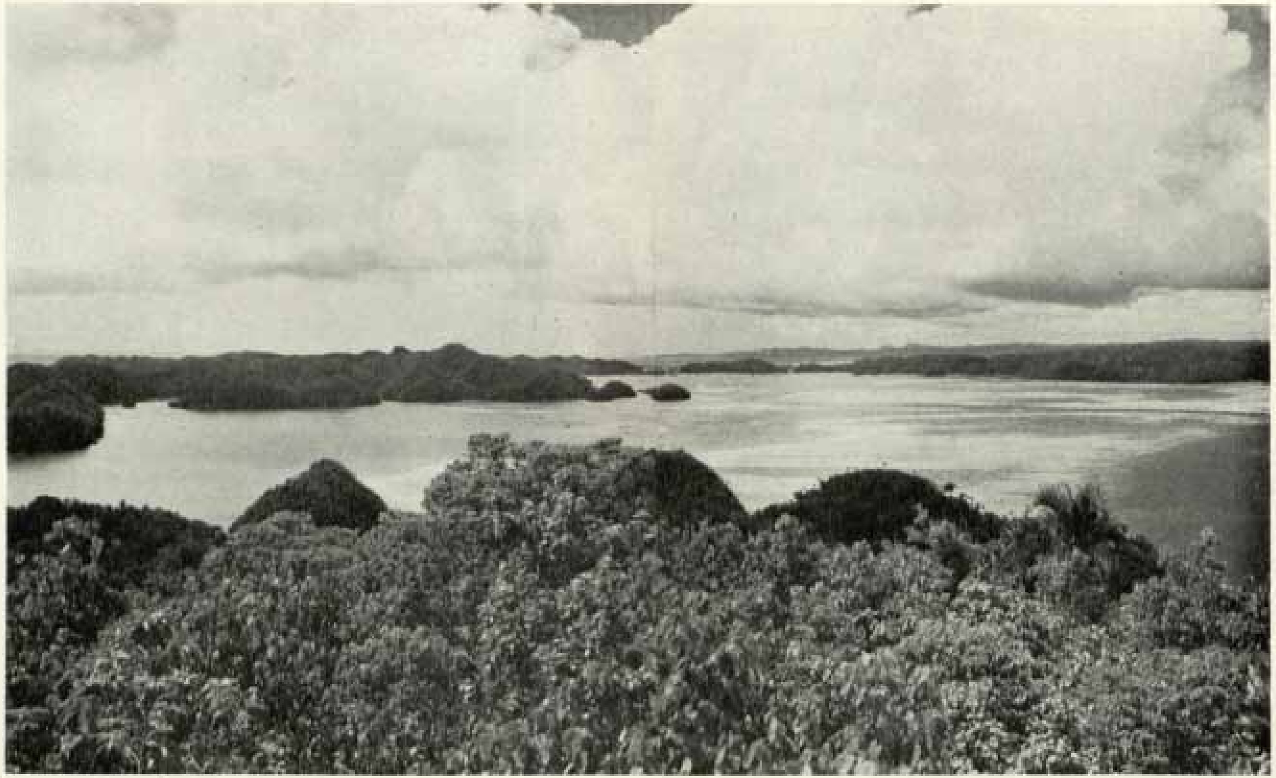


1. The gables of this abai on Koror are gaily decorated with surgeonfishes, one of the common reef fishes around the Palaus.



2. Two surgeonfishes swim over coral gardens near Ngaremediu. These and other fishes were commonly used in decorating the gables of old-time abais, of which few remain standing today.

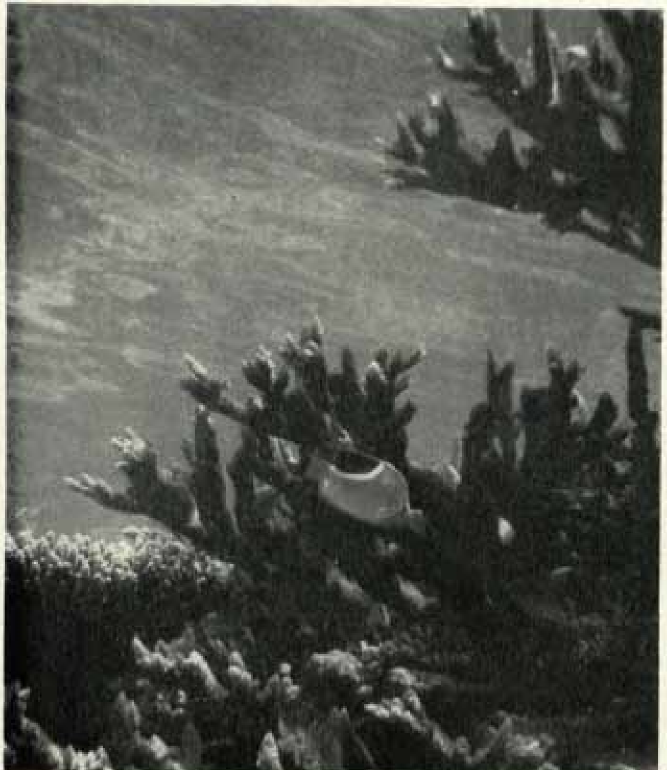
Composite view of Iwayama Bay, looking south from a high ridge on Koror. The main expanse of water belongs to L Division (see text fig. 3), with tiny island 21 toward the middle. The conical island to the left is the northern end of island 22. Toward the center, behind island 21, island 20 can be seen, with island 17 to the right. Near the shore is island 15, which is connected to Koror by mangroves. Small patches of J and M Divisions can be seen to the far left and far right, respectively. In the foreground, which is Aiekasol village on Koror, cultivation for tapioca and taro is visible, with banana trees here and there.



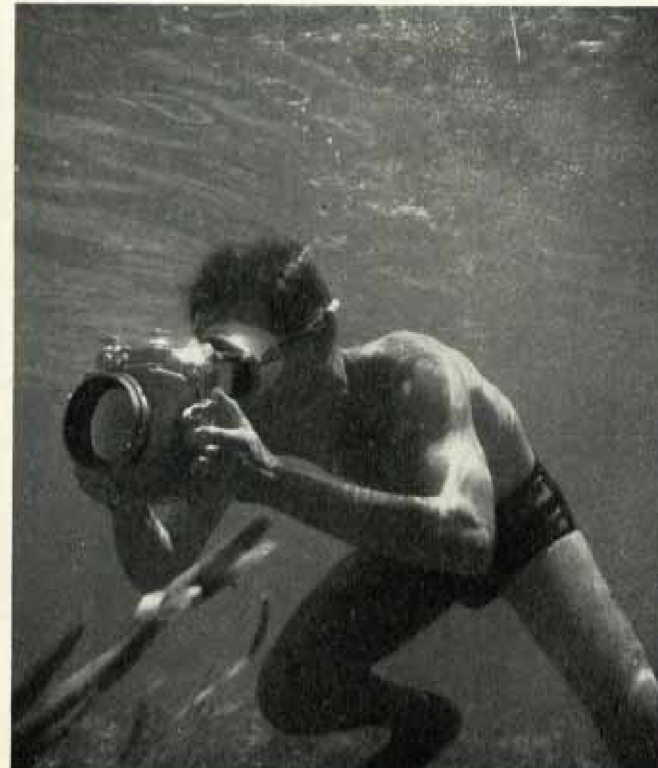
View looking north toward Malakal, taken from the ruined lighthouse on Ngaremediu, the high eastern cape of Urukthapel. To the left is the northern arm of Urukthapel with its surrounding maze of islets. The broad, pale area in the water is the reef flat, across which Malakal Pass extends as a dark line. At the right Aurapushekaru (Auluptagel) Island can be seen in the distance. Koror iesl hidden beyond it, to the north. The vantage point from which this view was made can be gained only up a steep and tortuous trail densely overgrown with vegetation. The overhanging branches were alive with a species of black ant that did not bite but swarmed over our dripping backs, helping to make the price of this photograph a dear one.

1. One of the authors looks into a small cave at high-tide line. The extent of undercutting at this spot may be seen in figure 2. Several kinds of sessile animals were hanging from the roof of this cave, including hydroids, the alcyonarian coral *Telesto*, and tunicates. Such rocky places form the typical habitat of a spotted cardinal fish, *Apogon orbicularis*.

2. The steep-sided limestone islands are deeply undercut at the high-tide level. The resulting notches are large enough to stand in. Jungle vegetation from the forest above spills over and meets the sea at floodtide. This view was taken just outside the mouth of the small cave shown in figure 1.

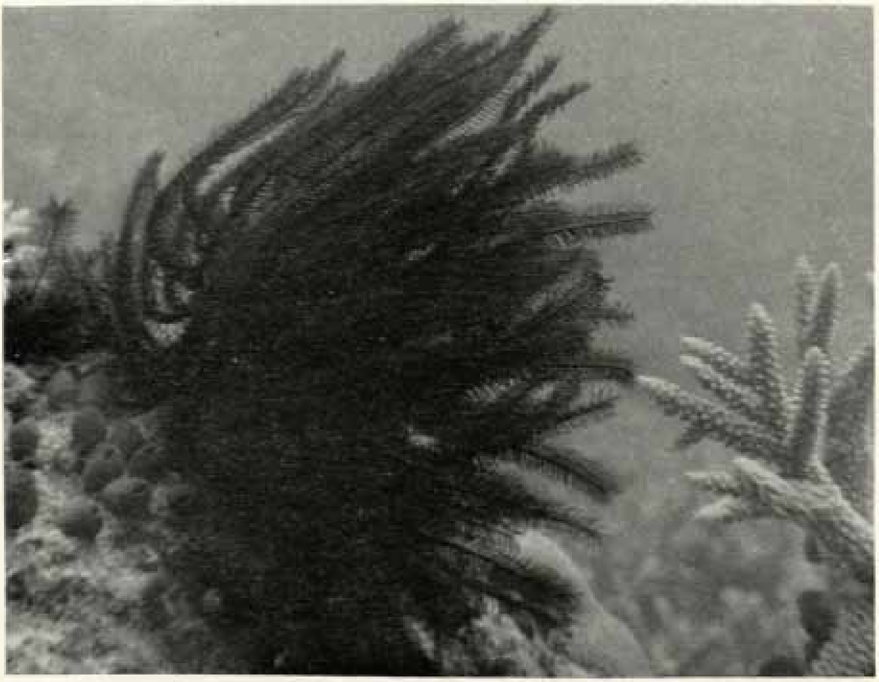


1. Coral growth bordering pass through the east barrier reef south of Ngaremediu. At this spot the reef facies greatly resemble some West Indian reefs with their antlerlike acroporas. At the center is a saddled butterflyfish, *Chaetodon ephippium* (Cuv. & Val.).



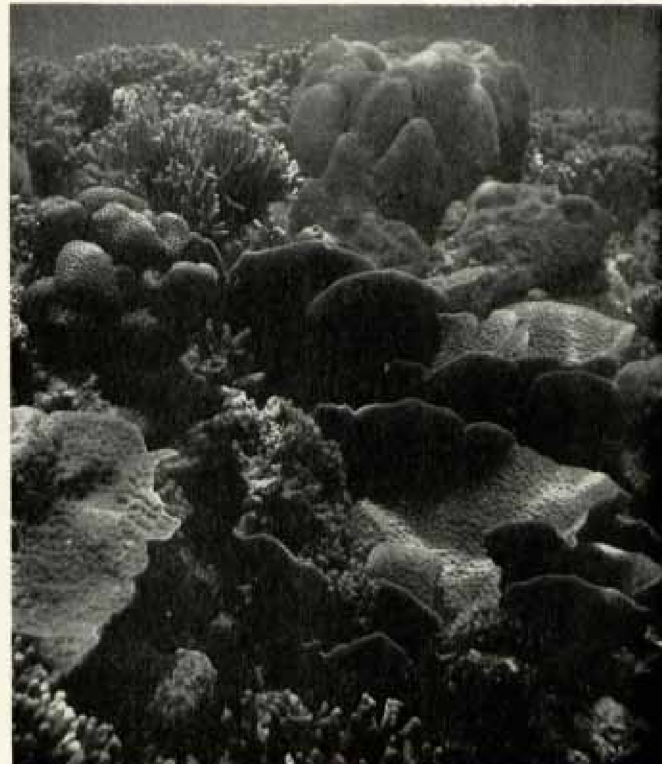
2. One of the authors operating an underwater camera of the kind used to make these pictures. This type of equipment makes accurate focusing and framing of scenes almost as easy as in photography on dry land.

1. One of the authors preparing to descend in a self-contained underwater breathing apparatus (aqualung).

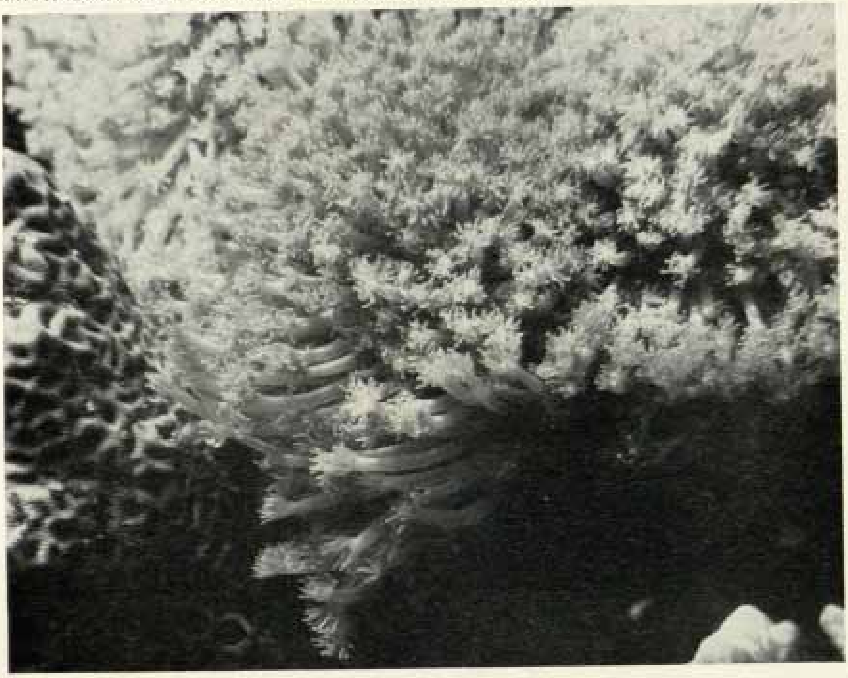


2. A dark green feather-star (*Comanthus*) of the species that is the host of the commensal clingfish. The small urnlike objects to the left of it are colonies of an ascidian, *Didemnum ternatanum*.

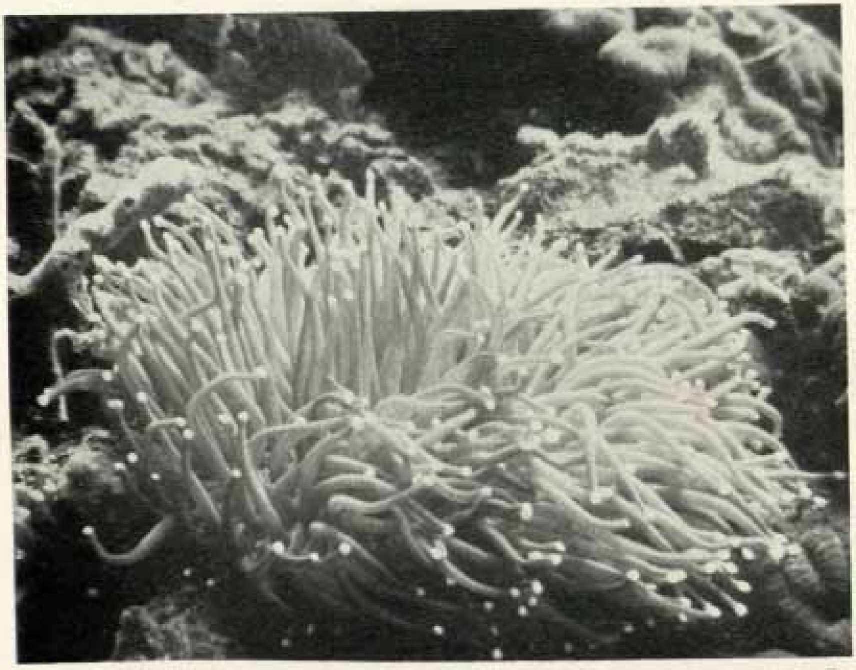
1. The colorful lettuce coral, *Pectinia lactuca*, is a characteristic species on the limestone notches in Iwayama Bay.



2. The margin of a reef in Iwayama Bay, showing a zone dominated by *Echinophyllia* (the foliate expansions). Also present are two species of *Porites* (one massive, the other with digitate branches), *Pocillopora* sp., and *Coscinaraea* sp.



1. Shallow reefs in Iwayama Bay are in some places dominated by the large poritid coral *Goniopora*. The stubby branches of its skeleton are obscured by the exceptionally large polyps, which remain extended even in daylight. Unlike most anthozoan corals, it can sting, thus making collecting near it very unpleasant.



2. This species of mushroom coral, *Fungia actiniformis palawensis*, has long, creamy-yellow tentacles that completely hide its stony skeleton which is nearly the size of a saucer. It is a solitary polyp that never forms a colonial skeleton as most other reef corals do. A small specimen of a wrasse, *Cheilinus*, that is common in enclosed bays like Iwayama, can be seen at the top of the picture.

period) when sold in Macao, and stands as a tribute to British fortitude and resourcefulness in the face of adversity.

The English, although at first apprehensive, found no difficulty in establishing friendly relations with the Palauans. Even though they "had not on board philosophers, botanists, draughtsmen, or gentlemen experienced in such scientific pursuits as might enable them to examine with judgment objects which presented themselves, or trace nature through all her labyrinths," they nevertheless gave us a fascinating account of the islands and people and their experiences among them.

Palau and the Palauans today present a far different impression from that described by Wilson and his men in 1783. Although the natives had complete power over the English, they did not take advantage of their superior position, but instead did everything possible to help their hapless visitors. Admittedly, the Palauans were awed by firearms, and the English assisted Abba Thulle (Ebadul or Ibedul) the chief of Koror, in some of his interisland campaigns. Good relations were thereby strengthened, but it probably was not guns alone that made the Palauans friendly. We ourselves have been residents of islands where the people have had little real contact with civilization as we know it, and found that they remain much as Wilson pictured the Palauans, with a high regard for honesty and respect for their fellows. Now the Palauan people have become sophisticated and mundane after 20 years of German administration and another 26 under the Japanese. Missionaries long ago insisted that they give up their native way of dress (or undress) in favor of less practical European-style clothing. Their airy, thatched houses and abais, or men's houses (pl. 3, fig. 1), decorated with colorful murals depicting historical and mythological events or droll folk tales, have given way to quonset huts and quasi-Japanese frame structures. Their elegant outrigger canoes are becoming a rarity, replaced by dirty little diesel boats like the *My Flower*—anything but flowerlike—that plies between Peleliu and Koror.

The Palau Archipelago in the western Caroline Islands (fig. 2) extends northeastward from about latitude 6°53′ N. to 8°06′ N., or over 70 miles, at a longitude of about 134°29′ E. The main islands, dominated by Babelthuap, lie between latitudes 7° and 7°45′ N. Except for Kayangel, the northern part of the islands is volcanic in origin. Babelthuap is about 25 miles long and 8 miles wide, covered with rugged hills and dense jungle, rolling grasslands, sparkling streams and dashing water falls, (pl. 12, fig. 1), and fringed with mangrove. Twenty miles to the north of it is Kayangel, a true atoll like the islands far to the east, and to the south of it is the maze of limestone ridges and conical islets (pl. 1) that forms one of the most re-

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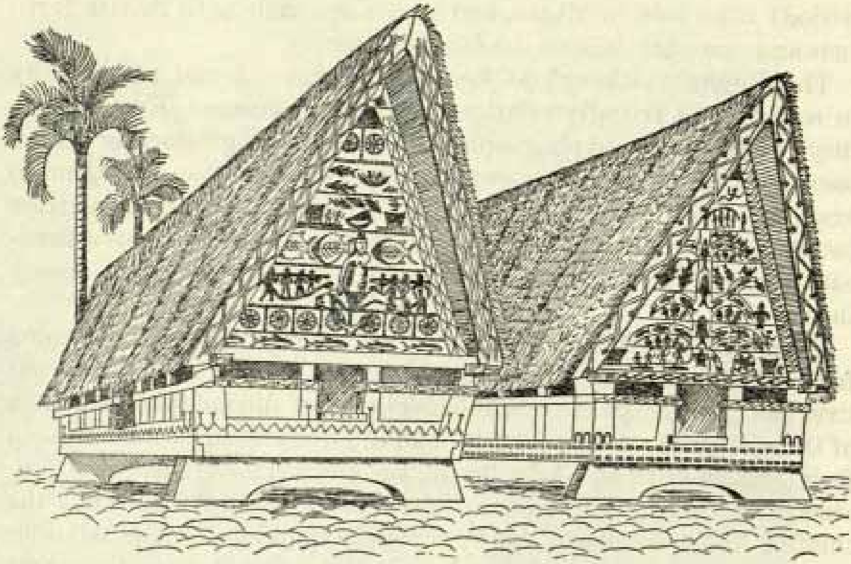


Sketch of old abais, based on several published photographs.

markable features of Palau. Here and there on the edge of the reefs there are islets of wave-tossed coral debris and sand, much like the atoll islands. Together, the Palaus offer the most diversified collection of marine habitats to be found anywhere in Micronesia.

The Japanese recognized the unusual scientific opportunities presented by the Palaus and, during their administration of the South Seas Islands (Nanyo Gunto), established at Koror a tropical biological station devoted to the study of coral reefs, under the directorship of Dr. Shinkishi Hatai. At that time, Koror was the capital of the Japanese mandated islands of the South Seas and was a thriving city. The Palao Tropical Biological Station is no more, but we hope to build upon its accomplishments and contribute further to a more thorough understanding of the fauna of Palau.

ACTIVITIES IN THE FIELD

Our first big job on Koror was to unpack and organize our field equipment. The territorial entomologist, Robert P. Owen, had generously provided us with laboratory space in the entomological laboratory (pl. 2, fig. 2), one of the few bullet-scarred Japanese buildings still usable. A rebuilt second story over the laboratory served as our quarters until a nearby house could be made ready for occupancy. For days we moved boxes and steel drums full of supplies from the district warehouse to the laboratory grounds, and the unpacking went on far into our first few nights in the islands.

One morning while we were busy setting up the laboratory with the help of Bob Owen's Palauan assistants, we became aware of a scowling stranger who at first hesitated around the periphery of activity, and then picked up a hammer and began energetically opening boxes. This was Rikrik (pl. 18, fig. 1). We asked the others about him and learned that he was a willing and able worker, knowledgeable in English, Palauan geography, and fishing. We had learned from experience that such a man is indispensable to an expedition, so we hired him on the spot. Rikrik's scowl broke into a broad but temporary grin and we had gained a true friend. Later, we added to our staff another Palauan named Sumang, who had a remarkable knowledge of Palauan natural history. He could speak both English and Japanese, was a village chief or "Ya'at," and knew practically everybody from Angaur to Kayangel. Amiable Sumang Y. was a valuable public-relations department whose good offices were a great advantage, particularly during the long overland trips on Babelthuap, and his memory of Palauan geographic names gave valuable documentation for our collection records.

The Palauan people use a different approach from ours to naming the various parts of their homeland. They often do not give names to islands as a whole, whereas groups of islands or localized regions on islands may have special names. Rivers and streams may have as many as three names—one for the part near the mouth, another for the headwaters, and a third for the parts between. The imposition of our own practice of giving a single name to geographical features upon the Palauan system has led to either a part taking the name of the whole, or the whole taking the name of one of its parts. Examples of the latter kind are Koror, which is the name of a village that we apply to an entire island, and Eil Malk, the name of a cape which we use for the island of which it is a part. The situation is complicated by the circumstance that we take many of our spellings of Palauan place names from Japanese maps, which expressed them in phonetic katakana characters. The English transliterations from the Japanese spellings usually bear little, if any, resemblance to actual pronunciation, but they appear almost universally on American maps so we are obliged to employ them in this account. Thus, the name "Ankosu" as we use it is correctly spelled "Nghus," and "Geruherugairu" should be "Ngaregelngáel." A complete list of the place names we will mention in these pages, giving the correct (and any common alternate) spelling, may be found on p. 507.

Actual fieldwork could not be started until our 18-foot fiberglass boat was put into commission. Sterling H. Pierce, our engineer and electronics technician, installed wiring, instruments, and cabin controls for the powerful outboard motor. In due time, the final coat

of paint was applied, the name *Lenore* and the George Vanderbilt Foundation insigne inscribed on her bows, and the boat was ready for launching. She was both speedy and seaworthy, and in her we could make trips to outlying islands and return to the laboratory the same day, a distinct advantage when perishable specimens must be promptly preserved.

When the *Lenore* was fully loaded for a day's work, there was scarcely room left for us. Nets, containers large and small, inflatable floats for receiving specimens as we took them from the water, spray apparatus for distributing the poison we used to stupefy fishes and other active specimens, tools for digging and breaking up coral, preservative, cameras and, often, bulky diving apparatus loaded the boat to capacity.

The self-contained diving apparatus was useful not only for collecting in water too deep for free diving, but also in shallow-water areas where we wanted to see the exact situation under which certain animals were living, or to observe their behavior at length. Whenever possible, both the habitat and the inhabitants at collecting stations were photographed in detail, both in color and in black-and-white, using reflex cameras in waterproof casings (pl. 7, fig. 2). These excellent cameras greatly minimized waste of film by enabling us to watch moving specimens until they were in range and focus.

Because one of our chief aims was to get as complete a biological sample as possible, every available means of collecting specimens was employed, from hand capture and hook-and-line to explosive charges. Although different situations required different techniques of sampling that had to be carefully decided upon before attempting to collect, the most generally useful method of obtaining active specimens was by the use of the vegetable poison rotenone. In liquid form this is extremely potent, so it must be diluted with water in a spray pump and distributed over the area to be collected. Fishes, crustaceans, cephalopods, and certain other types of animals are suffocated by it and are soon made helpless. When we used this technique, we needed every available hand to collect specimens before they were swept away by the current or eaten by larger fishes not affected by the poison. Often we enlisted the aid of youthful spectators, who are characteristically good collectors, and they would scurry about in response to Sumang Y.'s commands, enjoying all the bustle of excitement.

IWAYAMA BAY

Our program of faunal sampling took us the length of Palau, from Arekolong Peninsula at the northern end of Babelthuap to Peleliu, but one of the most fascinating and complex areas in the islands was virtually in our own front yard. The Japanese scientists of the

Palao Tropical Biological Station were attracted by it 20 years ago and made a survey of it that was reported in the first volume of their journal (Abe, 1937). We became greatly interested in that study and had decided, even before reaching Palau, to resurvey the same area to see what had happened to the different habitats since they were originally studied. This area is an island-studded lagoon, partly enclosed by Koror Island (pl. 4), which the Japanese called Iwayama-wan, or "Rocky-mountain Bay." The Japanese name is generally accepted now, because the nearly forgotten original Palauan name for it is a matter of debate (some maps use Krämer's coined name for it, "Songel a Lise," which, although utilizing Palauan words, is a European invention). We therefore use Iwayama Bay as a neo-Palauan name.

Iwayama Bay is a roughly circular body of water about 1½ nautical miles in diameter, enclosed by Koror on the north and Auluptagel on the south (see map, fig. 3). Its west entrance is a long, narrow pass called Lebugol Channel, and its east entrance a wider, coral- and sand-choked passage called Ngasaksao Pass. The western arm of Koror is volcanic land with a wide, muddy mangrove shore; its eastern arm is limestone, like Auluptagel and the 40 small islands in the Bay, with a fringe of corals. The Palauan names for most of the islands are all but forgotten (Sumang Y. succeeded in tracking down most of them by lengthy conferences with the prominent patriarchs of Koror) so, to simplify matters, the Japanese students assigned each island a number, which they actually emblazoned on them in white paint. These roman numerals are still legible on some of the islands, and we also found that system more convenient to use than names, either Palauan or Japanese. N. Abe and his colleagues further divided the Bay into "divisions" bearing letter designations (see fig. 3), in most of which they studied transects from island shore to reef margin. In the process of collecting, we revisited each of the transects in the bay and studied the 16 divisions, wherever possible taking photographs of the coral growth, animal communities, and general habitat.

Because of the many islands and narrow passes, tidal currents are swift at many points in Iwayama Bay. The Islands, which are very close together, rise up almost vertically from the bay floor and create very narrow, deep waterways many of which are 100 feet or more in depth. The islands are deeply undercut at the high-tide line (pl. 6, fig. 2)—as much as 5 to 10 feet—forming deep "notches" above a submarine shelf of variable width. In favorable localities where the current is strong, as on the north shore of island 29, coral growth on the shelf and vertical submarine cliff is exceptionally luxuriant. Here, one could stand among flourishing corals and look either directly overhead into dense jungle vegetation or straight down the coral precipice into a hundred feet of deep blue water. Occasionally we saw the

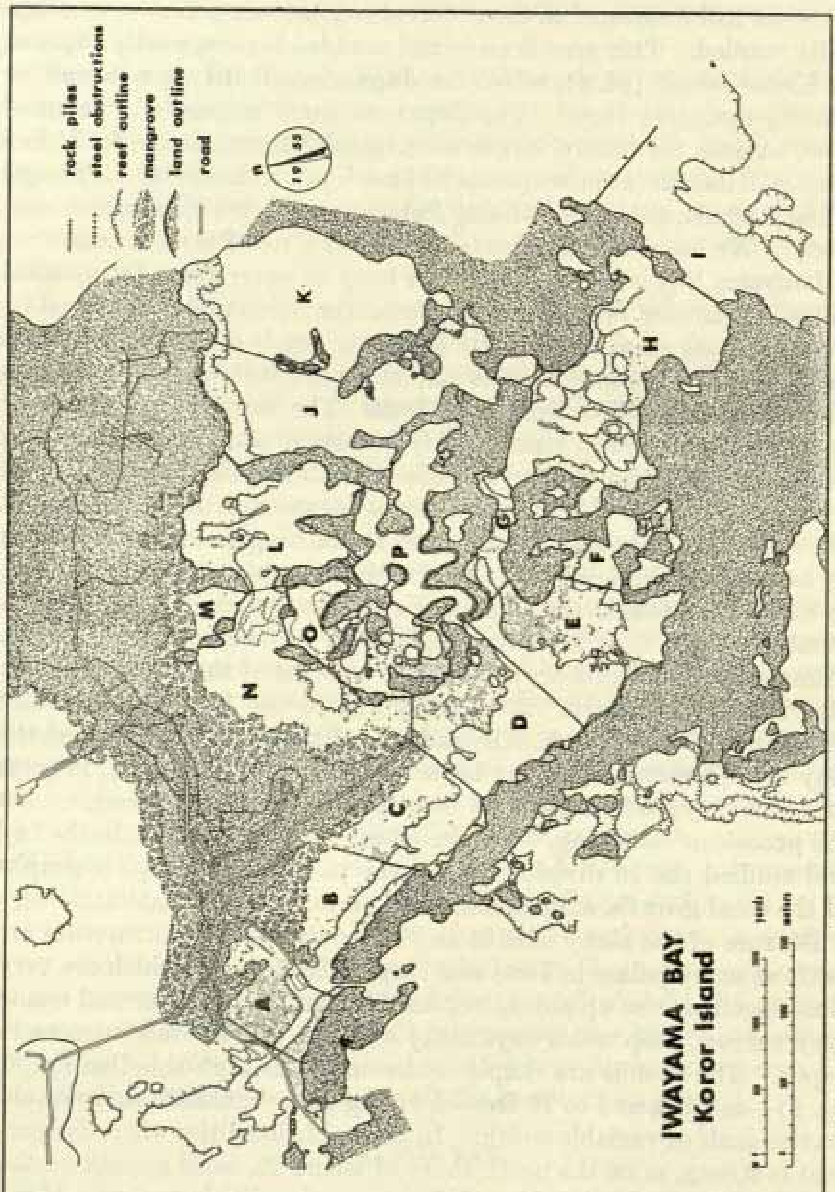


FIGURE 3.—Iwayama Bay and its divisions. Map based on aerial photographs; divisions after N. Abe et al.

shadowy shapes of giant blue parrotfishes, perhaps 6 feet long, rise from the depth to which they had fled at our coming, or a shark patrolling his accustomed beat, or the faint silvery glint of sunlight on a distant school of swift predators, perhaps some kind of jack (Carangidae), near the limit of our vision.

On the submarine shelf of these undercut shorelines, the coral variety was great, with multicolored *Pectinia lactuca*, commonly called lettuce coral (pl. 9, fig. 1), green, orange, or brick-red *Lobophyllia*, and a few others dominating the shallower areas. The less colorful *Plerogyra*, with bubblelike tentacles an inch across, the closely related *Physogyra*, and long, wiry antipatharians (black corals) were usually found on the vertical face of the cliffs. On the shadiest slopes we often met with handsome specimens of *Palauphyllia*, a subgenus of corals named in honor of their homeland.

The bright colors of *Palauphyllia*, like those of most other stony-reef corals, are located not in the coral skeleton but in the soft tissues of the polyps themselves, and are due in part to the presence of minute unicellular algae living in the cells of the endoderm. These remarkable algae, called zooxanthellae, actually serve the coral polyps in the capacity of excretory organs by taking up from the animal tissues such waste products as they can use in their own life processes. They have never been found living free of corals, and have never been artificially cultured. Their only reproductive process seems to be simple division and they are passed on from generation to generation of corals through the eggs, which become infected before leaving the parent.

Several species of fishes were found only in such situations in Iwayama Bay. Among these were the brilliant gold-and-black striped butterflyfish (*Chaetodon octofasciatus* Bleeker), wrasses of the genus *Cheilinus* (pl. 10, fig. 2), and several kinds of cardinal fishes belonging to the genus *Apogon*. Many species of highly colored fishes that reach a length of no more than one or two inches balance like jeweled spangles among coral branches that rival them in beauty, or conceal their splendor in holes in the coral cliffs. Ever present are the predators that seek out these defenseless inhabitants of the coral slopes. Some, like trumpetfish, have long snouts with which they relentlessly explore all holes and crevices in search of prey; others, such as the turkeyfish, have wide jaws and gaping mouth that enable them to engulf their prey in one quick gulp, in much the same way that a vacuum-cleaner may inhale a feather. Solitary sharks were patrolling the bottom of the deep waterways, but their presence was of most importance to the inhabitants of the deeper waters for the sharks seldom came to the surface.

Some of the islands in Iwayama Bay have protected little baylets in which the coral growth may consist largely of *Goniopora*, a thick-

branched stony coral with huge, protruding polyps (pl. 10, fig. 1). We soon learned to expect trouble when we collected these secluded spots, for the unusually virulent nematocysts, or stinging capsules, of the *Goniopora* polyps were easily dislodged by the currents we produced by swimming, and stung us so badly that we sometimes were obliged to leave the water.

Much more troublesome than *Goniopora*, however, was an arborescent, colonial scyphistoma (called *Stephanoscyphus*) of the medusa *Nausithoe*, which also released its nematocysts into the water upon agitation by strong currents. The stings produced by this animal left angry red welts that itched for days afterward, and even caused swelling of adjacent lymphatic glands. It seemed probable to us that a dense growth of *Stephanoscyphus* could liberate enough nematocysts into the water to inflict serious stings upon unsuspecting swimmers. Fortunately, this coelenterate seems to be common only locally in Palau, where we found it in only two localities.

In spite of seemingly ideal surroundings in most parts of Iwayama Bay, dead corals could be found at almost any location, suggesting that conditions are not always so favorable. A day or so of heavy rainfall will dump tons of fresh water not only into the bay but also upon the islands, from which it cascades down to the Bay, carrying with it great quantities of silt and forest debris. Salinity must be much reduced, especially near the surface, for many hours, if not days; the normal water temperature of about 85° F. may be lowered by 5° or more; suspended matter beclouds the water and the more delicate corals may be smothered. But, after a few clear days and several tidal cycles, the water clears and the survivors continue their struggle for existence.

The northwest corner of the Bay, forming divisions M, N, and O, is bathed by good tidal flow, but silt from the nearby mangrove shore discourages coral growth and the reef has a sickly appearance that belies the large number of species that comprise it. One of the resurveyed transects crosses the reef-flat at the south end of island 15, and we studied it during several low tides. Here we collected dead coral heads with cylindrical black sponges growing on them, which we soon found were only the external portions of a boring sponge that had excavated great hollow caverns in the coral boulders. Some coral heads were thus reduced to hollow shells, and we have yet to learn what becomes of the sponge after it has completely "eaten itself out of house and home"—whether it then assumes a massive, free-living form as do some other boring sponges, or simply dies of exposure. Whatever its fate after the destruction of the rock in which it lives, it is certainly an active reef-destroying agent. At the same locality we found another rock-boring sponge that attacked not only

dead corals but also the limestone floor of the tide-level notches. This sponge is almost certain to prove to be one of the important biological agents contributing to the formation of undercut shorelines.

The swift tidal currents that breath life and variety into the reefs do not reach the upper part of division K in the northeast corner of Iwayama Bay, which is a quiet backwater. An abundant growth of coral is nevertheless present, but it lacks variety. Fingery masses of *Porites* and great, white, papery chalices of *Montipora* (pl. 11, fig. 2) flourish everywhere, but few others can be seen. Even the fishes are fewer in kind and smaller in size. Small dragonets (Callionymidae) dart about in sandy patches or seek refuge among the coral branches. One of these dragonets (*Synchiropus splendidus*) is

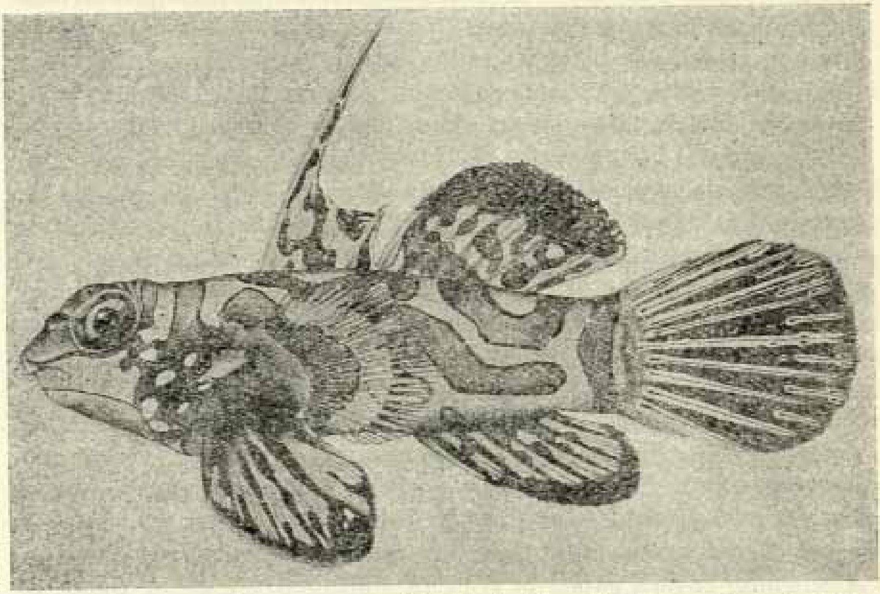


FIGURE 4.—The splendid dragonet, *Synchiropus splendidus*, slightly larger than natural size.

probably the gaudiest fish we found during the summer—colored blue, green, and red in an intricate design of spots and bands (see fig. 4). A few species of damselfishes (*Abudefduf*) were abundant, each fish with its own territory of coral and water. Each individual vigorously defends its own particular home, bullying intruders with threatening advances, cheeks distended, clicking and grunting indignantly. Hovering over the branches of *Porites* we could always find little bronze and maroon cardinalfishes (*Apogon nematopterus*), ready to retire into their stony sanctuaries at the approach of our staring camera lenses (pl. 11, fig. 1).

In the undercut shoreline of Koror nearby we found a small cave of the sort that permeates many of the limestone islands (pl. 6, fig. 1).

It was too small to crawl into very far, but in its dark and narrow recesses we found some alcyonarian corals (*Telesto*) hanging from the roof, completely exposed by the ebbing tide. Elsewhere there are larges caves, some at water level and large enough to admit a boat, others equally large but completely submerged. In most of the major limestone islands there are large caves that have collapsed, forming lakes connected with the sea by subterranean passages. These salt-water lakes contain large gobies, mussels, and sedentary jellyfish (*Cassiopeia*).

One of our reconnaissance techniques was to cruise slowly along the coral slope in the *Lenore*, watching for changes in the appearance of the reefs to indicate interesting spots to be examined more closely. We followed the bay shore of Koror south from the little cave, around the so-called Arappu Peninsula (Ngalap), where the submarine cliff was almost devoid of corals and the only conspicuous organism was a large, sprawling, branched, pale pink sponge that looked white in 20 or 30 feet of blue water. Even the stiff snaky "wire corals" (Antipatharia) that usually thrive on the cliffs were missing. We could find no explanation for the absence of corals there, for the current flow is better than it is in many other places, the water clearer.

After we passed through the narrow strait called Kaki-suidô (Oyster Pass) in the Japanese reports (Palauan name Ngerikiuul), the situation changed, and we came upon one of the most interesting areas in Iwayama Bay, one that we visited and revisited, each time to find something new. Here the undercut was very deep and the foliage of the jungle-covered slopes above hung far down over the water, blocking the midday sunlight and producing an almost constant twilight. For only a few moments in the afternoon could a few rays of sunshine slip through before the shadow of island 29 across the pass crept up to throw the waters into increasing darkness. A yawning cavern gaped in the cliff wall, entirely under water, its roof festooned with huge, netlike antipatharians ("black corals") hanging down like drapes. They were so flexible and so large that they could grow only in hanging position (pl. 18, fig. 2). When fresh, their polyps were brilliant orange in daylight, but they appeared almost white in the murky blue water of the cave.

ANIMAL PARTNERSHIPS

Only on this half-lit slope did we find the whip-corals, *Juncella;* they grew here like tall, waving grass reaching out toward the light, with their tips drooping like buggy whips. They form the hub of an interesting association that we will describe in detail in a future paper. The most unusual member of this association is a little transparent pink goby, a new species allied to the genus *Cottogobius*. It is a tiny

fish, not much more than an inch in length, that clings to the stalks of the whip-corals. They may be pursued up one side of the coral and down the other, but rarely will they move to another coral even though it is very near. Our ingenious Rikrik found that by sliding a coral stalk through his fist, he could catch its fish in a small net as it popped off the end. The water was often murky and the light always poor, but we did get a picture of Rikrik catching gobies in a field of junceellas (pl. 16, fig. 1). Also clinging to the whip-corals were many handsome gray feather-stars, or stalkless crinoids (comatulids), some of them grasping several corals at once (pl. 16, fig. 2). The cirri (the clawlike "feet") of the crinoids irritated the surface of the corals and scarred it permanently wherever they had clung, indicating that these "free-living" crinoids move about little, if at all. One of the crinoid's distant cousins, a bright orange brittle-star, lived entwined in the arms of the crinoid, and among them could also be found a spider crab, *Harrovia*, that had joined the partnership. Another crustacean, a small porcellanid crab, scuttled over the surface of the whip-corals, completing this curious association of vertebrates and invertebrates.

Among the most studied of symbiotic relationships to be found on tropical reefs is that involving several species of large sea-anemones that allow certain kinds of small but colorful damselfishes (genera *Amphiprion* and *Dascyllus*) to seek protection among their tentacles. These clownfishes, as they are sometimes called, rarely stray far from their host anemone, and are ready to dart down among the stinging tentacles at the first hint of danger (pl. 14, fig. 2). In spite of years of study, the details of this association are still not clear (Gohar, 1948; Gudger, 1946). It is believed that the fishes avoid being stung by swimming in a distinctive fashion that is "recognized" by the coelenterate. Clownfishes have been seen to drag food to the waiting tentacles of the anemones, but, on the other hand, we watched an *Amphiprion* seize a tentacle of its host in its mouth and with a few quick tugs pull it loose and eat it. This finny ingrate expected, and received, sanctuary from the very anemone it had been nibbling upon, for it dashed headlong among the tentacles when we approached too closely. Some investigators have suggested that by eating bits of the anemone, *Amphiprion* builds up an immunity to nematocyst poison, but this suggestion has never been scientifically confirmed. It does seem fairly certain, however, that the clownfishes recognize their preferred species of host anemone partly by sight and partly by chemical emanations. There is also some indication that the anemones do not sting their partner fishes because of some kind of chemical "recognition."

Coelenterates and echinoderms seem often to play the host role in these partnerships, probably not because of any inherent good nature or native generosity, but because they are slow moving or sedentary

and therefore an easy mark. One of our most startling discoveries of the summer was a fish that lives with an echinoderm. This, of itself, is not unusual, for the eel-like pearlfishes (*Carapus*, *Fierasfer*, and *Jordanicus*) have long been known to inhabit the cloaca of holothurians (sea-cucumbers) and the body cavity of *Culcita* (the cushion starfish). But our fish was a previously unknown species of clingfish (Gobiesocidae) and the echinoderm host was a feather-star (*Comanthus*), a completely unexpected combination. The clingfish was black with a bright yellow stripe down each side, perfectly camouflaged among the arms of its host.

It was on August 7 that we discovered it, as we were returning from a 2-day trip to Ngemelis. We had stopped in Meharehar, the labyrinthine lagoon of Eil Malk, to look for future collecting sites and to obtain some samples of the lagoon bottom sediments. It was a stormy day with heavy downpours that had hampered our observations and dampened the spirits of everyone aboard the *Lenore*. We had taken the bottom samples in the rain, and were heading for home by way of the inside route west of Urukthapel when we found ourselves over some coral flats near Ankosu Point, the southernmost cape of Urukthapel. Not wishing to pass up any likely localities, we dropped anchor and went over the side to look around. The water was about 6 feet deep and the bottom was covered with a tangle of staghorn coral (*Acropora*), most of it lying loose upon the sandy bottom. A few knolls of massive coral could be seen, with chalice-shaped acroporas and sea-fans (*Melithaea*) growing on them. Here and there, hidden among the corals, we found a many-rayed spiny starfish (*Acanthaster planci*), which is a real danger to bare feet (even those tough enough to disregard the jagged coral). It is widely feared by the natives of Micronesia, and with ample justification. A friend of ours was virtually incapacitated for a week or more by wounds inflicted by this animal, and he was not fully recovered for a month or more.

Between the coral branches everywhere, and on the coral knolls, the restless, fernlike arms of feather-stars swayed with the rising tide. Because we knew that crinoids are ever-gracious hosts to a variety of invertebrates, we collected some of them to find their lodgers. There are usually two kinds of shrimp, a galatheid (or "squat-lobster"), and a polychaete worm, all protectively colored to match their host—usually black and greenish yellow in this locality. The first feather-star that Adair Fehlmann collected had some black-and-yellow striped shrimps among its arms. Safely inside a glass vial, they gave us a real surprise. They were not shrimps at all, but fishes—and clingfishes at that—the only ones we would find all summer. A careful search disclosed a number of additional specimens before the current became so swift that we could work no longer. We

continued our homeward trip with one of the prize catches of the expedition—some tiny black-and-yellow fishes little more than an inch in length.

In practically any protected sandy area of the lagoon we could expect to find the unusual partnership of shrimps and fishes that we first observed at Ifaluk Atoll in 1953. We were delighted to find this association at Palau in such shallow water and in such abundance that we could observe it closely and collect the animals in numbers. At Palau, two kinds of alpheid shrimps and at least four kinds of gobies live together with identical habits.

Each pair of shrimps excavates its own burrow and then plays host to a pair of fishes. The fishes sit just outside the mouth of the shrimp burrow (pl. 14, fig. 1) while the shrimps repair and deepen it, bringing load after load of sand to the surface on their large claws, bulldozer-fashion. But should any danger threaten, the gobies dart down the hole in a trice, tumbling the shrimps over in their haste. From this activity the shrimps detect that something is amiss and cease digging until the gobies regain their composure and their usual position on the front doorstep. Whether this inadvertent warning is the only benefit derived by the shrimps from the association we are unable to say at present. It seems probable that the gobies obtain, in addition to shelter, an occasional banquet at the expense of their hosts, since one of the specimens collected was stuffed with larval crustaceans—probably the young of the shrimps whose home it had shared.

There is still much to be learned about these and various other rarely observed biological associations, and it will take patient observation, study, and experimentation in the field before we know the exact nature of the relationship between the partners and how it may have developed.

THE OUTER REEFS

The outer reefs have an entirely different appearance from the lagoon reefs of Iwayama Bay and the staghorn coral thickets of the shallow passes. On the west side of the archipelago the reefs are barriers, but on the east they are fringing reefs that follow the land closely, with an offshore barrier in only a few places. Whether barrier or fringing reefs, they are bathed with the always clean water of the open sea and pounded by its sometimes thunderous surf. Different and stronger corals live in these exposed situations, and a whole new population of fishes swims among their branches. The surgeonfishes, butterflyfishes, and wrasses that live here are for the most part peculiar to this zone of churning, turbulent water. Few species of the quiet lagoon waters are hardy enough to adapt to this rigorous environment. Sharks and barracudas in particular prefer this region,

constantly patrolling it for food. Certain surgeonfishes also are characteristic of the surf zone, among them *Acanthurus lineatus*, a yellow and neon-blue striped fish that loves turbulent, surging water. Their relatives, the fan-finned zebrasomas, hide under the spreading table corals. Huge parrotfishes, six or more feet in length, graze like cattle upon the corals, producing a noisy chorus as they crunch their limy meals in large, gregarious schools. Moray eels (*Gymnothorax*) lie in wait in their holes, their malicious eyes alert for any unwary fish that may pass within striking distance. The butterflyfishes (*Chaetodon*), so named because of their brilliant coloration, are especially numerous and are endowed with an insatiable curiosity. They seem unafraid of divers and will approach very close in order to get a good look. On many occasions they have startled us by a quick nip or a tug on some especially attractive hair. This has an electrifying effect upon swimmers already fearful of a surprise attack by prowling sharks, and the sheepish feeling combined with relief upon seeing these small challengers, is more amusing now than it was on the reef.

The spiny lobsters (*Panulirus*) that lurk in crevices of the outer reef are different species from those found in the lagoon. So are the coral crabs (*Trapezia*) among the massive branches of pocilloporas, veritable giants by comparison with their relatives in more protected waters.

Any specimens taken from the surf zone are collected only through great exertion, for it is one of the most difficult habitats to sample. Swift currents rapidly dissipate the rotenone and sweep away the specimens killed by it. The collector himself may be picked up by the swell and dropped 15 or 20 feet away, as likely as not on a jagged coral. When explosives are used instead of rotenone, all the nearby sharks materialize as if from nowhere, considering its sound a dinner bell inviting them to a free meal. Needless to say, we used this explosive technique infrequently, so as to avoid becoming the pièce de résistance of some shark's luncheon.

Near the reef passes and in the deeper waters offshore the corals flourish in stony gardens of eerie and awesome beauty. Some species of *Acropora* produce towering spires and antlers (pl. 7, fig. 1) that bring to mind the reefs made by the same genus of corals in the West Indies, and others form great, spreading disks and platforms composed of tiny branchlets, a growth form peculiar to the Indo-Pacific area (pl. 13). The sea gardens of swaying alcyonarians (sea-fans and sea-whips) that give the West Indian reefs their color and fluid beauty are nowhere to be seen, for the alcyonarians here are nearly all massive, rubbery kinds (pl. 13, fig. 2) that have not the elegance of their Caribbean relatives. The few species of sea-fans that do occur

are more abundant along deep channels or in the protected lagoons than on the seaward reefs.

EEL-GRASS ENVIRONMENT

A conspicuous feature of the Palau lagoon is the great extent of sandy bottom covered with eel-grass (*Enhalus acoroides* and some related species). It is a distinctive and complex habitat. The most expansive eel-grass beds lie near Peleliu, to the south of Koror, although the west coast of Babelthuap also has some fine ones. We made two trips to Peleliu to survey the grass beds there, but on both occasions we found poor conditions due to the stage of the tide. The water was so murky and full of plant debris that collecting was unpleasant and photography impossible.

Among the animal inhabitants, fishes are particularly abundant and thrive in the eel-grass environment. Sharks, jacks, barracudas, and other predaceous fishes constantly search the eel-grass beds for prey. Food is not easy to find here, even in the midst of plenty, for the eelgrass forms the home of many highly specialized fishes that blend with their background in both form and color. Some of them, such as the pipefishes (Syngnathidae) and certain wrasses (*Cheilio*), are elongate in outline and green in color, so perfectly camouflaged that sharp eyes are needed to separate them from the grass in which they live. Others, such as the parrotfish (*Scarichthys*), spinefish (*Siganus*), and some snappers (*Lethrinus*), are not shaped like the grass blades but are so much like it in color that they are virtually invisible. The filefishes (*Monacanthus*), blennies (*Petroscirtes*), and dragonets (*Callionymus*) go a step farther in having their bodies covered with waving filaments and hairlike growths that resemble the hydroids and other epiphytes covering the eel-grass blades.

The Palauan boys pointed out some peculiar little black-and-yellow fishes that were swimming about a water-logged branch half buried in the sand and hidden by grass and warned us that they were very dangerous. When we insisted upon catching them, Sumang Y. and Rikrik must have regretted pointing them out to us. The fish were small catfish (*Plotosus anguillaris*) with barbed pectoral and dorsal spines that are venomous and can inflict a nasty wound. They were swimming in a curious manner, very close together and wiggling vigorously, in a compact school that moved slowly forward like a dark cloud. It was simple to frighten them into the range of a large dipnet, and each fish captured caused our sturdy Palauans to wince in anticipation of the painful punctures to come when we pulled them out of the nets, and later, when we placed them in containers of formalin. A month or so later, when we were in Japan to consult with biologists who had worked in Palau before the war, we encountered this

same fish in southern Honshu. It was living in a completely different ecological situation, in rocky tide pools near the Seto Marine Biological Station at Shirahama.

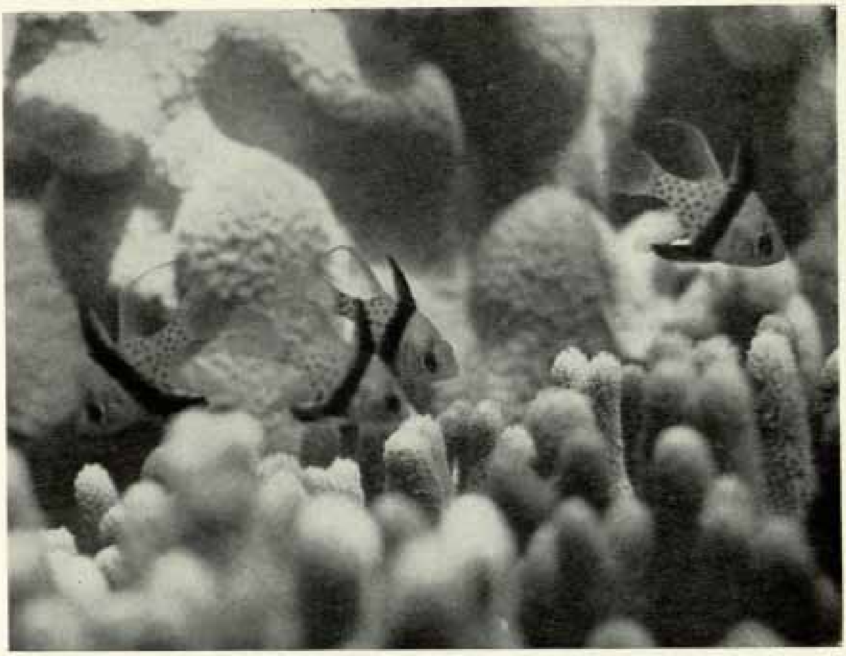
One of the major eel-grass inhabitants is a mammal, the little-known dugong, or sea-cow (*Dugong dugon*). During our stay in Palau we were always especially watchful while passing over eel-grass areas, in the hope of seeing some dugongs, but as they are quite scarce we never did see one in its natural habitat. During our last few days at Koror, however, some Palauans speared and captured alive a half-grown specimen that provided us with considerable excitement and became the first ever to be exhibited alive in an American aquarium. We bought this dugong, otherwise destined for sale as food in the local market, and kept it alive in a large pool at the end of Koror dock until we were ready to begin our return trip to the United States. Then we caught it, wrapped it in wet blankets (pl. 20, fig. 1), and carried it, lying on the floor of the plane between our seats, to Guam (pl. 20, fig. 2). At Guam it was ensconced in a sturdy crate and transferred to a commercial airline for shipment to California. The California Academy of Sciences had arranged for its transportation to the Steinhart Aquarium, where it proved to be an unusually popular exhibit. It was certainly the first Palauan dugong ever to fly to America, and we have no doubt provided some material for the "talking picture" carvings that decorate Palauan abais.

HERPETOLOGICAL STUDIES

Another Palauan animal that never before had been displayed alive in an American zoo or aquarium, and which we succeeded in bringing back to the United States, is the deadly poisonous sea snake (*Laticauda colubrina*), a relative of the cobras and coral snakes.

Our first encounter with the banded sea snake in the wild was on a field trip to Ngemelis, a group of islands along the southwest barrier reef. We were making our way toward the beach just before dusk when, a hundred yards or so from shore, we came upon a huge snake, a good 6 feet in length, slowly working its way seaward along the bottom, poking its head into nooks and crannies and in and out of corals, carefully feeling with its tongue. It paid no attention to us, and we stood or swam near it for several minutes, in water perhaps 5 feet deep. At no time did we see it surface for air, and as we continued on our way it was still swimming seaward along the bottom.

The Palauans have an odd story about using sea snakes to catch fish. They say that if one holds the snake by the tail, it will probe among the rocks and catch fish, which can then be easily seized. We never saw this method of fishing practiced. Probably no modern Palauans are courageous enough to try it, for our helpers invariably let out

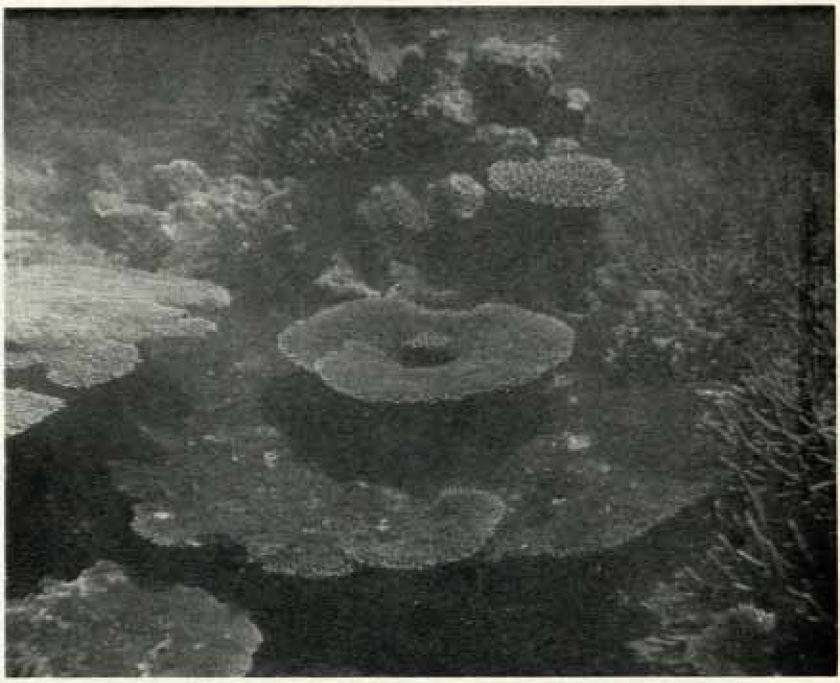


1. Graceful, spotted cardinalfishes (*Apogon nematopterus*) hover over the branches of a *Porites* colony that is their refuge in times of danger. This little fish, with its red spots on a bronzy ground color, and a dark-brown cummerbund, is one of the loveliest denizens of protected reefs.

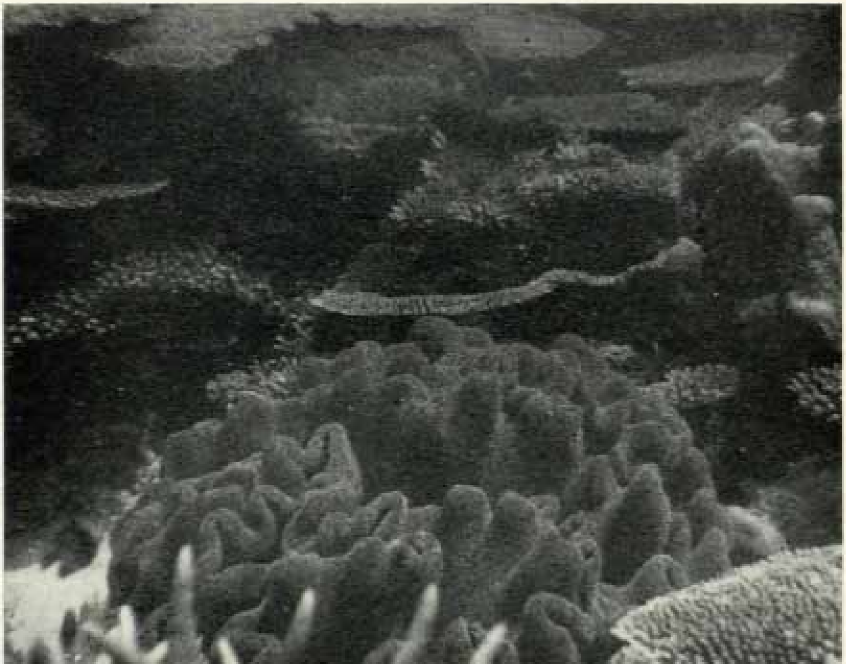
2. Huge, fragile chalices of *Montipora foliosa* dominate the reef slope in the innermost part of K Division of Iwayama Bay. They form an uncertain retreat for fishes like the small damselfish (*Pomacentrus*) swimming above them.

1. The beautiful falls of Matal Eigad on the Ateshi River, in Ngardmau Municipality of Babelthuap. Note figure at foot of falls. The only fishes collected above the falls were eels, which can travel overland around obstacles insurmountable to other fishes. (Photographed by H. A. Fehlmann.)

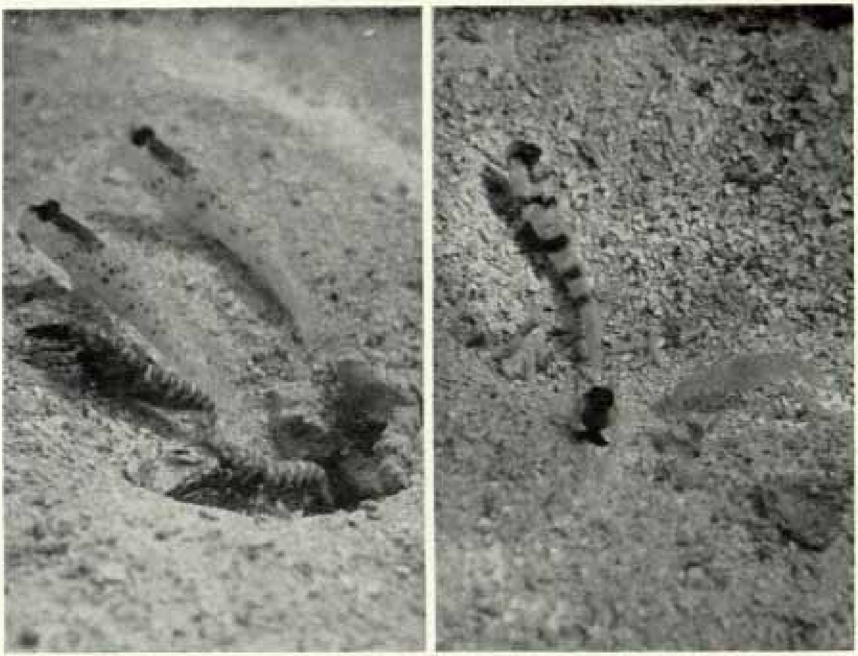
2. H. Adair Fehlmann and Rikrik collecting in a small stream on Arekalong Peninsula of northern Babelthuap. Such a locality yields many gobies, and prawns of the genus *Macrobrachium*.



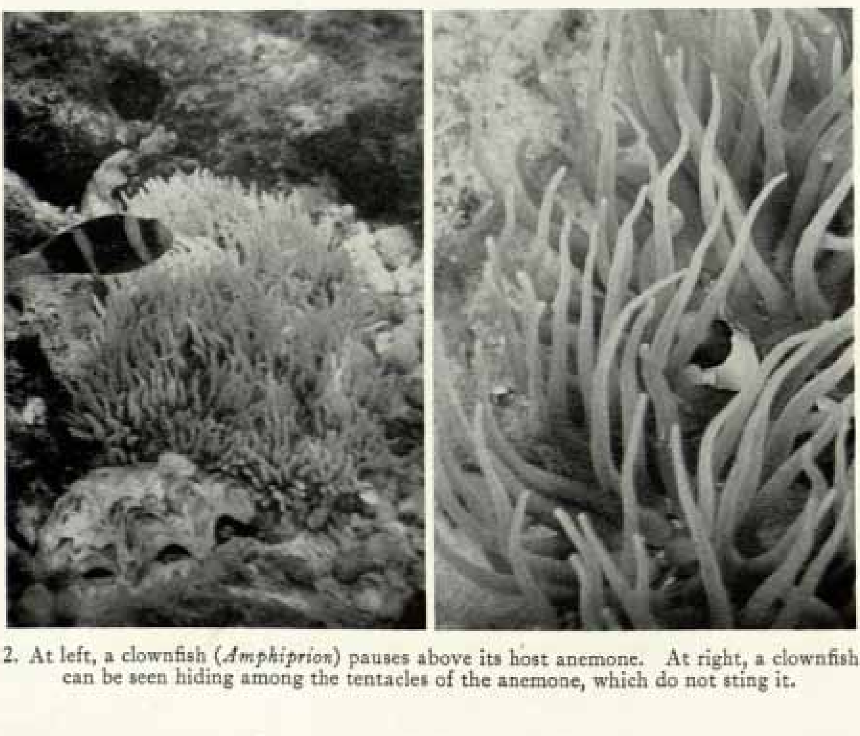
1. Great, circular plates of acroporas grow one above the other like modernistic buildings in this scene along a reef channel south of Ngaremediu.



2. The convoluted mass in the foreground is a massive, fleshy alcyonarian, *Sarcophyton*, as large as a bushel basket. This type of alcyonarian is typical of Pacific reefs, whereas in the Atlantic the bushy gorgonians dominate.

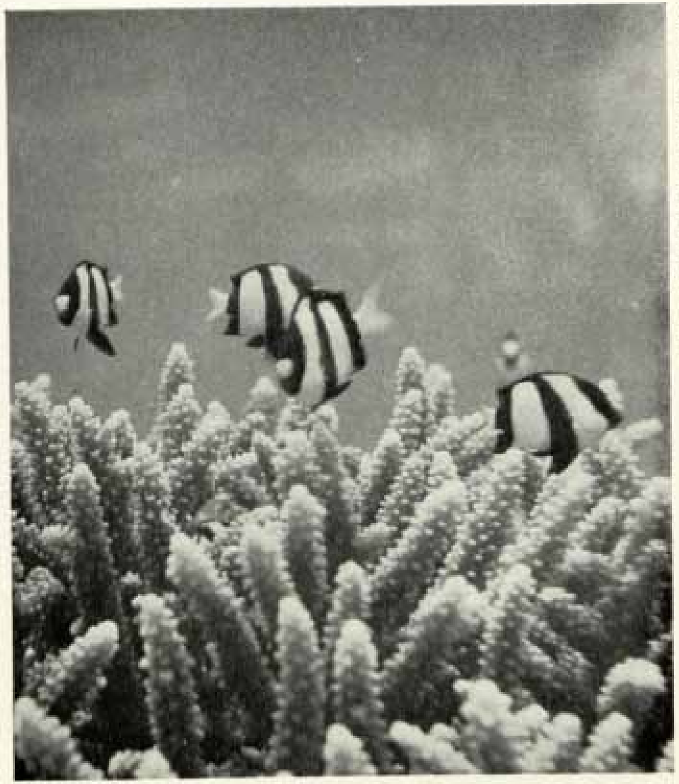


1. At left, a pair of speckled gobies sit outside the burrow made by the dark-banded snapping shrimps. At right, the banded gobies are living with a pale, fine-striped shrimp that is almost invisible against the sand.



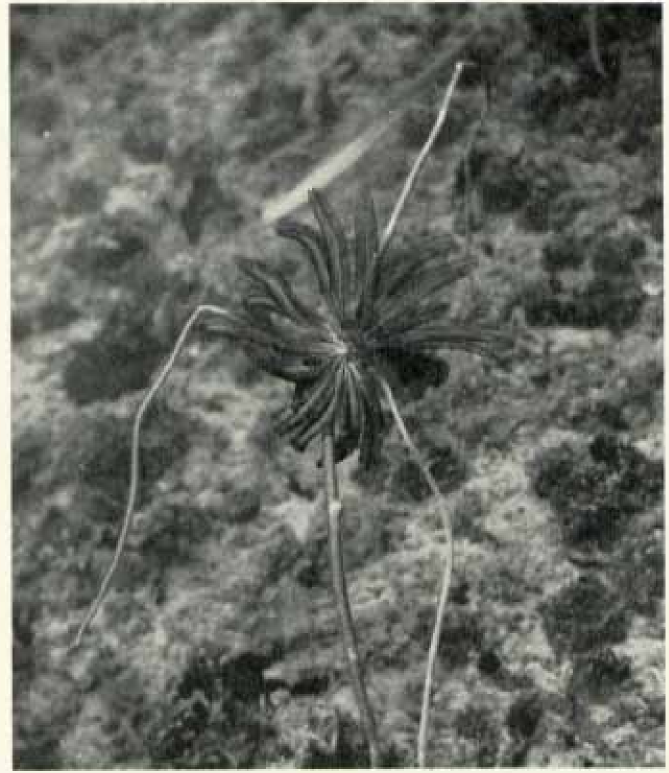
2. At left, a clownfish (*Amphiprion*) pauses above its host anemone. At right, a clownfish can be seen hiding among the tentacles of the anemone, which do not sting it.

1. A pair of moorish-idols (*Zanclus canescens*) swim with stately elegance among the coral branches. Their long snouts are well adapted for obtaining food deeply hidden in crevices or among branches of coral.

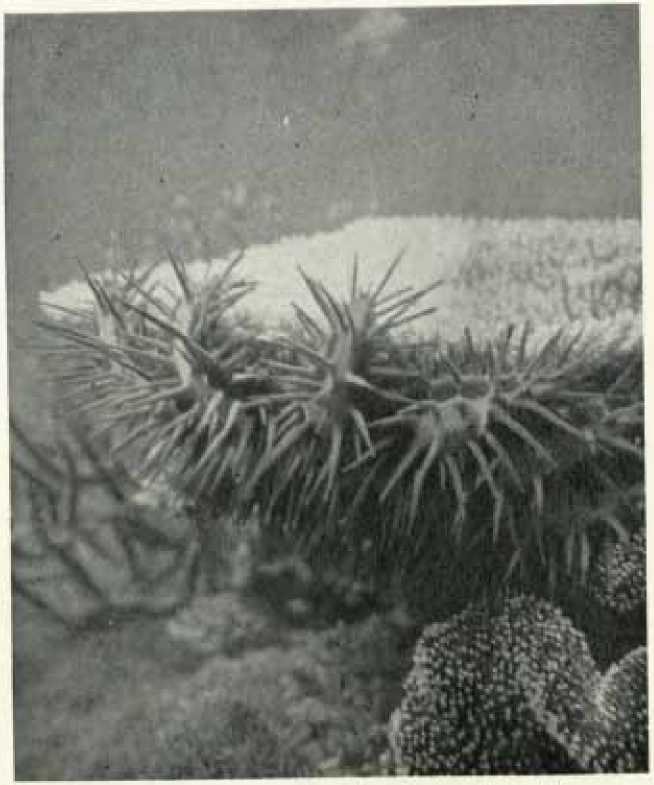


2. A school of banded damselfishes (*Dascyllus aruanus*) hovers over branched corals, into which they retreat when pursued. The fishes remain in the coral even if it is removed from the sea, and may thus be captured readily.

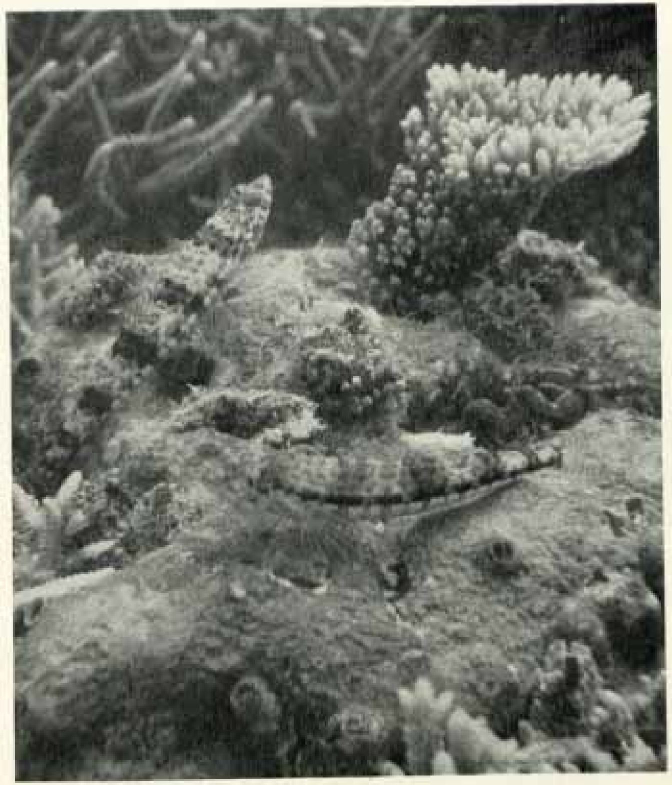
1. Rikrik catching "Junceella-gobies" in a bed of sea-whips on the coral slope of Oyster Pass. This photograph, taken at a depth of 20 feet, shows characteristic appearance of the *Junceella* bed.



2. A feather-star, or unstalked crinoid (comatulid), grasping two whip-coral stalks (*Junceella fragilis*). A tiny species of goby clings to the whip-corals, and crabs, shrimps, and brittle-stars live among the arms of the crinoid.

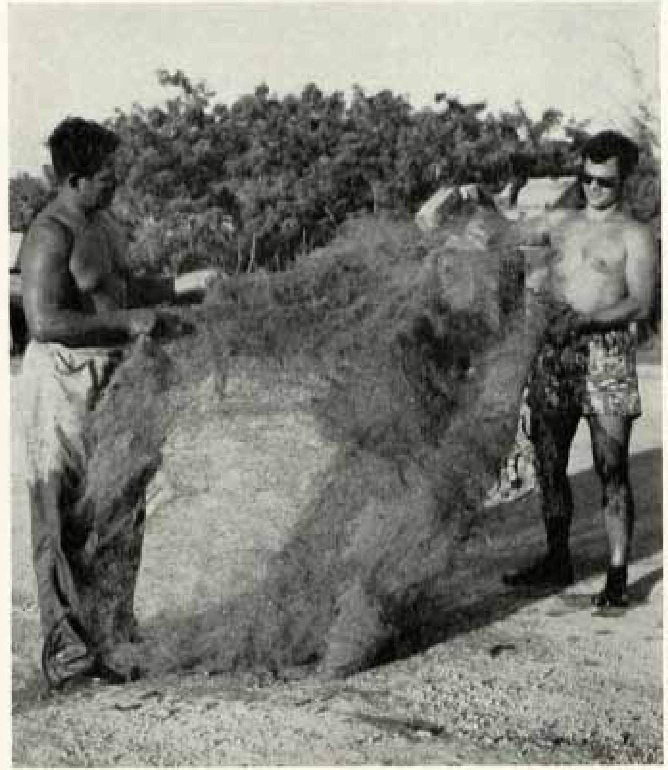


1. A spiny, many-rayed starfish (*Acanthaster planci*) hides under a coral ledge. The needle-sharp spines, covered with epithelium and a toxic mucus, can inflict dangerous wounds if stepped on.

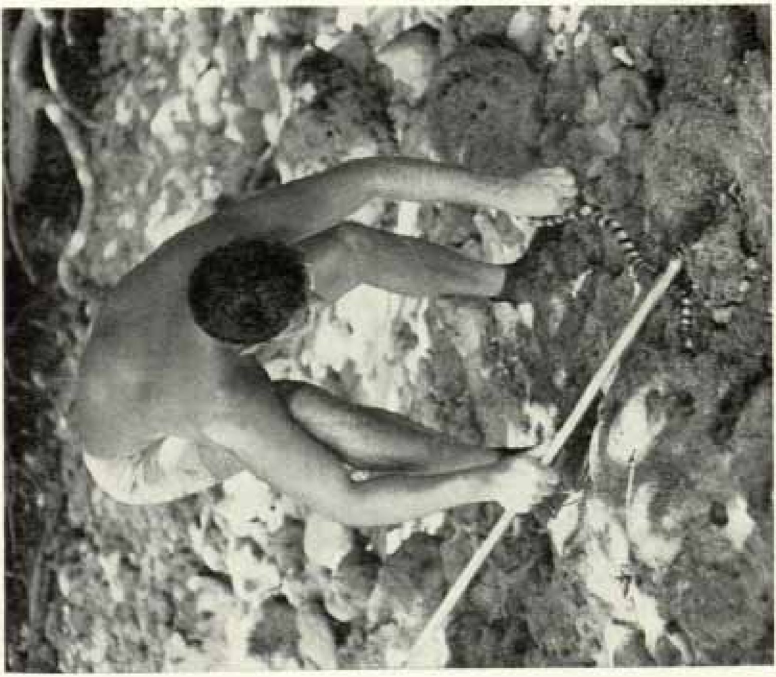


2. A pair of lizardfishes (*Synodus*) pause atop a coral knoll. They are effectively camouflaged by their color pattern, but may hide themselves in sand as a further protection. Lizardfishes have extremely sharp teeth and are voracious predators. The famous "Bombay Duck," esteemed by gourmets, is a larger species of lizardfish.

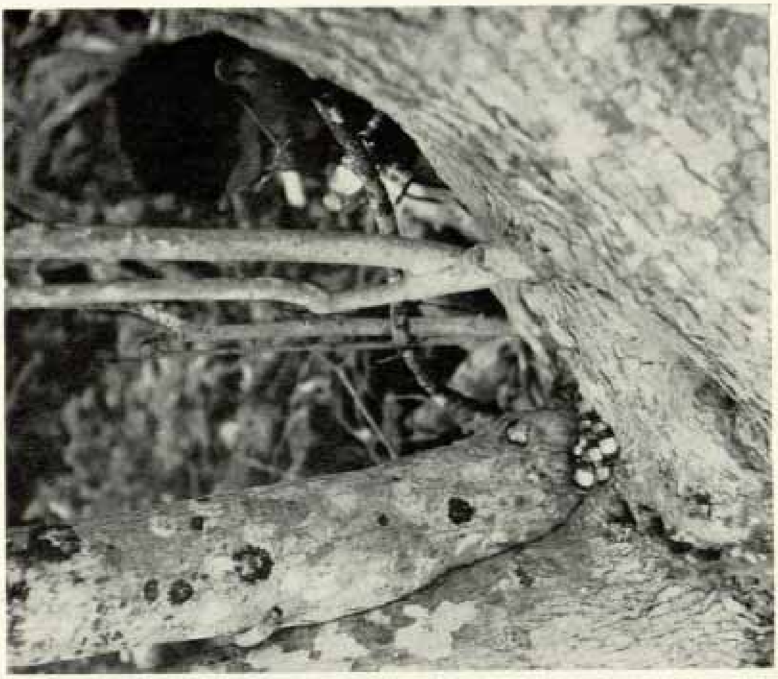
1. Rikrik displays the stingray (*Dasyatis*) that he had just speared along the muddy, mangrove-choked shore at Ngardmau, in northern Babelthuap. (Photograph by H. A. Fehlmann.)



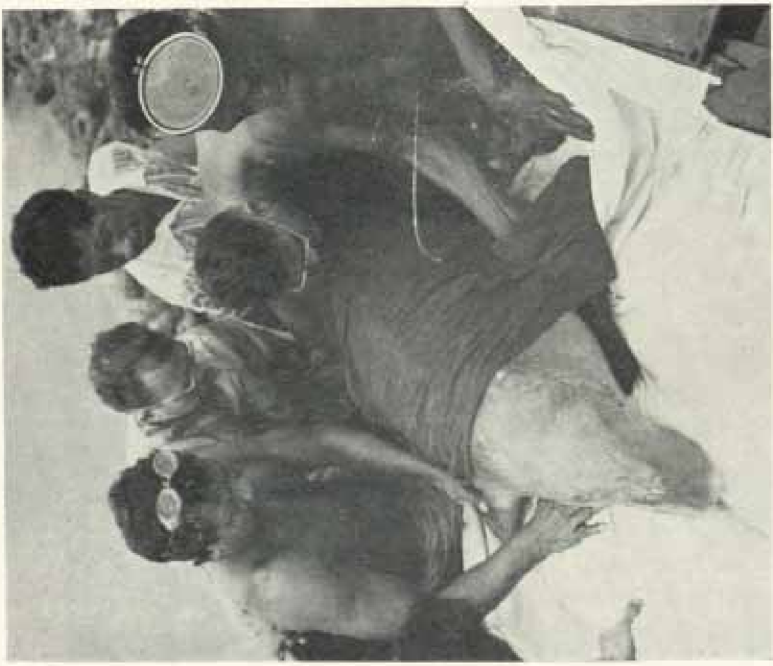
2. Sumang Y. and one of the authors spread a large, antipatharian sea-fan that was taken from the undersea cave in Oyster Pass.



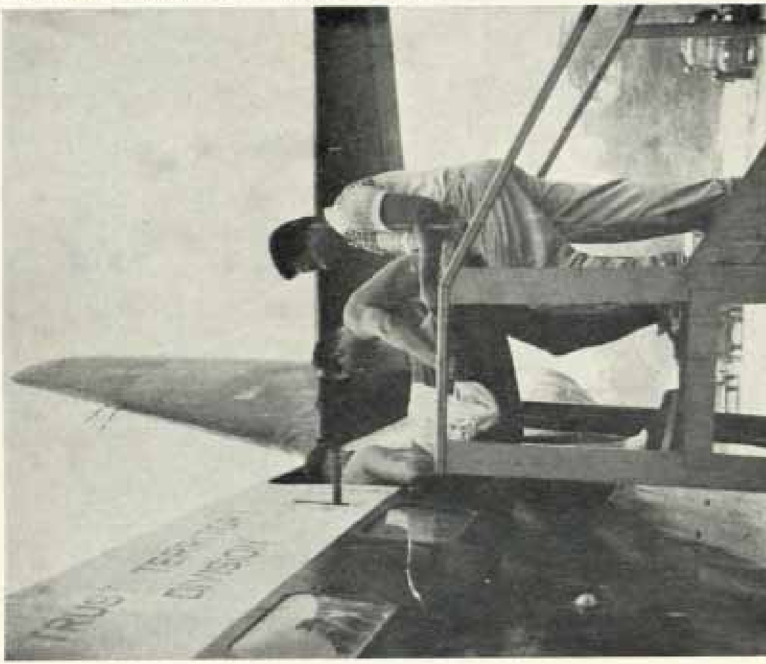
1. H. Adair Fehlmann captures a banded sea snake on the rocky seaward coast of Narducis Island off the southeast coast of Babelthuap.



2. Sea snakes rest among underbrush and in trees, far above the high-tide mark. This one in a tree is being photographed by H. Adair Fehlmann.



1. Sumang Y., Rikrik, H. A. Fehlmann, and airline officials place the dugong, wrapped in wet blankets, on an air mattress, to make it as comfortable as possible on the long flight to California.

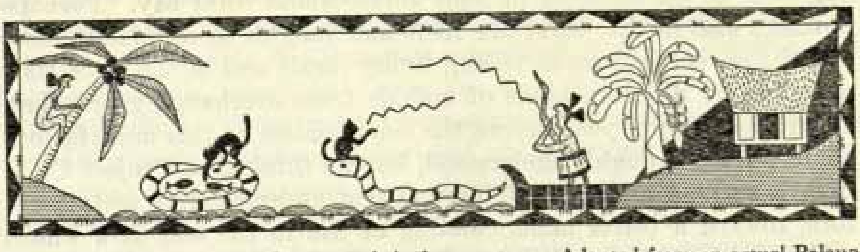


2. At the Koror airport on Arakabesan Island the dugong goes aboard the Trust Territory seaplane for the 6-hour flight to Guam.

great yelps of fear whenever we caught sea snakes (or any other kind, for that matter), and their repugnance extends also to eels, perhaps with more justification. Another droll story, frequently seen on the carved "talking picture" boards, tells how the sea snake taught Palauans to fish with nets. In this tale, a Palauan woman, whose children were a banana tree, a pussycat, and a sea snake, grew weary of her offspring and told them to make their own way in the world. The banana tree pointed out the impracticality of this suggestion, at least from its rooted standpoint, and thus won a reprieve, but the two more active "children" were sent packing. As they swam toward Orukuizu, the cat riding on the snake's head, they grew hungry, and in Palauan carvings we see the snake encircling some fishes so the cat could catch them as they swam out through the narrow space between the snake's head and tail. A villager who was up in a palm tree gathering toddy caught sight of this procedure and at once recognized its possibilities. He rushed down to the shore and asked the snake to show him how to fish that way, so the snake showed him how to set up a fence of sticks in shallow water, in which fish would be trapped. But the Orukuizu man still needed the cat to catch the fish as they passed through the mouth of the weir, so he asked the snake if he could have the cat, too. The snake agreed but made the man promise to give the cat one of the fish each time they made a successful catch. Such was the origin of cats and fishweirs.

This particular species of sea snake is not so completely aquatic as are some of its relatives, and it could be found on the seaward shore of exposed islands, coiled up in underbrush on dry land or even in the branches of trees (pl. 19, fig. 2). They were very common at Nardueis, off the southeast shore of Babelthuap, where we caught as many as a dozen in a couple of hours. Some of these are still living in the Steinhart Aquarium in San Francisco, but the specimens destined for the National Zoological Park in Washington perished during the flight across the continent.

The herpetological collections we assembled contain at least four other species of snakes, including a burrowing form (*Typhlops*) no



The story of the sea snake, the cat, and the banana tree. Adapted from an actual Palaun carving.

larger than a moderate-sized earthworm. Geckos (nocturnal lizards with adhesive toe pads that aid in climbing) of several kinds abound in the trees and on window screens of buildings where they catch insects attracted to electric lights at night. The toad is extremely abundant in the vicinity of Koror, and two kinds of frog seem to be widespread throughout the islands. The monitor lizard is not especially common but may be encountered on Babelthuap. The collections and notes of Dr. Masamitsu Oshima, who studied the reptiles of Palau, were unfortunately destroyed during the course of the war before they could be published. Our collections will therefore fill an important gap in our knowledge of the terrestrial fauna of the Palaus.

HOMEWARD BOUND

By the time November rolled around and Project Coral Fish had been active in Palau for four months, we began to make plans for the homeward journey. On November 4 we made our last marine collecting station, and on the following day the dismantling of the laboratory began. All equipment had to be either packed for shipment or stored for use by Project Coral Fish II. Outboard motors were cleaned and boxed, the *Lenore* was stripped and crated; collections were packed in tins, drums, and boxes, labeled, and stacked up to await the next freighter to Guam. In a few days the laboratory was starkly in order and deserted. Arrangements were made for the transportation of the live cargo of sea snakes and dugong. "Plane Day" on November 15 was a typical rainy-season day in Koror. Rikrik and Sumang Y. went early to the dock and caught the dugong, and it was difficult to say if it was wetter in the pool or on the dock. Dugong, snakes, other precious collections, and ourselves were loaded on the Albatross amphibian in the still-pouring rain, and we were off, it seemed after having scarcely arrived, so swiftly did the months pass on these coral-fringed islands and broad lagoons. Only yesterday, so it seemed, we had made our way up one of Babelthuap's rivers as the crocodiles slid off the banks into the dark water, or had been listening to the little bird with a "pipe sweet as a flageolet" as we collected in some forest-bound coral bay. Perhaps nowhere else in the world are reefs and jungles so intimately associated that one can stand among living corals and at the same time collect many different kinds of orchids from overhanging branches. It will be many a year before the complexities of this multifarious habitat are thoroughly understood, but we think that Project Coral Fish is making a long stride toward that understanding and, therefore, toward a better understanding of life in the seas as a whole.

During the 1955 expedition to Palau, Project Coral Fish assembled thousands of specimens from 276 collecting stations extending from

the northern end of Babelthuap to Peleliu. Phylogenetically, the collections contain animals ranging from the Protozoa to the vertebrates, as well as many specimens of marine plants. The largest collections are those of fishes, crustaceans, and sponges, but the smaller collections are no less significant. Taken together, they represent a contribution toward a more complete faunistic and zoogeographic knowledge of the Palaus, an especially significant one in view of the fact that the collections made in the same territory by Japanese scholars prior to World War II are either widely scattered over Japan or were destroyed during the war. In addition to their systematic and zoogeographic value, these collections include information on reef communities and biological associations, which forms the framework of reef ecology. In spite of its encouraging success, the first field season of Project Coral Fish did not accomplish all there was to be done in Palau. Neither will the 1956 season. Some of the smaller component projects will certainly see early completion, but they bring into bold relief many other problems, not a few of which demand an experimental approach that can succeed only at a place like Palau.

CHARACTERISTICS OF THE PALAUAN MARINE FAUNA

The large collection of marine animals assembled in Palau during the summer and fall of 1955 is only now being studied in detail, so it is not yet possible to analyze the fauna from a zoogeographic standpoint. However, some impressions of both its richness and its affinities were inescapable during the course of observing, collecting, and preserving the many specimens handled. These impressions, superimposed upon what we already know from the literature, enable us to reaffirm the East Indian relationships of the Palauan marine fauna.

Many East Indian fish groups not common in the oceanic islands were found to be abundant in the Palaus. Especially noticeable is the archerfish (*Toxotes*), which travels in large schools along the lagoon shores, particularly in mangrove regions, where it penetrates the narrow waterways and ascends a considerable distance up streams and rivers. Glassfishes (*Ambassis*) and spotted scats (*Scatophagus*) are abundant in the mangrove swamps and lower reaches of streams but are not found in the limestone islands of the southern Palaus. Fresh-water eels (*Anguilla*) grow up to 5 feet long in even the smallest streams. Some groups of fishes, such as the snappers (*Plectorhynchus*, *Caesio*, *Lethrinus*, and others) are represented by many more species than are known from the multitudes of oceanic islands in the Marshalls, Marianas, and Carolines.

Among the invertebrates, the only two shallow-water gorgonaceans (Octocorallia) to extend an appreciable distance eastward into Micro-

nesia, *Subergorgia mollis* and *Rumphella antipathes*, are common East Indian species that occur also, as expected, in the Palaus. Another species of *Subergorgia*, two magnificent melithaeas, the so-called "*Plexaura*" *flava*, a species of *Euplexaura*, and *Junceella fragilis* are more or less common in Palau, indicative of close ties with the East Indies and Philippine faunas. Among the Alcyonacea, *Dendronephthya* occurs in abundance and *Studeriotes* was found in slightly deeper water in the lagoon, both genera being well represented in the Philippines. These various octocorallian genera are centered mainly in the East Indies-Philippines area, but range also northward to Japan and southward to Australia, thence eastward to Fiji, Tahiti, and Tonga, but reduced in species peripherally. Furthermore, the alcyonarian genera typical of Micronesian reefs, such as *Sinularia*, *Sarcophyton*, *Lobophytum*, and *Sphaerella*, are represented in Palau by a greater number of species than is usual in the central Pacific atolls.

The molluscan fauna is notably richer in many elements than that of the Micronesian atolls to the east, especially in such genera as *Murex*, *Spondylus*, and *Pecten*. Since the distribution of *Simnia* and related gastropods is tied to that of the gorgonians on which they live, they accordingly do not extend very far to the east, probably not beyond Palau. However, the large egg-cowry (*Ovula ovum*), which lives on soft-corals, enjoys the much wider range of its hosts.

The fauna of the Palaus will probably not be found to approach the richness of that of the Philippines, East Indies, and New Guinea, but it certainly far overshadows that of the oceanic atolls.

PROSPECT

As we write these words, Project Coral Fish II is continuing the program of investigations embarked upon in 1955. It is anticipated that the field phase of a survey of the fresh-water fish fauna of Babelthuap, begun in 1955, will be completed successfully during the present season, and the marine survey continues with special attention to areas not previously visited. The research program has been broadened by the addition of an oceanographer to the field party, so that more detailed data regarding the aquatic environment may be gathered.

During Coral Fish III in 1957, we hope to complete our ecological resurvey of Iwayama Bay, and to make more detailed studies of some of the commensal, symbiotic, and parasitic relationships mentioned in the foregoing pages. The results of the 1956 expedition should permit much more efficient observations on the physical environment and enhance the value of the Iwayama resurvey. We hope that it will also

be possible to inaugurate a program of current and plankton studies, especially within Iwayama Bay, to determine the reasons for, and to provide a better understanding of, the distribution of various corals and other benthic invertebrates within the confines of the Bay.

ACKNOWLEDGMENTS

The fieldwork described in these pages was carried out under arrangements with the Pacific Science Board (NAS–NRC) and the Office of Naval Research [contract N7onr-291(57)]. Work in the Palaus would have been impossible without the approval and thorough cooperation of the Trust Territory of the Pacific Islands. Especially we wish to express our appreciation to High Commissioner D. H. Nucker, Executive Officer A. M. Hurt, and their staffs in Guam. In Palau, District Administrator Donald Heron extended every possible courtesy, and his staff, including Francis B. Mahoney, Robert P. Owen, and many others, were wholeheartedly cooperative and interested in our program. We likewise cannot overlook the Trustees of the George Vanderbilt Foundation and the authorities of the Smithsonian Institution, who made our participation possible.

PALAUAN GEOGRAPHIC NAMES

The names used in this account are those to be found on the charts of the U. S. Hydrographic Office and the maps of the U. S. Corps of Engineers. The spellings of these names may bear little resemblance to their pronunciations. We therefore offer the following table, the left-hand column listing the names as taken from published charts and used herein, and the right-hand column listing the phonetic spellings by Krämer, or supplied to us by Sumang Y.

Angaur (Island)	*a* Ngeaur
Ankosu (Point)	Nghus
Arakabesan (Island)	Ngarekobasáng
Arekalong (Peninsula)	Ngaregolong
Ateshi (River) [also Addeido]	*a* Did
Aulong (Island)	*a* Ulong
Aurapushekaru (Island) [also Auluptagel]	Ulupságel
Babelthuap (Island)	Babldáop
Eil Malk (Island)	*a* Ilmálk
Geruherugairu (Pass)	Ngaregelngáel
Kayangel (Atoll)	Nggelangel
Malakal (Island)	Maláგal
Matal Eigad (Falls of *a* Did R.)	Madál a Jegád
Narduels (Island)	Ngarduais
Orukuizu (Islands)	Ngerkuid
Palau [also Palao, Pelew, etc.]	Pelau or Belau
Peleliu	Pelíliou
Urukthapel	Ngurukdápel

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Archeological Work in Arctic Canada

By Henry B. Collins

Bureau of American Ethnology
Smithsonian Institution

[With 14 plates]

Southampton Island, a bleak and treeless land mass some 17,000 square miles in extent, forms the northwestern boundary of Hudson Bay, separating it from Foxe Channel and Foxe Basin to the north. Though the island is 50 miles below the Arctic Circle, its shores remain icebound for about eight months of the year, and its climate, vegetation, flora, and fauna are all typically Arctic.

The island is of particular interest to archeology for two reasons. It was the home of a strange, primitive tribe of Eskimos—the Sadlermiut—who became extinct in 1903 before they had been studied by ethnologists. And long before this, in prehistoric times, the island had been occupied by two other groups of Eskimos, those of the Thule and Dorset cultures. The Thule people had come originally from Alaska, about 800 years ago, and were commonly assumed to have been the ancestors of the Sadlermiuts. The Dorsets were a little-known Eskimo people of markedly different culture who had occupied the central and eastern Arctic long before the arrival of the Thule migrants from the west. This was the locale and these the problems selected by our 1954 expedition to Southampton Island, sponsored by the Smithsonian Institution, the National Museum of Canada, and the National Geographic Society. We hoped to obtain information on the early inhabitants of the island and the different ecological, climatic, and cultural conditions that had prevailed there at different times in the past, on the physical type of the old populations, and on the cultural relationships between the three Eskimo groups—Dorset, Thule, and Sadlermiut.

We planned to establish camp at Tunermiut (Native Point), 40 miles down the coast from Coral Harbour, and spend the greater part of the summer excavating at a large abandoned Sadlermiut site and a smaller Dorset culture site that had been reported there (Bird, 1953). In midsummer we planned to charter an Eskimo Peterhead boat for a trip over to uninhabited Coats Island to the south, where the

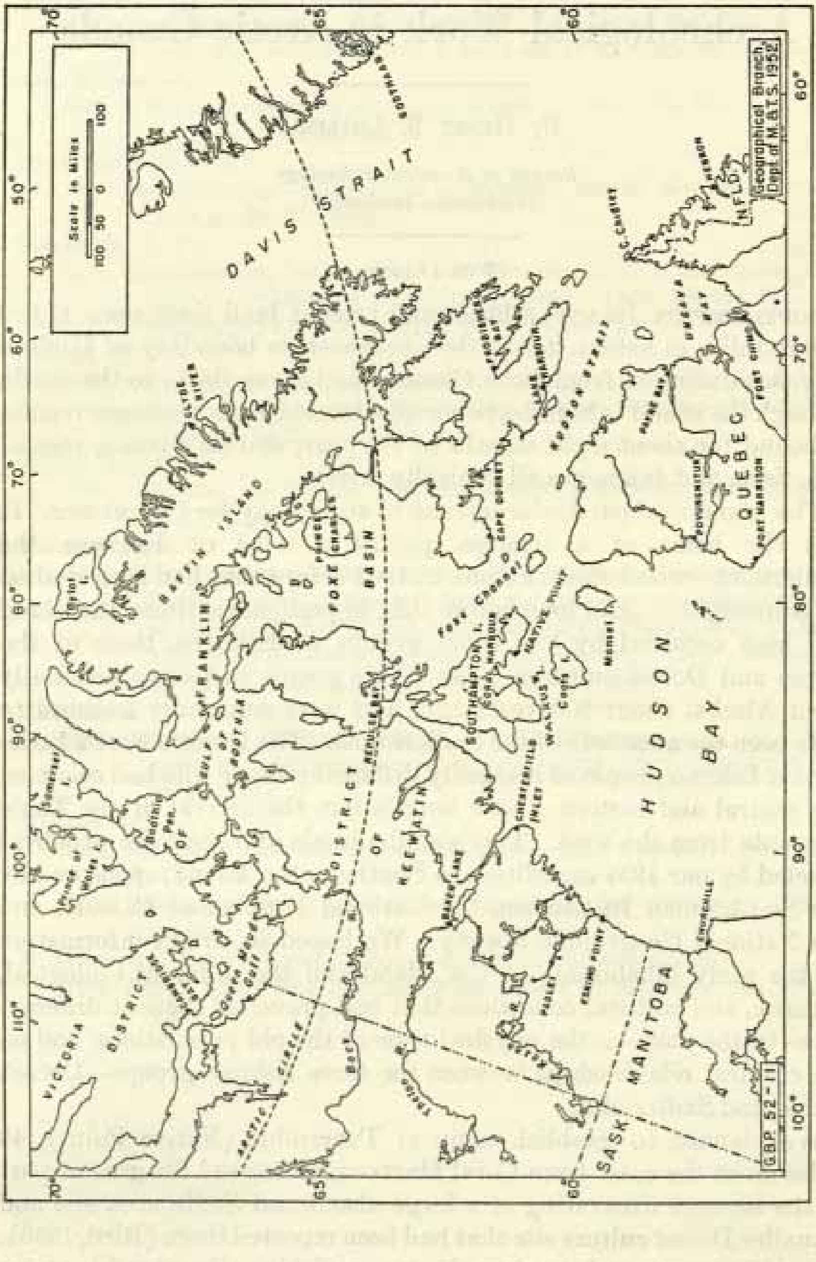


FIGURE 1.—General map of eastern Canadian Arctic.

Sadlermiuts were first encountered by Capt. Lyon in 1824 and where we hoped also to find village sites of the earlier Dorset people. This paper will be in the nature of a narrative account of the expedition, describing the circumstances under which the work was conducted, as well as the results accomplished.

On June 23 our party, consisting of Dr. J. Norman Emerson, William E. Taylor, Jr., Eugene Ostroff, and myself, was flown by the R. C. A. F. from Montreal to Churchill on the west coast of Hudson Bay. Here we stopped overnight and picked up a supply of 5-in-1 military rations, tents, and Arctic clothing which the U. S. Quartermaster Corps had kindly provided for our use. The next morning we flew over to Coral Harbour on the south coast of Southampton Island, arriving around noon. Our immediate destination was the Hudson's Bay Company post and Eskimo village 3 miles east of the airstrip, but as most of the snow had disappeared from the ground, making sled travel overland impossible, we had to get there by a roundabout route. Our supplies and equipment were loaded on an Air Force truck and taken to a small Eskimo settlement bearing the strange name of "Snafu," on the coast 3 miles to the south. Here we engaged Eskimos to take us the rest of the way by dog team over the sea ice. It was a short trip of about 7 miles, a new experience for most of the party and a prelude to the much longer sled trip we were to begin next day. The name of this little Eskimo settlement comes from a wrecked oil tanker, referred to as the *Snafu*, which ran aground there during World War II. The proper tribal name of these Eskimos is Okomiut, but they are now also called "Snafumiut," a designation they cheerfully accept, unaware of its somewhat derogatory connotation. The Okomiuts came originally from southern Baffin Island, having been brought to Southampton when the Hudson's Bay post was established there in 1924. They constitute the minority element in the present Eskimo population of Southampton Island. Most of the Eskimos now living on the island are Aiviliks from the Repulse Bay-Wager Bay area on the mainland to the west, who were brought over by the whalers around 1908. The total Eskimo population is about 240, mostly concentrated around the Hudson's Bay post, where we were now headed.

A. T. Swaffield, the post manager, met us and had our equipment taken up to one of the company storehouses and the neat little 3-room lodge where we were to stay until we left for Native Point. The problem now was how to get down to Native Point. Normally the ice breaks up by July 4th so that boat travel is possible by that time. This year, however, the prospects were that the breakup would be possibly as much as two weeks later. As we were anxious to get to Native Point and begin work as soon as possible, Mr. Swaffield called

in one of the Eskimos, Pangiyuk, to discuss the situation. Like most of the other Southampton Eskimos, Pangiyuk speaks hardly any English, but Swaffield, through years of experience as a Hudson's Bay manager, has developed a considerable proficiency in the Eskimo language.

Pangiyuk said that the sea ice, though somewhat rough and sloppy, was still safe for sled travel and that his dog team and three others were ready to take us down to Native Point as soon as the weather permitted. The sky was then dark and overcast, it was raining and windy and the barometer was falling; but the weather changes with surprising rapidity in the Arctic, and by next morning the rain had stopped and the sun was out. Our food supplies, tents, sleeping bags and other equipment were hauled down to the rocky beach and loaded onto the four sleds. Because of weight limitations, the aircraft that had taken us to Coral Harbour had been able to bring only half of our food supplies. The remainder was to be brought over from Churchill on the July flight and delivered to us at Native Point by the Eskimo Peterhead boat that was to take us to Coats Island.

It was perhaps just as well that we had no more of a load for the four sleds were already filled to capacity. A skiff was lashed on each sled and the boxes and other gear piled inside (pl. 1, A). This was necessary in order to keep the supplies from getting wet, as the sleds were very low and would have to traverse areas where at this time of year there would be up to six inches of water on top of the ice. It was also desirable as a precautionary measure in case we encountered wide leads in which a sled without a boat would sink.

As the weather was fine and the night as bright as day, we planned to go directly to Native Point without stopping for the night, hoping to make the 40-mile trip in around 10 hours. This proved to be a somewhat optimistic estimate, for the trip required 14 hours, including time out while the Eskimos hunted seals basking on the ice beside their breathing holes.

The sleds were pulled by from 8 to 10 dogs who jogged along at a good trot to the constant accompaniment of the drivers' "Wo-ah" (right), "Ah-ee" (left), and other sounds more like grunts than words but which were clearly intelligible to the dogs. Sometimes, though, when the dogs had not responded properly there would be a deluge of words—undoubtedly Eskimo invective and profanity—similar in purpose to the conventional remarks a mule driver uses in addressing his team. When language failed, the long whip would swish out and the offending dog would emit a surprised yelp and start pulling.

There was almost as much water as ice surface, though most of it was only a few inches deep, in pools that usually contained deeper

holes which had to be avoided (pl. 1, B). The sleds negotiated the open leads and pools with little trouble, though for the passenger sitting on top it was a rather bouncy, bumpy ride, frequently interrupted by his having to jump off and help pull the sled over an ice hummock or through a patch of soft snow. Most of the leads were narrow enough for the dogs to jump over. Occasionally, however, there were wider leads, half the length of the sled, which the dogs would have to swim, and here it would be necessary for Eskimo driver and passenger to hop off and help pull the sled across.

At 5 a. m. on June 26th the long trip was over as the weary dogs pulled the sleds up to the beach at Native Point and settled down to rest. But before we could rest we had to unload the sleds and haul our gear over the rocky beach to the dry level spot 100 yards away that we had selected as a camp site. The wall tent was set up, we brought our sleeping bags inside and went to sleep about 6 a. m. Later that day we put up the other tent, got camp organized and made a preliminary inspection of the ruins we were to dig.

With the departure of our Eskimo friends next morning, we were the sole inhabitants of Native Point, or indeed of the whole southeast end of the island. The first day was spent looking over the sites, exploring the gravel ridges—old beach lines—to the east, south, and west, and planning our operations for the summer. I had selected Native Point for excavation largely on the basis of a manuscript report by W. D. Bell, archeologist on Dr. J. Brian Bird's geographical expedition of 1950 (Bird, 1953). Bell had reported that this site, known to have been the principal settlement of the extinct Sadlermiut, contained the largest aggregation of old Eskimo house ruins in the Canadian Arctic. He had also discovered some middens containing Dorset culture material on an elevated headland 1 mile away.

Though we expected this to be a fine spot archeologically, we were hardly prepared for what we found. The Sadlermiut site was tremendous. It consisted of the ruins of about 75 semisubterranean dwellings in addition to a dozen old "qarmats" or autumn houses built by Aivilik Eskimos who had camped there in recent years. Some of the older Sadlermiut houses appear now as only slight depressions on the grass-covered surface of the old beach ridges, but most of them are fairly well preserved, their sunken interiors and entrance passages filled with a jumble of stones that had formed the walls and roofs (pl. 2, A). Whale bones, which the Thule Eskimos and the Sadlermiuts on the northern end of the island often used in house construction, had been rarely used for that purpose here. The walls were made of stones and blocks of sod, and the floor, roof supports, and sometimes even the roof itself were of stone. The ground outside the houses was littered with the skulls and bones of animals eaten by the

Sadlermiuts, mainly seals, walrus, caribou, and polar bears, and additional thousands of such bones were visible in the bottom of a shallow pond which dried up before the summer was over (pl. 2, B). Stone cairns and meat caches by the hundreds were found along the beach in front of the site and on the old shorelines for miles around. Human burials, numbering well over 100, were to be seen at the site itself and along the adjacent beach ridges. The burials within the village were of the surface variety; the bodies had been laid on the surface of the ground and merely surrounded by a row of stones. Away from the village the bodies had been placed in carefully constructed vaults of limestone slabs (pl. 3). Human skulls and bones were also visible in some of the house ruins. These were the remains of the very last of the Sadlermiuts, who died here in the epidemic of 1902–3. Most of the graves, however, were made of stones that were heavily incrusted with lichens and were probably more than a hundred years old.

To excavate a site of such magnitude completely and carefully would have required years of work by a party far larger than ours. However, our plans did not call for extensive excavations. We wished only to sample the houses and middens, digging enough to give us a rounded picture of Sadlermiut culture and leaving the bulk of the site intact for future archeologists. We planned to dig only two houses, Number 37, which appeared to be one of the most recent, and Number 30, one of the oldest (pl. 4). The excavation of these houses and of selected midden areas and graves yielded a large collection of artifacts which provided the essential information needed. Some of the Sadlermiut artifacts are illustrated on plate 5.

The Sadlermiuts have been one of the puzzles of Eskimo ethnology. They were first described by the British explorer Capt. G. F. Lyon, who met them in 1824 on the southwest coast of Coats Island, which then and for many years later was thought to be a part of Southampton Island. American, English, and Scotch whalers began operating in Hudson Bay in the 1860's, but as far as known they rarely came into contact with the Sadlermiuts who, probably because of their isolation, remained aloof from other Eskimos as well as whites. Three of the whalers, Captains Comer (1910), Munn (1919), and Ferguson (1938), published brief observations on the Sadlermiut, and a number of their typical artifacts, collected by Comer, were described by Boas (1901–7). In 1922 the Danish archeologist Dr. Therkel Mathiassen while excavating on the north side of Southampton Island, obtained valuable information on the Sadlermiut from two old Aivilik Eskimos who had lived for a few years among them (Mathiassen, 1927).

The Sadlermiut population seems to have declined steadily after the coming of the whalers. In 1896 Capt. Comer estimated their number at 70, most of them living at settlements on the south side of

the island, mainly at Native Point. In the winter of 1902–3 the Sadlermiut were struck by an epidemic, which seems to have been typhoid, and the entire tribe perished except for two children who had previously been adopted by the Aivilik.

Without exception, those who had an opportunity to observe the Sadlermiuts were impressed by the many differences between them and other Canadian Eskimos. Their language was different, they lived in permanent semisubterranean stone dwellings instead of snow houses, and the men wore bearskin trousers and tied their hair in an enormous knot above the forehead. Another striking difference was that the Sadlermiut, instead of using iron tools like the Eskimos all around them, still made their knives, harpoon blades, and other implements from chipped flint.

It has been commonly thought that the Sadlermiut were the descendants of the old Thule people, the last remnant of this prehistoric Eskimo population which originated in Alaska and spread eastward to Arctic Canada and Greenland some seven or eight hundred years ago. There was undoubtedly a connection of some kind between Sadlermiut and Thule, but as a result of our work at Native Point it seems more likely that the Sadlermiuts, instead of being the actual descendants of the Thule people, had merely been influenced by Thule culture. On the other hand, there are strong indications that the Sadlermiuts were related in some way to the Eskimos of the prehistoric Dorset culture, perhaps even descended from them. One of their most important implements, the harpoon head with which they captured seals and walrus, was demonstrably derived from one of the Dorset types. In our excavations at the Sadlermiut site and the three Dorset sites at Native Point, we found harpoon heads that clearly show the transition from Dorset to Sadlermiut. Stone side blades on knives and lances are another feature which the Sadlermiuts appear to have taken over from the earlier Dorset people. Our later work on Walrus Island suggests that even the Sadlermiut form of dwelling may have been borrowed from the Dorset Eskimos. It might also be mentioned that the Sadlermiut, according to their own tradition, came to Southampton from Baffin Island, and that their dialect seems to have been related to that of the Okomiut of that area. The Sadlermiut also lived on Coats Island and probably on Mansel and the islands in Hudson Strait, and it was on these same islands and the southern part of Baffin Island that the Dorset culture had previously flourished. In short, both prehistoric Dorset and modern Sadlermiut occupied the same territory in the Hudson Bay and Strait area. Though the evidence is still incomplete, it would seem not unlikely that the Sadlermiut, whose anomalous position has long puzzled ethnologists, were the descendants of the mysterious Dorset people who were the other, and principal object of study of our expedition.

The Dorset culture was first described by Dr. Diamond Jenness (1925) on the basis of material in the National Museum of Canada excavated by Eskimos at Cape Dorset on the south coast of Baffin Island and on Coats and Mansel Islands. The material described by Jenness differed strikingly from that found at Thule culture sites. The Dorset people had used chipped-stone instead of rubbed-slate implements. Their harpoon heads and other bone and ivory artifacts were small and delicate, and entirely different in form from those made by the Thule Eskimos. The Dorset collection contained no trace of such typical Thule elements as whalebone mattocks, snow shovels, bone arrowheads, bow drills, ulus, harness toggles, or other evidences of dog traction. Another striking difference was that the Dorset artifacts were usually deeply patinated. In the past 25 years Dorset sites have been excavated at a number of localities in the eastern Arctic from Newfoundland to Greenland. These excavations, however, added little to what Jenness had originally deduced as to the age, relationships, and significance of the Dorset culture. It was clearly older than the Thule culture, for Dorset implements, and in some cases Dorset occupation levels, were found underlying Thule (Holtved, 1944; Collins, 1950). Though the Dorsets had ocupied the central and eastern Arctic many years before the arrival of the Thule people in the twelfth and thirteenth centuries, a few groups of them continued to live on long after that. Evidence of this is a small Dorset site of post-Thule age excavated by Dr. Deric O'Bryan (1953) on Mill Island to the east of Southampton. And if the hypothesis mentioned above is correct, the Sadlermiut themselves may have been such a remnant group, though one greatly modified by contact with the Thule culture. To test this hypothesis we would need information on Sadlermiut sites somewhat older than the one at Native Point, sites that might reveal an earlier stage of Sadlermiut or Dorset-Sadlermiut culture lacking distinctive Thule traits, particularly the bow drill.

The main Dorset culture site at which we excavated was 1 mile to the east of the Sadlermiut site. It was situated on the gently sloping surface of a 70-foot-high headland, a hill or plateau of glacial till, which had once fronted on the sea but which now lies half a mile back from the present beach (pl. 6, A). Extending east and west over this now elevated surface and clearly visible only from the air, are a number of low, closely spaced curving ridges of sand and gravel—remnants of marine bars that were formed when sea waves washed over the surface during the post-glacial marine submergence that inundated the Hudson Bay lowlands following retreat of the glacial ice.

It would be difficult to imagine two Eskimo habitation sites more different than this and the big Sadlermiut site. The Dorset site,

which was much larger than we had anticipated, had the appearance of a flat, level meadow or pasture (pl. 6, B). Its surface was covered by a sparse, dry growth of vegetation, mostly low-growing saxifrages, *Dryas*, grasses, and lichens, in striking contrast to the lush growth of grass and other vegetation at the Sadlermiut site. This in itself was an indication of age, for recently abandoned habitation sites, which still retain much of their organic content, always support a dense plant growth. At this Dorset site, however, the scanty plant cover showed that the nutritive elements had long since been absorbed from the soil. At the edges of the steep bluff and at other places where wind erosion had removed the vegetation the ground was littered with flint chips, occasional stone and ivory artifacts, and bleached animal bones, mostly of seals and birds. We soon found, from testing, that shallow midden deposits extended discontinuously for an area of over 30 acres. These middens, covered by scarcely more than an inch of sod and vegetation, were the only indication that the site had ever been occupied by man; there were no large stones, no house pits, no surface irregularities of any kind. But before the summer was over, our excavations had yielded over 25,000 mammal bones, additional thousands of bird bones, and about 3,000 artifacts that were to throw new light on the whole problem of the origin and relationships of the Dorset culture.

We called this old Dorset site T 1, from Tunermiut, the Aivilik Eskimo name for Native Point. A second, and later, Dorset site, which we found buried beneath about a foot of windblown sand near the Sadlermiut site, was called T 2 (pl. 7, A). In 1955 a third Dorset site, T 3, only slightly younger than T 1, was found on the old beach line immediately below it, at 40 feet above sea level (pl. 7, B).

Midden areas at different parts of T 1, designated as Middens 1, 2, 3, and 4, were laid off in 5-foot squares, and a number of test pits were dug at other places. As the midden deposits were shallow and rested on well-drained sand or gravel, they were not frozen. Permafrost was encountered only at a depth of 2 feet or more in the underlying gravel. The first day's digging was sufficient to show us that this was a very unusual Dorset site. Flint implements were far more abundant than any other artifacts, and they were small and delicately chipped, like Dorset implements generally (pls. 8, 9). Most of them, however, differed in form from previously known Dorset types, and some of them were unlike anything known from America. The majority of the blades would be described as microlithic, and some of them in shape and technique resembled microlithic types found at early pre-Eskimo sites in Alaska and at Mesolithic sites in the Old World. The ivory harpoon heads, though basically Dorset in character, were specifically different from those found at most other Dorset sites.

Other artifacts of ivory and bone such as dart points, knife handles, scrapers, and ornaments (pl. 10), were recognizable as Dorset mainly because line holes and other perforations, when present, were always cut or gouged out, according to invariable Dorset custom, for these, like all other Dorset people, had no knowledge of the bow drill. However, the forms of the implements themselves were for the most part new to the Dorset culture. The few ornaments and the simple straight-line decoration on artifacts also had no exact counterparts in Dorset culture. Finally, we found no trace at T 1 of such typical Dorset types as closed-socket harpoon heads with two line holes, open-socket heads with single spur and line hole at edge, harpoon foreshafts with lateral line hole, small knife handles with deep side sockets, ivory runners for hand sleds with ends fitted together, ivory spatulas, projectile points with deeply concave bases, end scrapers with expanded edges, concave side scrapers, asymmetric knife blades, and grotesque human and animal carvings. The absence of these typical Dorset features could hardly have been accidental for the amount of material excavated here was considerably greater than from any other Dorset culture site. As the work progressed it became clear that the T 1 site, though conforming in general to the basic Dorset pattern as known from other sites of this culture in the central and eastern Arctic, was in many other respects specifically different. It represented a new and distinctive phase of the Dorset culture; or, if it could be proved to be older than other Dorset sites it might more properly be described as proto- or formative Dorset.

The question that confronted us was whether the T 1 site did, in fact, represent an older, simpler stage leading up to the classic Dorset culture, or perhaps a later, somewhat degenerate stage. The former explanation seemed more probable, for several reasons. First, the small T 2 site, which was typical Dorset, seemed definitely later than T 1. It was adjacent to the recent Sadlermiut site and was only 25 feet above sea level in contrast to the 70-foot elevation of T 1. The material excavated at T 2 included hardly any of the types that were prominent at T 1. On the other hand, it was significant that the limited excavations at T 2 yielded a number of typical Dorset implements that were not found at T 1. These were harpoon blades with deeply concave base, asymmetric knife blades, slender knife handles with deep side socket, ivory sled runners (for hand sled) with ends fitted together, and late Dorset-type harpon heads (pl. 11). As these were types that were characteristic of O'Bryan's late Dorset site on Mill Island, it seemed clear that T 2 was later than T 1.

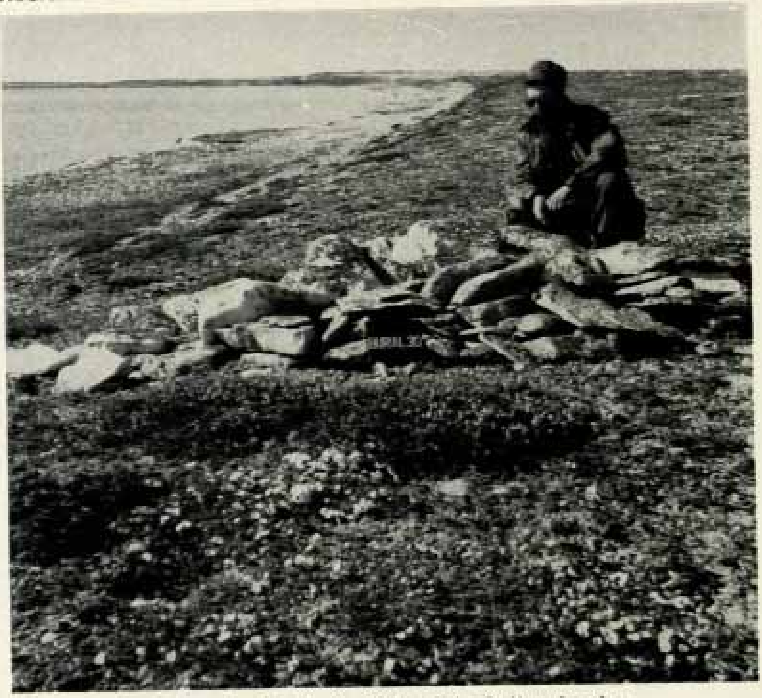
The stone implements provided another means of deciding the question. As mentioned before, some of the T 1 implements were types not previously found in America. Among these were long rectangu-

A. Loading dog sleds at Coral Harbour for 40-mile trip over the sea ice to Native Point, June 23, 1954. Boats were lashed to the sleds to hold the cargo and protect it from surface water.

B. One of the sleds crossing a pool of water on the ice.

A. One of the more recent house ruins at Tunermiut (Native Point), once the principal settlement of the extinct Sadlermiut Eskimos. This house, built of stones and sod, was probably abandoned around 1902–03, when the tribe became extinct. The houses, numbering around 90, were measured, mapped, and described, and two of them were excavated.

B. Generations of Sadlermiuts threw their bone refuse into this shallow now dried-up pond. Visible here are thousands of bones of seals, walrus, caribou, dogs, polar bears, belugas, and foxes. Equally heavy concentrations of bones were found wherever excavations were made at the old village site, testifying to the abundant food supply available to the Sadlermiut.

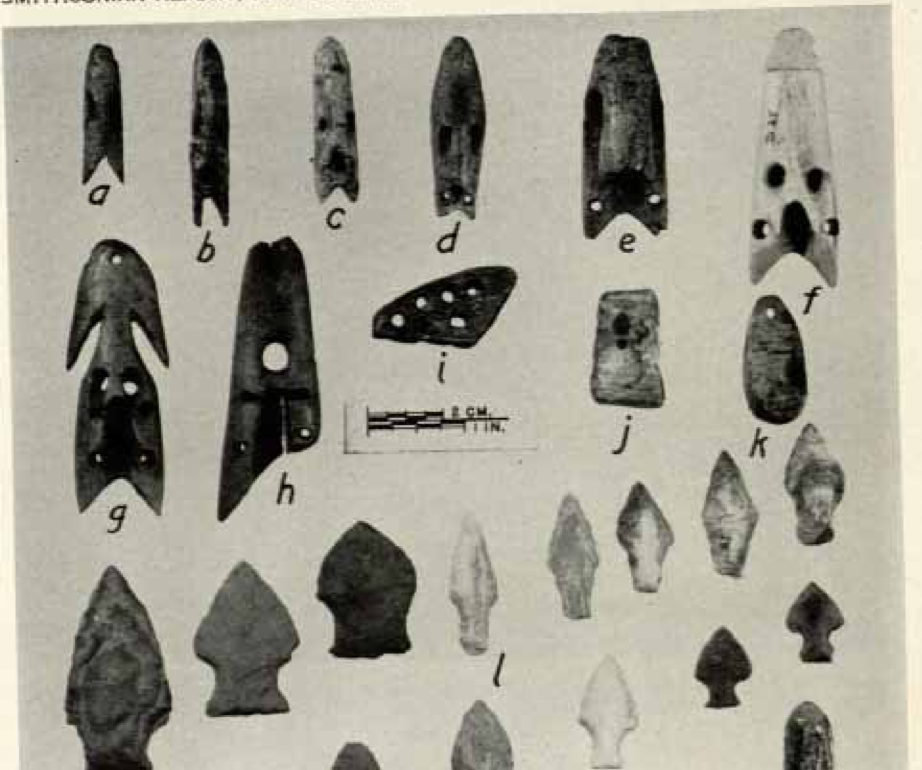


A. Stone burial ½ mile SSW. of the Sadlermiut site.

B. The same burial with covering stones removed. The body was that of a 35 to 40-year old woman. As in all the Sadlermiut burials, lemmings had built their nests here and were responsible for partial disarray of the bones.

A. Excavations at House 30, one of the oldest houses at the Sadlermiut site. The house depression, at right, and areas adjacent to it were marked off in 5-foot squares.

B. The House 30 excavations at a later stage.



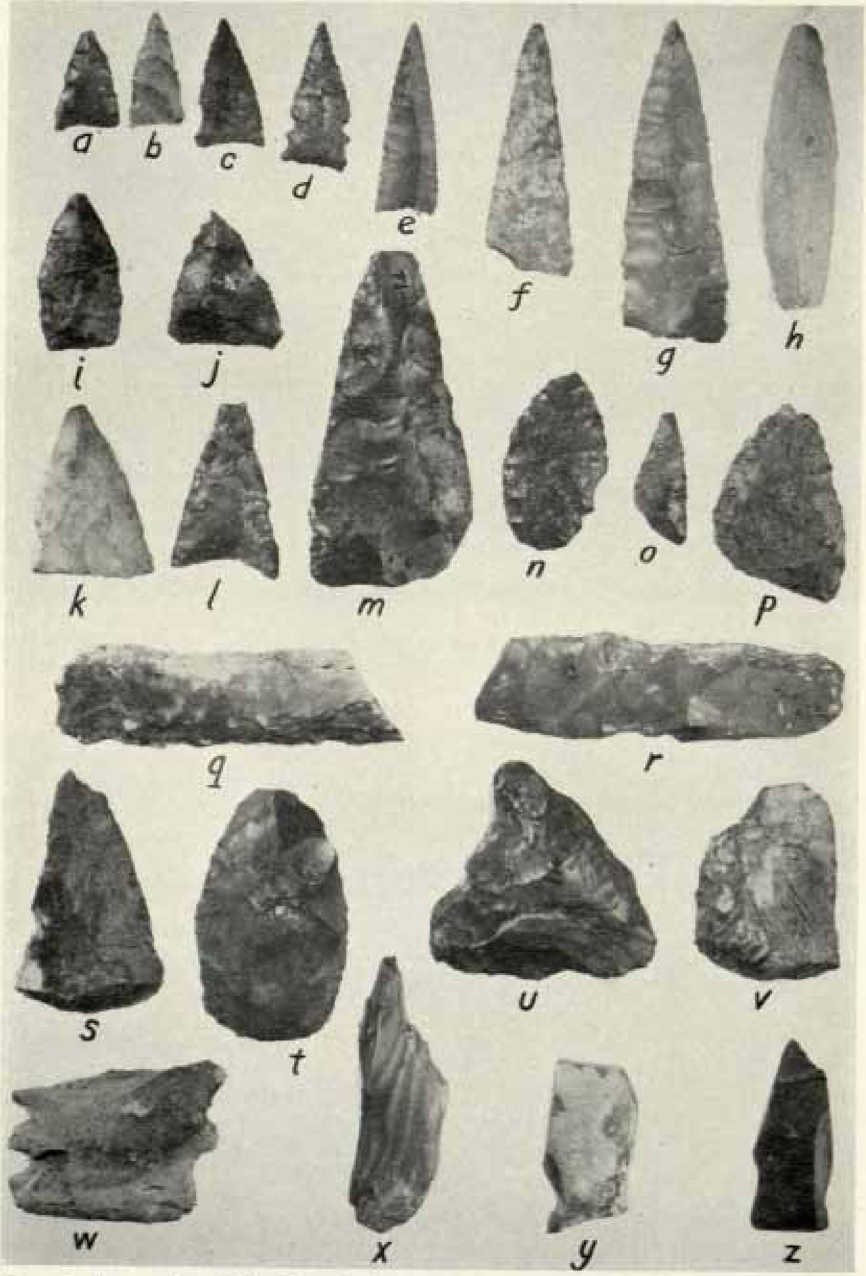
Artifacts from Sadlermiut graves, middens, and house ruins at Native Point. ½ natural size. *a*, Dorset harpoon head, antler; *b-d*, small Sadlermiut harpoon heads, ivory and bone; *e-h*, closed- and open-socket harpoon heads, bone and ivory; *i*, harpoon finger rest, bone; *j*, *k*, bolas weights, ivory; *l*, stone end blades for knives, harpoons, and lances; *m*, stone side blades and arrow points; *n*, woman's hair ornament, bone; *o*, *p*, ivory ornaments; *q*, ivory wound pin; *r*, *s*, walrus-rib drills; *t*, rim sherd of limestone cooking pot; *u*, wooden socket; *v*, bone shaft for iron-pointed drill.

A. Helicopter view, July 3, 1955, of plateau on which the proto-Dorset site T 1 was situated. One of the expedition's shelter tents is visible at right. Looking inland, toward the south.

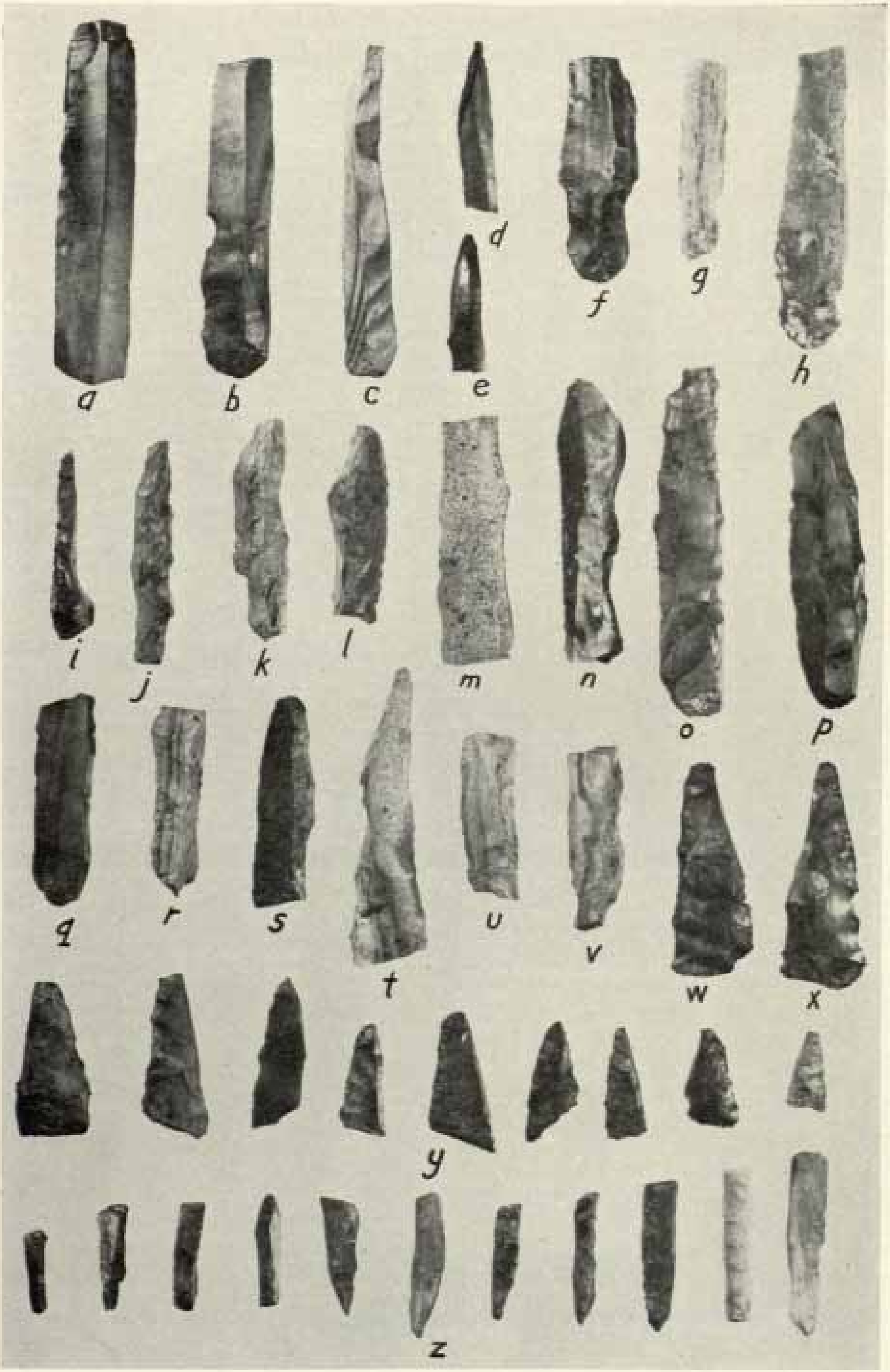
B. Excavations at Midden 1 of the T 1 site. The shallow midden was prolific in artifacts and mammal bones, the latter shown piled up beside the squares. A radiocarbon date of 2060 ± 230 years was obtained from samples of charred animal bones from another part of the site.

A. The late Dorset site, T 2, adjacent to the Sadlermiut site. Sadlermiut artifacts and well-preserved animal bones were found in the 12-inch layer of windblown sand that covered the Dorset stratum. The latter, a layer of black earth, contained numerous stones and weathered and patinated animal bones and artifacts of Dorset origin.

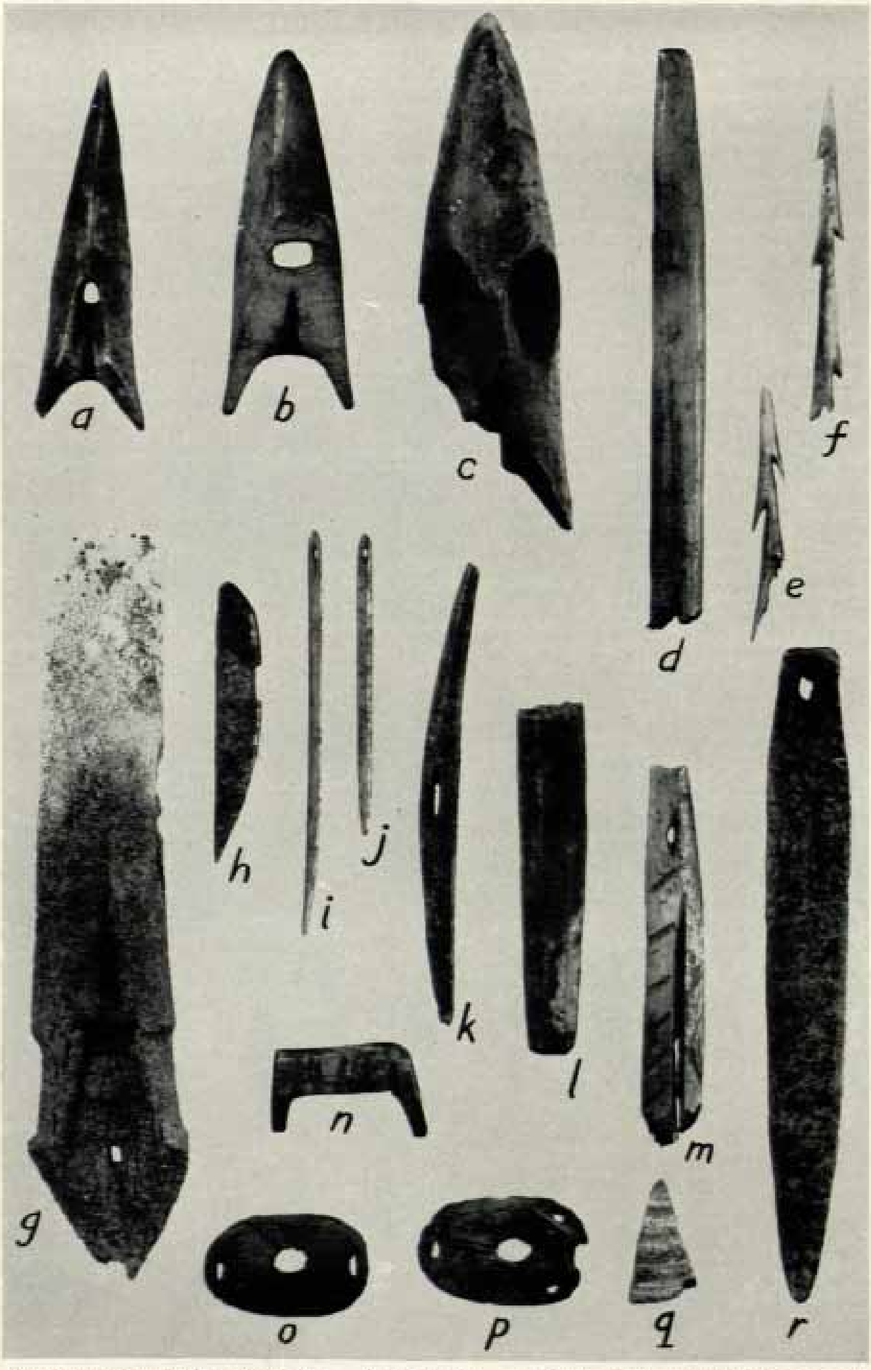
B. Beginning excavations at T 3, an early Dorset site only slightly younger than T 1. Photograph taken June 23, 1955, looking ESE. toward the T 1 plateau with snow bank at its base.



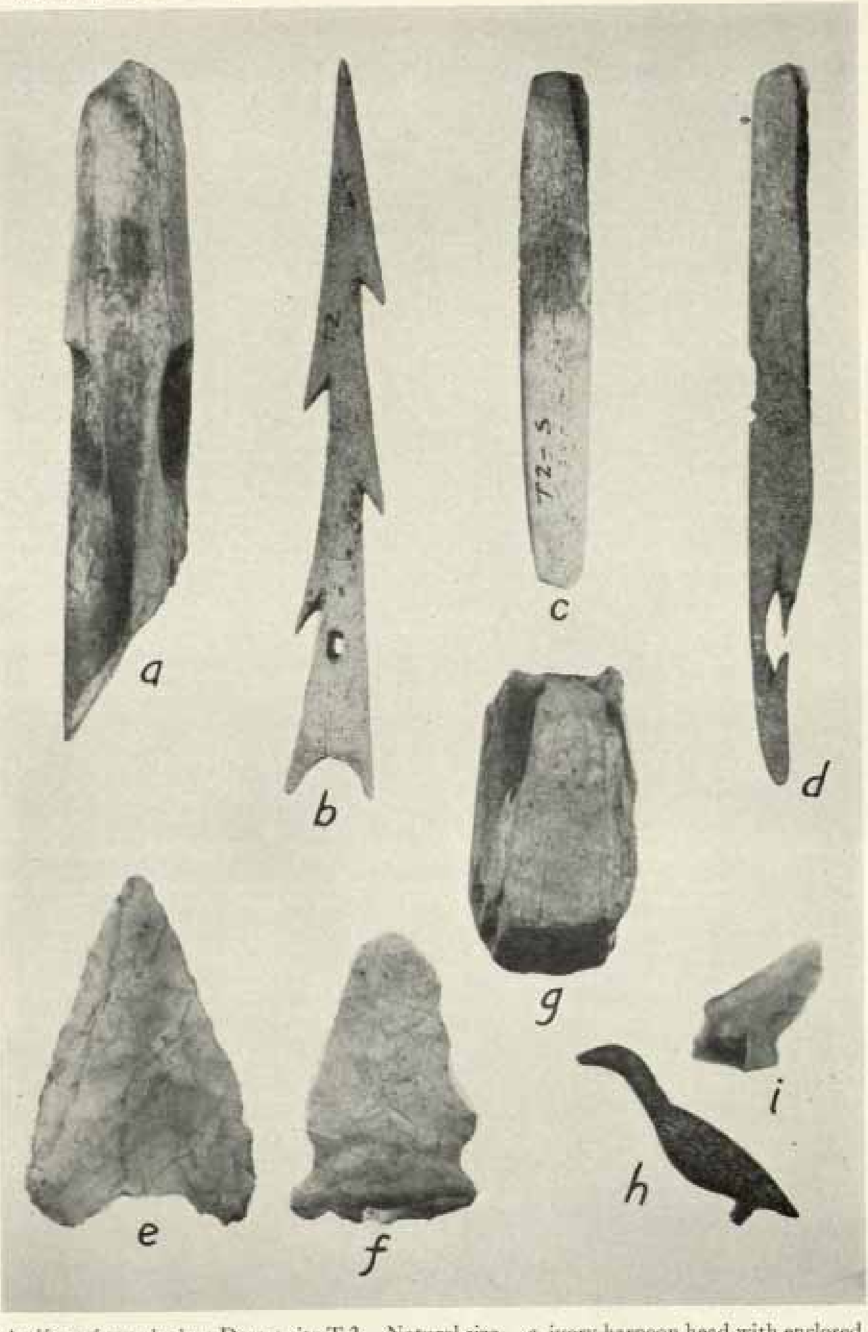
Stone implements from T 1. Natural size. *a-y*, chert, *z*, nephrite. *a-l*, end blades, bifaced and unifaced; *m*, large bifaced blade with slanting base; *n-r*, side blades (*q*, worked on both surfaces; *r*, worked on outer surface only); *s-v*, scrapers; *w*, blade tang with side notches; *x*, burin; *y*, *z*, burinlike implements with ground edges and sides.



Flake and spall implements from T 1, chert. Natural size. *a-e*, microblades, struck from prepared cores; *f-h*, microblades with tangs; *i-l*, heavy spalls struck from edges of prepared cores or chipped blades (*i*, struck from the edge of a bifaced knife or projectile blade, retains the tip of the parent blade); *m-v*, knives made from microblades and heavier flakes, with one thick edge and the opposite edge sharp for cutting; *w-y*, triangular microliths, usually with one edge dulled and a spall removed from opposite edge; *z*, spall implements, some finely retouched at upper end, probably used for grooving, inserted in composite handles like plate 10, *h*.



Representative artifacts from T 1. Natural size. *a-c*, ivory harpoon heads; *d*, harpoon foreshaft, ivory; *e,f*, barbed ivory points; *g*, ivory lance head with side blade socket; *h*, half of a composite ivory handle or socket for holding flint spall; *i,j*, needles made of bird bone; *k,m,n*, ivory objects, use unknown; *l*, flint flaker made of walrus jaw bone; *o,p*, ivory disks; *q*, triangular section of purple clamshell; *r*, ivory knife or scraper.



Artifacts from the late Dorset site T 2. Natural size. *a*, ivory harpoon head with enclosed rectangular socket, right half of basal spur broken off; *b*, barbed dart with enclosed rectangular socket, ivory; *c,d*, ivory knife handles with deep socket for side blade at upper end; *e*, harpoon or lance blade with concave base; *f,i*, asymmetric knife blades; *g*, section of ivory runner for hand sled; *h*, ivory carving of loon.

A. Counting and identifying mammal bones excavated at House 30, Sadlermiut site. Over 45,000 mammal bones excavated from this and the early Dorset site T 1 revealed interesting differences in the food economy and hunting practices of the two groups of Eskimos who had inhabited the same region 2,000 years apart. Bird bones, numbering in the thousands, were brought back to the Smithsonian for identification.

B. The Peterhead boat *Nayavak* being loaded with supplies and equipment for an exploring trip to Coats Island, June 18, 1954.

A. Two Aivilik members of the boat crew, Okerluk and Napayuk, stand beside a mushroom-shaped cairn at an abandoned Sadlermiut site on north shore of Coats Island. Cairns of this shape, peculiar to the Sadlermiut, were used as platforms for storing meat.

B. House No. 3 at the Sadlermiut site on Coats Island, after excavation had revealed the stone flooring and one of three sleeping platforms, shown at left. At center, stone roof supports, still in place, hold the flat slabs of limestone that had formed the roof of the house.

A. House No. 3, one of the oldest-looking house ruins at the Walrus Island site. Limited excavations in and around this house yielded only Dorset artifacts.

B. House 6, one of the more recent houses at Walrus Island. The house, constructed of granite slabs and boulders, was cloverleaf in shape.

lar side blades with shallow flaking on one or both surfaces (pl. 8, *q*, *r*); spalls struck from the lateral edges of prepared cores or of chipped blades (pl. 9, *i-l*); and knives made from microblades and heavier flakes, having one edge sharp for cutting and the opposite edge thick, like the back of a penknife, to serve as a rest for the finger (pl. 9, *m-v*). The first two are types that occur at Mesolithic and early Neolithic sites in Mongolia and Siberia (Maringer, 1950, pl. 30, figs. 1, 4, 5; pl. 25, figs. 7, 8; Okladnikov, 1950, fig. 62). The third type is one that was similar in function, though not in method of manufacture, to the "backed" blades so characteristic of the Old World Mesolithic. Plate 8, *h*, is an unusual flake blade, the under or bulbar surface of which is carefully retouched along the base, lower right edge and upper end, while the outer surface, illustrated, is unmodified. In form and technique this blade is closely similar to some of those from Mesolithic sites (Khina period) in the region of Lake Baikal and the Angara River (Okladnikov, 1950, figs. 16, 17).

There was still another reason for believing that the T 1 material may have had Mesolithic affinities and that it represented an early or formative stage of Dorset culture. Microblades—narrow rectangular or pointed flakes struck from prepared cores (pl. 9, *a–e*)—and delicate spall implements (pl. 9, *z*) were present in large numbers at T 1, and several burins (pl. 8, *x*) were also found. Burins, spalls, and microblades are among the implements most characteristic of the Denbigh Flint Complex recently discovered by Dr. J. L. Giddings on the Bering Sea coast of Alaska (Giddings, 1951). The Denbigh culture is at least 4,000 years old and probably older, and it has strong connections with the Old World Mesolithic. Though older than any known stage of Eskimo culture, there are strong indications that the Denbigh Complex was one of the sources from which the Dorset culture was derived (Collins, 1951, 1953; Harp, 1953).

More conclusive evidence of the age of T 1 finally came from radiocarbon analysis, the newly developed technique which makes it possible to date organic materials by measuring the amount of carbon 14 which they contain. Pieces of charred mammal bones from one of the test cuts were submitted to the University of Pennsylvania Carbon-14 Laboratory and were found to be 2,060±230 years old. This may be taken as a minimum date, for grass roots had penetrated even the deepest parts of the T 1 middens, and thus could have contributed an unknown amount of more recent carbon to the bone fragments.

The T 1 finds are also of interest in connection with a larger problem, that of the origin and relationships of Eskimo culture as a whole. Close resemblances have previously been observed between the tools and techniques of the earliest Eskimos and those of the early Neolithic and Mesolithic peoples of Eurasia, particularly in the region of Lake

Baikal and northern Europe. On the basis of these resemblances the present writer has suggested that Eskimo culture was of Old World origin, its earliest roots stemming from the Mesolithic cultures of Eurasia (Collins, 1943, 1951). The T 1 artifacts, which include additional types resembling those of the Mesolithic, as well as those of the Denbigh Flint Complex, would seem to lend weight to the hypothesis. In drawing this conclusion it is recognized of course that the T 1 site is thousands of years later than the Old World Mesolithic. It is equally true, on the other hand, that established culture patterns may persist over long periods of time. The Dorset people, in the isolation of the Arctic, may have perpetuated Mesolithic techniques and traditions that had long since faded away in the Old World.

The early Dorset Eskimos who lived at the T 1 site were a hunting people, like all Eskimos, and sea mammals were their principal source of food. The village they occupied 2,000 years ago is now half a mile back from the shore, an inconvenient location for people who were dependent on the sea for their livelihood. However, when the site was occupied geographical conditions in the Hudson Bay region were considerably different from those of today. As a consequence of the postglacial marine submergence the sea level stood higher in relation to the land, so that the T 1 plateau was much nearer the sea than at present.

Though we uncovered a number of hearths where the people had done their cooking, we could find no traces of dwellings of any kind. They might possibly have lived in snow houses, which would have left no trace, but this seems unlikely as we found no snow knives which Eskimos always use in constructing these winter dwellings; moreover, the large number of bird bones in the refuse suggested that the site had been occupied in summer as well as winter. If the climate 2,000 years ago was milder than at present, for which there is some geological evidence, the people could have lived there the year around in light skin-covered tents. Whatever the climate may have been, we can be sure that the early Dorset people wore tailored skin clothing, for bone needles, which could only have been used for sewing skins, were exceedingly common in the midden deposits. The skins used were probably those of seals and birds or, less likely, foxes.

In order to learn as much as possible of their food habits we kept every animal bone that was excavated. These were counted and whenever possible identified as to species. The majority of the mammal bones, such as ribs, vertebrae, and foot bones, were too difficult to identify in the field, but the skulls, jaws, and body bones such as scapulae, pelves, and limb bones presented no great difficulty. In 1954 over 25,000 mammal bones were excavated at T 1, of which over 3,000 were identified, and almost as many were obtained from the excavations at the Sadlermiut site (pl. 12, A).

TABLE 1.—*Distribution of identifiable mammal bones excavated at T 1 and Sadlermiut sites*

	T 1		Sadlermiut	
	Number	Percent	Number	Percent
Seal	2, 035	66. 5	1, 840	65. 2
Walrus	379	12. 4	149	5. 3
Bearded seal	299	9. 7	204	7. 2
Fox	315	10. 3	75	2. 7
Caribou	25	. 8	332	11. 8
Polar bear	4	. 1	38	1. 3
Dog	0	. 0	180	6. 4
Whale	0	. 0	6	. 2
Total	3, 057	99. 8	2, 824	100. 1

Comparison of the two series reveals some interesting differences in the hunting practices and food habits of these two groups of Eskimos who had occupied the same locality at different times in the past. The seal was the principal food animal of both groups, represented by 66 and 65 percent of the bones. Next in importance were the walrus and bearded seal. Fox bones were much more numerous at the Dorset site and polar bear bones were relatively rare at both sites. One somewhat surprising result of the bone count was evidence that the Dorset people made very little use of the caribou, which was one of the most important sources of food of the later Sadlermiuts. More striking still was the fact that not a single dog bone was found at T 1, though they numbered over 6 percent at the Sadlermiut site. The absence of dog bones may explain the paucity of caribou bones at T 1. Since they had no dog sleds and therefore no effective means of winter travel, the early Dorset people would have been unable to go on long hunting trips to the eastern side of the island where the caribou mostly lived.

Birds were also an important element in the diet of the Dorset and Sadlermiut people if we may judge from the thousands of bones excavated and brought back to the Smithsonian for identification. In the eastern part of the Dorset site about 90 percent of the bones were those of birds. It is probable that this part of the site was occupied only during the summer months when enormous flocks of migratory birds come north to breed. There are no indications as to how the birds were captured. We found no bolas weights or bird spears such as other Eskimos, including the Sadlermiut, used for this purpose. The early Dorset people may have caught their birds with snares made from perishable materials such as skin thongs or sinew, which would not have been preserved.

Identification of the bird bones from T 1 will provide at least a partial inventory of the kinds of birds that migrated to this area 2,000 years ago, for comparison with those now found there. The low-lying area around Native Point, with its network of ponds and lagoons, fairly swarms with bird life during the summer. The principal species that we observed nesting were king eider and Old Squaw ducks, gulls, terns, various kinds of waders, snow buntings, and Lapland longspurs. Flocks of Canada, snow, and blue geese were constantly passing by. Loons, singly or in small groups, seemed to maintain regular flight schedules over our camp, filling the air with their strident cacophony as they shuttled at high speed from one pond or lagoon to another. From two to seven beautiful white swans were usually visible on the surface of the large pond, which we called Swan Lake, a few hundred yards from our tents. Longspurs and snow buntings nested all around the camp area, seeking the protection of grassy tussocks and of fallen rocks and crevices in the old house ruins. The snow buntings showed a special predilection for old tin cans and human and animal skulls lying on the surface around the Sadlermiut site.

Under a permit from the Canadian Wildlife Service we collected a small number of migratory birds, mainly jaegers, gulls, ducks, geese, and loons, as well as lemmings which were particularly abundant in 1954 and 1955. As the avifauna of Southampton Island is fairly well known, our purpose was not to collect bird skins for museum specimens but for the ectoparasites—lice and mites—which they might contain. Each species of bird and mammal has its own species of insect parasites, and Col. Robert Traub of the Walter Reed Medical Center was interested in obtaining these for study in connection with his investigation of the role of such parasites in the transmission of typhus and other diseases. One of my most tedious afterdinner chores was the "louse hunt," in which I would painstakingly examine birds and lemmings in search of the elusive quarry. The jaegers, rapacious gulls with hawks' habits that prey on smaller birds, were heavily infested with mites, and several hundred could easily be scraped from a single wing feather and dropped into a vial of alcohol. Examination of the other birds and lemmings required constant use of the magnifying lens and was a much greater strain on one's eyesight and patience. Often the most prolonged fluffing of fur and feathers would produce no more than one or two lice or mites.

Our other afterhours activities involved the collecting of plants, fossils, fresh-water invertebrates, moths, butterflies, beetles, and other insects. The most abundant, and unwelcome, form of insect life was mosquitoes. July was "mosquito month" and life would have been miserable indeed if we had had no protection against them. Fortu-

nately, however, Dr. S. A. Hall of the U. S. Department of Agriculture had provided us with mosquito repellents that worked like magic. With faces and hands covered with liquid repellent, we were able to dig in relative comfort even on warm, calm days, despite the frustrated buzzing of the clouds of mosquitoes that surrounded us.

We were fortunate, too, in the weather we had. Though many days were cold and windy and we had to wear our heaviest clothing, there were many other fine clear days when we could enjoy the warm sun and wish that there were more hours for digging, for exploring the surrounding country, and doing the other things we wanted to do. The average temperature was in the low 40's, sometimes dipping down to freezing at night and then rising to 60° or more at midday.

On July 17 Sandy Santiana and three other Eskimos from Coral Harbour—Napayuk, Okerluk, and Kolugjak—arrived in the Peterhead boat, *Nayavak* (Little Gull). They had come to deliver the rest of our food supplies and take us on an exploring trip to Coats Island. This island, though the second largest in Hudson Bay, is still relatively little known. Few scientists have been there, and the geology, botany, and animal life have not been studied. I planned to collect plants, fossils, and insects, and was especially anxious to obtain lemmings, which might be of a different species from those on Southampton. My lemming traps, however, proved useless, for as I learned from Sandy and later saw for myself, this little rodent, so typical of most Arctic areas, does not live on Coats Island. Another typical Arctic mammal missing there is the hare.

Our principal purpose was to look for Eskimo ruins, as the archeology of the island was also unknown. Some of the material utilized by Dr. Diamond Jenness when he first described the Dorset culture was reported to have been excavated by Eskimos on Coats Island. It would appear, therefore, that Dorset sites existed somewhere on the island. We also wished to locate Sadlermiut sites. The Eskimos whom Capt. Lyon found at the southwest end of the island in 1824 were in all probability Sadlermiuts, but so far as known this was the first and last time that anyone had seen living Eskimos on Coats Island, except, of course, the few Okomiuts who were brought there by the Hudson's Bay Company almost a hundred years later. The native inhabitants of Coats Island had simply disappeared from history. They may have died out or moved away soon after Lyon's time, or some of them may have continued to live there, isolated from other Eskimos, for some years later. From the ruins that we might find on the north side of the island we hoped to determine whether the Coats Island Eskimos were, in fact, Sadlermiut, and if so whether they differed in any way from the main body of the tribe that had lived on Southampton.

The *Nayavak* was a trim little vessel, 40 feet long and powered by a gasoline motor. Our quarters were in the tiny cabin in the bow, which was large enough for three men but rather crowded for four (pl. 12, B).

About an hour out of Native Point we encountered dense fog and heavy fields of ice. With visibility of 100 yards or less we slowed down to half speed, about 5 miles an hour. Sandy was now forced to follow a zig-zag course, steering with his foot as he stood up in the little wheelhouse peering ahead in search for safe openings among the ice floes. By midnight we were out of the ice but the fog continued until we finally anchored at 2 a. m. When the fog lifted later in the morning we found we were about 2 miles offshore from Coats Island, about midway of the north coast.

The *Nayavak* then headed eastward and a few hours later was approaching the north end of little Bencas Island when we saw four old house ruins on the opposite Coats Island shore. We moved in closer and went ashore in the canoe to investigate the ruins, prepared to stay all day. The houses were not the only evidence of human activity at this abandoned settlement. Between the houses and the beach we found an array of stone structures—caches, cairns, and a number of others difficult to identify as to function. The most impressive of these stone structures were two well-preserved cairns of a peculiar "mushroom" shape (pl. 13, A), a type which had been reported previously only from Sadlermiut sites on Southampton Island. This suggested at once that the site was Sadlermiut.

We lost no time in getting to work. Emerson and Taylor began excavating in House 3, the largest of the group, their first task being to remove the heavy fill of sod that had accumulated in the sunken interior. Ostroff photographed the houses and other structures and then began to excavate in House 4, the westernmost of the group. I began collecting samples of the grasses, mosses, and flowering plants that grew around the site, and made notes, measurements, and sketches of the houses and other stone features. I also made a careful but futile search of the surrounding area for traces of Dorset occupation.

House 3 was a 3-room structure, built somewhat in the shape of a cloverleaf (pl. 13, B). It had an over-all width of 22 feet and measured 15 feet from entrance to rear wall. It had a carefully constructed floor of stone slabs and four sleeping platforms, also made of stones, rising about a foot and a half above the floor. The roof, still partly intact, consisted of large flat slabs resting on stone uprights. The walls were made of stones piled one above the other. Blocks of sod were banked up along the outside of the walls and over the roof. The house was entered by means of a narrow passageway 10 feet long and 30 inches wide, at the outer end of which was a small

stone anteroom. The other houses varied somewhat in size and shape, but had been constructed in the same manner.

By 8 p. m., when we went back to the *Nayavak* for the night, we had accumulated a rich store of artifacts, most of them from House 3. These included harpoon heads of bone and ivory, some equipped with stone and some with iron blades; ivory knife handles also with stone and iron blades; harpoon foreshafts and socket pieces, bone arrowheads, bolas weights for catching birds, lumps of iron pyrites for making fire, lamps made of limestone slabs cemented together, iron-bitted drills with nicely carved ivory handles, harness toggles, whetstones, ivory combs, and dish bottons made of whalebone. These artifacts were all typically Sadlermiut in form, as were the houses themselves and the curious mushroom-shaped stone cairns. The well-preserved houses, some with roofs partly intact, could not have been abandoned for many decades, and the presence of considerable quantities of iron was a clear indication of white contact, probably with the whalers. We had evidence, therefore, that Sadlermiut Eskimos had lived here on the north coast of Coats Island, probably within the past 50 years, though there had been no record of their existence.

The next day we examined two house ruins on the north end of Bencas Island. They, too, appeared quite recent but much less promising than those on Coats, so we returned and spent the rest of the day completing the excavations we had begun there, after which we started back to Native Point.

The warm, calm weather that had favored us throughout the trip continued on this last day and the Peterhead glided along over a glassy sea, surrounded by floating masses of ice that shone like blue crystal in the brilliant sunlight. We followed a course to the east and north of Coats and Bencas Islands, where ice conditions were favorable for hunting walrus and the big bearded seal, or ugchuk, which the Eskimos prize for its tough skin as well as its meat. One walrus and three ugchuk were shot by the Eskimos and their meat and hides stowed away in the hold.

After the Coats Island trip we resumed our work at Native Point, remaining for another month until the Peterhead *Akpa* (Guillemot), under command of Pamiulik, came to take us back to Coral Harbour.

We had realized soon after beginning work at Native Point in June that another season's work would be necessary at this remarkably rich and important old site. Accordingly we returned early in June of 1955, supported in part by a research grant from the American Philosophical Society. The party consisted of Bill Taylor, Norman Emerson, Jim Wright, and myself. As in the previous year we went from Carol Harbour to Native Point by dog team, making the trip in two days instead of one, a more comfortable arrangement that al-

lowed us to camp overnight at Prairie Point and examine an old Sadlermiut village site of 15 stone and sod house ruins.

At Native Point we had another busy and productive summer. Additional excavations were made at the Sadlermiut site, at the early or proto-Dorset site, T 1, the later Dorset site, T 2, and at a third site, T 3, which appeared to be slightly younger than T 1. A large body of material was excavated which strengthened and rounded out the archeological picture obtained the previous year.

We planned to make another reconnaissance trip to Coats Island, this time toward the southwest end, and on July 20 we set out in the *Nayavak* for that purpose. As it was not much out of the way we decided to stop briefly at Walrus Island where there were several old house ruins we wanted to examine.

Walrus Island is a small granite islet 25 miles off the south coast of Southampton. The six house ruins lay in a valley extending east and west across the south end of the island. The three oldest-looking houses (Nos. 1, 3, and 5) consisted of a single room round to oval in shape (pl. 14, A). Another (No. 4), more recent in appearance, had two oval-rectangular rooms. The two remaining houses (Nos. 2 and 6), also recent looking, were cloverleaf in shape, with three rooms (pl. 14, B). The house walls had been made of massive blocks of granite piled one above the other. Most of the houses were deep and all had entrance passages from 5 to 10 feet in length. In some cases natural rock ledges and huge boulders *in situ* had been incorporated into the house structure to serve as parts of floors, walls, or sleeping platforms. House No. 6, the best preserved of the group, had upright stone pillars—roof supports—still in place, and fallen slabs indicated that the roof itself had been made of stones as in the case of the Sadlermiut houses on Southampton and Coats Islands. The absence of roofing slabs and supports in the other houses suggested that the roofs had been made of skins.

When we began to excavate we had naturally assumed that these well-preserved house ruins were of Sadlermiut origin. They were similar in general structure and two of them, Nos. 2 and 6, had the cloverleaf shape characteristic of many Sadlermiut houses. Moreover, some of these Walrus Island houses had been partially excavated in 1936 by the British Canadian-Arctic Expedition (Manning, 1942) and found to contain material described as resembling Sadlermiut, with only a few Dorset artifacts which might easily have been explained as relics. We had not been digging long, however, before we began to suspect that the houses were Dorset rather than Sadlermiut. With this unexpected development, we stayed at Walrus Island for five days instead of going on to Coats Island as originally planned.

Our excavations in and around five of the houses produced over 100

typical Dorset artifacts, mostly stone, and large numbers of stone flakes with retouched edges such as had been found at T 1, and which were also probably Dorset. In contrast we found only three artifacts that were unquestionably Sadlermiut and seven others that were non-Dorset and therefore probably Sadlermiut. Eight of the non-Dorset artifacts came from House 2, the recent-looking house that was irregularly cloverleaf in shape; however, the bulk of the material from this house, found on and between the floor stones, was Dorset. The other two non-Dorset objects were found in House 4, together with several Dorset pieces, also from the floor area. The three oldest-looking houses (Nos. 1, 3, and 5) yielded only Dorset material, though little digging was done in the last two. No work was done in House 6 and no artifacts were found in or around it; this well-preserved cloverleaf-shaped house, typically Sadlermiut in form, may well have been built by the Sadlermiuts.

The few Sadlermiut artifacts that we found in Houses 2 and 4 and the apparently larger amount of such material reported by the British Canadian-Arctic Expedition indicate that some of the Walrus Island houses had been occupied by Sadlermiut Eskimos, probably around the beginning of the present century. Such an occupation, however, would have been secondary, for our excavations, which revealed Dorset material in the floor areas of Houses 2 and 4, as well as in Houses 1, 3, and 5, showed that the Dorset people were the original occupants of these houses.

If the Dorsets had lived in the houses originally they also in all probability had built them. The Walrus Island ruins thus provide the first adequate information on Dorset house types. One of the houses that contained Dorset material, No. 2, was of the cloverleaf shape characteristic of many Sadlermiut houses. This suggests that the Sadlermiut may have derived their principal house type, like other features of their culture, from the Dorset. It lends weight to the supposition that the Sadlermiut were culturally, perhaps even physically, descended from the mysterious Dorset people, who now appear to have represented the basic, dominant Eskimo population in the eastern part of the Canadian Arctic. The Walrus Island finds thus rounded out the cultural reconstruction previously established at Native Point. There, at the proto-Dorset site T 1 and at the somewhat later site T 3, we had been able to trace the earlier history of the Dorset Eskimos and obtain an insight into Dorset culture in the process of formation. The excavations at these early sites, plus those at the later, classic Dorset site T 2 and the Sadlermiut site, had thus brought to view a picture of cultural development and continuity over a period of 2,000 years.

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The Cherokees of North Carolina: Living Memorials of the Past

By William H. Gilbert, Jr.

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[With 8 plates]

THE CHEROKEE STORY

When the first English settlers came to the shores of North America they encountered a series of environmental barriers to their settlement that had to be surmounted in the conquest of the continent. First the Atlantic Coastal Plain, then the Piedmont above the fall line, and finally the Blue Ridge loomed up as great natural features of the continent's terrain requiring subjugation. Almost to the very end of the Colonial period the Blue Ridge and the Appalachian Mountain chain constituted a certain natural and formidable limitation to the horizons of expansion of the new nation then coming into existence.

Finally, however, the Blue Ridge Mountains and their aboriginal inhabitants, the Cherokee Indians, were conquered and their original area and range made part of the expanding domain of the newly formed republic, the United States of America. As the Scotch-Irish, Germans, English, and other populations spread down from Pennsylvania through Maryland, Virginia, the Carolinas, and into Tennessee and Kentucky, the Cherokee Indians were gradually displaced and the greater bulk of them moved westward to a new home beyond the Mississippi to the west of the Ozark Mountains. Only a fraction of these mighty warriors remained to guard for all time the inner fastnesses of the Appalachians in the Great Smokies of our day.

The story of the Cherokees and their homeland begins back in the dim recesses of geologic history in the latter part of the Paleozoic age when the Appalachian Mountains came out of the great thrusts of the earth's crust and became a major feature of the earth's surface.

Throughout the vast period of at least 10,000,000 estimated years of the Paleozoic Era a gigantic land mass called "Appalachia" existed along what is now the eastern coast of the United States. Its western

shores were most of the time just east of the present Appalachians, while its eastern border must have been in the neighborhood of the present Continental Shelf. The rocks of Appalachia were of pre-Cambrian age and from them was derived an enormous mass of sediment in the western sea trough which was latterly uplifted to form the Appalachian Mountain chain. Hence the home of the Cherokees is formed by the remnants of deposit of ancient seas of far-off geologic periods.

The actual origin of the Cherokee tribe has been the subject of considerable speculation by scholars and students of these matters. As we see them today the Cherokees appear to be a race well adjusted to a mountain habitat and who may well have dwelled in these areas of western North Carolina for millennia. The early writers on the Cherokees thought that they detected many resemblances to the ancient Hebrews in the priesthood, "cities of refuge," and ceremonial procedures of these Indians. They even pointed out physical resemblances in color of skin, shape of face, and other traits which would ally the Cherokees with the so-called "lost tribes of Israel."

John Haywood, in his book "Natural and Aboriginal History of Tennessee" (1823, p. 231 ff.), thought that the Cherokees were a tribe compounded of two populational elements. The first element was a group from southern Asia, perhaps from India, or from the ancient Near East, who established an empire centering at Natchez on the lower Mississippi River. These people built mounds, erected idols, performed human sacrifices, erected walled wells of brick, constructed fortifications, worshiped the phallus, revered the number seven as sacred, and lived under despotic rulers. The second element, which entered later, was "from the north" and composed of a savage people, rude but under democratic institutions, well organized for military purposes, and who conquered and amalgamated with the first element to form the Cherokees as the white man encountered them.

In a work entitled "The Cherokees in pre-Columbian Times" (1890) the great American archeologist Cyrus Thomas traced the Cherokee Indians as a mound-building group to the upper reaches of the Ohio River and thence to the Mississippi River and to its upper sources near Lake Superior. His evidence lay in the discoveries regarding the distribution of mounds, platform pipes, engraved shell work, traditions of northern affiliation, and other items.

It has been known since 1798, through the work of Benjamin S. Barton (New views on the origin of the tribes and nations of America) that the Cherokee language shows many similarities to that of the Iroquois Indians of New York. On the basis of this and other northern affiliations it has been assumed that the common ancestors of the Cherokees and the Iroquois found their way from the Mississippi up

the Ohio to its origin at the junction of the Allegheny and Monongahela Rivers and that they there divided into two groups, one going northward and the other southward. Certainly, we may cite in partial confirmation of this the course of the Tuscarora Indians, another southern Iroquoian tribe, who left their homes in North Carolina within the historic period and moved up to New York State to join their ancient kinsmen.

Yet there is much that points to southern affiliations of the Cherokee tribe. On the basis of their historic culture, John R. Swanton (1928) classifies the Cherokees as a cultural subtype of the Creeks.

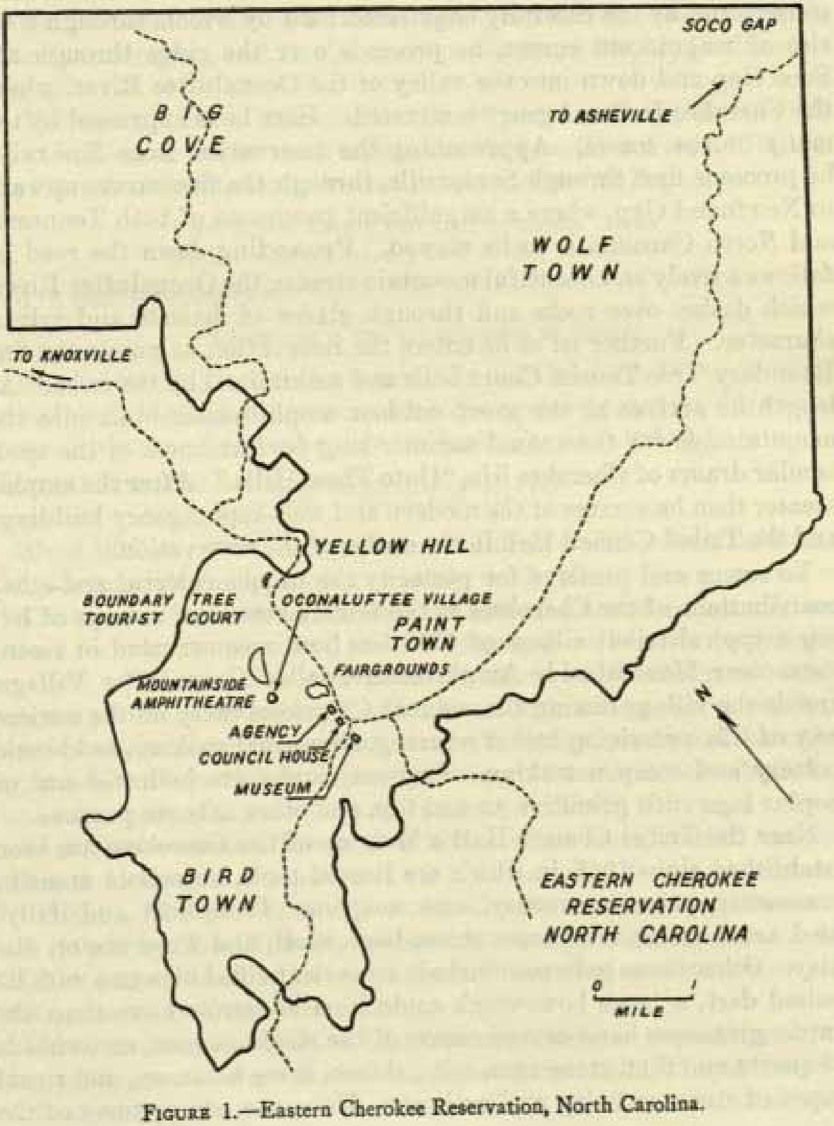


FIGURE 1.—Eastern Cherokee Reservation, North Carolina.

Studies of Cherokee art motifs and basketry types show that these were indubitably of southern origin and traced back to the lower Mississippi River area. The evidence would seem to point to the Cherokees as hangers-on and pupils of better developed cultures of the southeastern area. The danger of inferring racial movements from cultural evidence is likely to be present here, however, and we must hold in reserve our final judgment as to the origin of the Cherokee and his civilization.

Today the traveler coming into the Qualla Boundary may approach from Asheville on the east or from Knoxville on the north. Coming from Asheville by car he will be impressed by the memorable mountain scenery and by the carefully engineered road by which, through a series of magnificent curves, he proceeds over the ridge through the Soco Gap and down into the valley of the Oconaluftee River, where the Cherokee Indian Agency is situated. Here he is impressed by the many tourist courts. Approaching the reservation from Knoxville he proceeds first through Sevierville, through the fine curves upward to Newfound Gap, where a magnificient panorama of both Tennessee and North Carolina is to be viewed. Proceeding down the road he follows a lively and beautiful mountain stream, the Oconaluftee River, which dashes over rocks and through glades of delicate and sylvan character. Further on as he enters the reservation he passes the fine Boundary Tree Tourist Court built and maintained by the tribe. At length he arrives at the great outdoor amphitheater built into the mountainside for the annual summer-long performances of the spectacular drama of Cherokee life, "Unto These Hills." After the amphitheater then he arrives at the modern and well-kept Agency buildings and the Tribal Council Hall in the center of the reservation.

To rescue and preserve for posterity the unique cultural and other contributions of the Cherokees to the world's resources in ways of living a typical tribal village of 1750 has been reconstructed in recent years near Mountainside Amphitheatre, called Oconaluftee Village. Inside the village during the summer Cherokees carry on the ancient way of life, practicing basket weaving, aboriginal cooking, beadwork, pottery and weapon making. Dug-out canoes are hollowed out of poplar logs with primitive ax and fire, and other arts are pursued.

Near the Tribal Council Hall a Museum of the Cherokees has been established since 1948, in which are housed tools, household utensils, ornaments, primitive money, and weapons. Household and daily-used artifacts made of cane, stone, bone, shell, and wood are on display. Other items to be seen include an ancient rifled blowgun with its poised dart, a large bow which could hurl its arrow more than 400 yards, grotesque hand-carved masks of the medicine men, arrowheads of quartz and flint, stone axes, celts, chisels, stone hammers, and ritual pipes of stone and clay and catlinite. Here, too, are pictures of the

great Cherokee chiefs shown wearing their colorful costumes and turbans.

In the same way in which the turbulence of the ancient seas was frozen into great rock strata of the Appalachian folds, so the turbulence of the early frontier life and the Indian way of living have been frozen into the present-day Cherokee Reservation in North Carolina. The Indians who can be seen there today memorialize the past in a very real and vivid manner. The conflicts of the Indians and whites furnish the theme of the drama "Unto These Hills," given annually at the Mountainside Amphitheatre. The intertown conflicts are symbolized in the boisterous Cherokee ball game. Everywhere we see action of the past memorialized in ancient weapons and implements, in the Cherokee Museum, and in the many products on display in the curio shops.

Commemoration or memorialization of past events typifies the cultural influences now at work among the Eastern Cherokees. It is as if the Cherokees had taken to heart the famous lines of Pope:

> First follow nature and your judgment frame
> By her just standard which is still the same.

and in another context:

> All nature is but art unknown to thee.

But before we proceed to expound the details of this theme it might be well to bring into our consciousness the contemporary condition and general picture of Cherokee life in North Carolina today.

THE CHEROKEES TODAY

Since 1917 an annual 5-day Cherokee Indian Fair has been held near the Agency late in September or early in October. The purposes of the fair have been to stimulate agricultural enterprise by offering prizes for various products, to encourage arts and crafts (especially weaving of linen and woolen goods, weaving and braiding of rugs), art metalwork, silverwork, beadwork, cabinetmaking, wood carving, jewelrymaking, basketry, and pottery. Various recreational activities include Cherokee stick ball games, archery contests, dances (both Indian and square dances), singing contests, and baby shows.

In 1947 the Qualla Arts and Crafts Mutual Incorporated was organized to market the products of 175 Cherokee Indian craftsmen. In 1950 the Cherokee Indian Farmers Cooperative was organized and the Boundary Tree Tourist Enterprise was opened for business. In 1955 it was estimated that there were 90 business enterprises owned and operated by Cherokees on the reservation.

Much of the growth of the Cherokee economy has come about since the development of good roads, beginning in 1931, brought swarms of tourists into the area. This has permitted the development of, and

access of visitors to, the Mountainside Amphitheatre, the Oconaluftee Village, the Cherokee Museum, and the innumerable curio shops of the reservation.

Institutional development has kept pace with the economic improvement. The Indian Bureau provides a free school system which includes five elementary schools and a central high school. The U. S. Public Health Service, of the Department of Health, Education, and Welfare, operates a modern 25-bed hospital at the Agency where indigent Indians receive free of charge diagnosis, treatment, hospitalization, and dental care.

There are 25 or more churches on the reservation, nearly all of which are served by Indian pastors. Baptists far outnumber other congregations, but there are also Methodist, Episcopalian, and Latter Day Saints missions among these people. Hymn singing is a favorite pastime, and all-day "sings" are frequent. Truckloads of singers from various communities meet at appointed churches to sing, and bring their basket lunches with them.

THE PHYSICAL TYPE

Along the road the visitor sees the Cherokees, here a mother or two walking with the children, there an old man humped with age and plodding his way slowly to some nearby goal. These rather small brown-skinned people contrast with the neighboring mountain whites, who are on the average taller and are fair-skinned. The older Indian men tend to be lean and wiry in build, the women more heavy-set and stocky. Prominent cheekbones often appear in the women and prognathism or projecting jaws may be present. The straight and jet-black hair is typical of the fullbloods and the Mongolian eye appears occasionally in the females. A hawklike or beaked appearance of the face is frequently noticeable and it reminds one of the Maya and Mexican sculptured faces.

Today about 25 percent of the enrolled Cherokees are fullbloods, and it is from these people that early students of blood type first recognized the distinctive predominance of type I blood in the American aborigines. There can be no doubt that in the present-day Cherokees we are dealing with an aboriginal racial island separated by distinct racial ancestry from the surrounding mountain people of the Appalachians. Here and there in an area from Georgia, through eastern Tennessee and the Carolinas, western Virginia, Kentucky, West Virginia, Maryland, and even Pennsylvania and New Jersey, the occasional appearance of Indian physical traits and ways in the local population is attributed, rightly or wrongly, to an infusion of Cherokee blood.

The long-continued habit of inbreeding or marrying within their own race has set the Cherokees apart from others. The ensemble of

genetic traits, including both matters of temperament and ways of acting, as well as physical traits, conjoined with the maintenance of the aboriginal speech and home-taught traditions, has made of the Cherokees a true nationality, sojourning in the same State with those of European and African descent but clearly differentiated from them.

WHITE MAN VERSUS CHEROKEE

A people firmly rooted in the soil and in their own traditions will never be extirpated but will persist and grow in spite of an adversity which may seem to undermine their continued existence. The strength of a race lies in the tenacity of its attachment to the physical environment, along with the degree of its adherence to traditional ways of life.

It is quite a problem at this late date to analyze the degree of blood admixture of Cherokees and whites. However, some indications exist which point to the continued existence of a considerable body of near fullbloods as the core of the band. Early descriptions indicate that the Cherokees were of fine muscular physique and tall in stature. The hair was described as always black, lank, and straight, and the beard variously noted as thick or sparse.

Blood admixture with whites, particularly Scotch and Scotch-Irish, Germans, and English, has been widespread and prolonged over the entire historic period. Mixing with other Indian tribes has occurred, particularly with the Catawba. L. H. Snyder (1926) reported on an examination of 250 individuals wherein the fullbloods showed a percentage of 93.6 of blood type I while mixedbloods were 59.3 percent of blood type I.

An examination of the clan affiliations of the heads of 321 families was made by the present writer in 1932 and clan affiliations were noted for 475 persons. Of the families listed, about 8 percent (28 families) showed no clan affiliation of either father or mother. These may be taken to be persons of little or no Indian blood. In the case of 71 families, i. e., 22 percent, only one of the two heads of the families showed clan affiliation. These may be taken as definitely mixedbloods. The remaining 216 families, or about 60 percent of the whole, gave evidence of clan affiliations in both parents.

The mixedbloods and "white Indians" occupied the bottom lands along streams which furnish the best agricultural possibilities, whereas the fullbloods and near fullbloods tended to live on the slopes and upper reaches of the streams. Of all the several communities at Qualla, the Indians at Big Cove seem to have retained their traditional culture the most effectively. However, predictions as to the future complete dissolution of the Cherokee tradition may have been premature. Much of the traditional culture probably continues through oral transmission from parent to child in fullblood families.

The activities of anthropologists have undoubtedly contributed to the conservation of the old cultural traditions, and the demonstration that the remunerative tourist industry can be developed through reconstruction of traditional community life and activities has helped also. What must be noted in this connection is the linkage between conservation of the culture and the conservation of the race. The one is inseparable from the other. An enlightened recognition of this fact by the white man is of the greatest importance to our generation. Respect for the integrity, not only of the race but also of the culture, is fundamental, and a characteristic of our times.

The position of the mixedbloods is a difficult one. Drawn by their diverse racial inheritance partly toward the white and partly toward the Indian, they have a hard row to hoe. In some respects they form an entirely distinct group which perhaps could develop a cultural tradition, partly Cherokee and partly white, with a happy blend of the best features of both. The history of mixedblood groups has not been a happy one, however, and time and patience are required to work out all the many problems that beset them.

THE CORE OF TRADITION

Cherokee life revolves about the traditional institutions that have survived over the centuries as means of maintaining and perpetuating the social and biological continuity of the tribe. Of these the most important is the system of clans. The clan is not what we think of as in the case of Scottish clans, but rather an outmarrying group that insures the marriage within the tribe but only within certain modes of relationship. In early times marriage within the clan was punishable by death and it is still observable that such breaches are the exception. Clan membership was transmitted through the mother. The clan names translated into English are as follows: Wolf, Deer, Bird, Red Paint, Blue, Wild Potato, and Twister. The following associations of ideas presented by the Cherokee may explain in part the derivation of these clan names.

The Wolf Clan was composed of great huntsmen—hunters who in their assiduity and attention to their profession were keen as wolves. It was also said that the members of this clan were fond of capturing young wolves and raising them in captivity and training them just as dogs are trained. It was and still is regarded as bad luck for any Cherokee to kill a wolf, although in former times a profession of wolf killers existed. To the east of Qualla on the reservation is a section called Wolftown.

Members of the Deer Clan were like the Deer for swiftness. It was thought that they also kept deer in captivity. They were reputed to be specialists in the hunting and killing of deer. Just east of the Agency is an area called Deer-place after this clan.

The Bird Clan people were always fond of birds and kept captive crows and chicken hawks. They were also noted for their successful use of snares and blowguns in bird hunting. Birdtown, near Qualla, is named after this clan.

Possession of magic was the principal characteristic of the Red Paint Clan who employed iron oxide or hematite for the purpose of securing success in love and protection in war. In fact these people were the great conjurers of the old days and Painttown, to the east of the Qualla Agency, was named after them.

The Blue Clan was named after a wild plant of bluish color which was gathered by them in the low swampy grounds along streams and used for food and medicine. The plant is described as being narrow-leafed, like grass, and with berries resembling a young cucumber, but it is explained that only the roots were used by the Indians. At each new moon, in the old days, children were bathed in a decoction of this plant to protect them from all diseases.

The Wild Potato Clan was also named after a plant of the swamps along the streams which was gathered and eaten by this clan. No tradition of any ceremony connected with this plant survives.

The Twister Clan was so named because of the haughty manner in which they formerly conducted themselves, twisting their shoulders as they walked. They were accounted a rather vain people who grew their hair long and adorned it with elaborate coiffures and decorations.

In order of numbers the most numerous is probably the Wolf Clan, followed at a distance by the Bird. These two clans, in fact, accounted for over 50 percent of all Indians in the reservation in 1932. Somewhat less numerous were members of the Twister and Deer Clans, with the Red Paint, Wild Potato, and Blue trailing at the bottom of the list.

The clan is an institution of fundamental importance in Cherokee tradition and way of life. It is symbolized in blood and is associated with descent from and through the mother. According to the myths the clan was derived, along with songs, dances, and magical formulas, from the great giant "Old Stonecoat," who was slain by the Indians at the beginning of time by being burnt at the stake. As he died he sang, as was the Cherokee custom, his "death song." In this song, uttered as the spirit of Old Stonecoat ascended into Heaven, was the entire Cherokee tradition. Included in it were the rules and regulations which governed the clan membership and the rituals associated therewith.

One such ritual was called "going to the water." This involved a group of brothers and sisters of the same clan ceremonially bathing in a stream and the conjuror prayed for the clan by name, prognosticating the future fortunes of the individual members present.

One's clan affiliation is of the utmost importance in determining kinship behavior and relationships to everyone else in the tribe. Since the most important relationships are those sustained by birth or consanguinity and by marriage or affinity, the clan is fundamentally involved with both.

To cite a typical example, let us take the individual W. L., whose clan, inherited from his mother, is Wolf. All members of this clan are brothers and sisters to him, in common with his own real brothers and sisters, and he visits and associates with members of this clan on the most familiar terms—familiar in all ways except that he may not, according to the rules of the clan, ever marry a "sister," that is, a woman of the Wolf Clan. It is his mother who makes known to him the rights and duties incumbent on him through his membership in the Wolf Clan. His mother will never permit familiarities with herself and her generation. Nor may W. L. behave otherwise than with great circumspection toward his sister and her children, who are also of his clan.

As a child W. L. is gently teased by his father who is of the Wild Potato Clan. "You must marry my aunt," he tells his son. W. L. thinks of the elderly and rather unattractive woman whom his father calls "aunt" and who is really W. L.'s father's father's sister and whom he himself calls "grandmother." He learns from his father's teasing that it is customary for him to joke with his paternal grandfather's sister about this marriage business and since she is of the Deer Clan he finds that all her "brothers" and "sisters," including those of his own age, are also joking about the same theme. Thus as time goes on his mind becomes accustomed to the idea that he will find his wife in the Deer Clan, which was the clan of his father's father. Toward his father's clan, i. e., the brothers and sisters of his father, the Wild Potato Clan, he maintains respectful and circumspect behavior. In fact anyone whose father is in the Wild Potato Clan is a brother or a sister to him. W. L.'s mother, like himself, is of the Wolf Clan, but her father is of the Red Paint Clan. Hence she too can tell him that he must marry her aunt or a woman of the Red Paint Clan when he comes of age.

It can be seen that there are four clans with whom an individual Cherokee is closely concerned: (1) His own clan containing his "brothers" and "sisters," both actual and classificatory; (2) his father's clan containing "fathers" and fathers' "sisters," toward which he must always show respect and deference; (3) his father's father's clan which contains "grandmothers" and "grandfathers" with whom he can marry; and (4) his mother's father's clan, containing "grandmothers" and "grandfathers" with whom he can marry.

Let us carry the type case a stage further. W. L. marries a wife of the Deer Clan. Her father, let us say, is of the Blue Clan which she

must always respect. Her father's father, however, was of the Wolf Clan and she marries a man of that Clan (W. L.). Her mother's father is of the Bird Clan, which also contains potential mates for her. W. L.'s children will have two clans to choose mates from, the Wild Potato Clan and the Blue Clan, i. e., provided the selected mates have grandfathers and grandmothers in the Deer Clan.

Thus it can be seen that lineage through the mother is of the essence in Cherokee life. One acquires a clan membership by birth, through the mother, and by no other way. Even after marriage the individual is still a member of the same clan and remains so until death. The solidarity of the clan lineage is the most important single element of traditional Cherokee culture and the most effective influence toward conservation of the race and the culture.

THE TIDES OF LIFE

Anyone who has ever spent time at the seashore is familiar with the phenomenon of the tides, those regular daily risings and fallings of the water level. The regularity of the tides, like the regularity of day and night, and the alteration of the seasons, impresses itself on the mind of man to the degree that he memorializes it in his ceremonies and rituals in a variety of ways. Thus the rituals of a primitive people commemorate, not only the events of past importance to their ancestors, but also the cyclic or rhythmic aspects of life generally.

Observations on Cherokee festivals by the missionary, D. S. Butrick, and others early in the nineteenth century were recorded and summarized in a manuscript by John Howard Payne, the famed author of the song "Home Sweet Home." This manuscript, now in the Newberry Library at Chicago, contains a very extensive and detailed account of the regular monthly and seasonal feasts of the Cherokee. From this account it can be seen that the great principle at work in primitive art forms, and perhaps in all art forms, is the commemoration of the past in terms of stressing the continuity between the lives of the many generations. In fasting as a ritual, we cannot fail to observe the periods of starvation and want in wintertime when game was scarce and the future problematic. The dances, lustrations, prognostications, ceremonial hunts, new-fire making, and the like, were artistic delineations of the great natural rhythms that tie together the life of the past, the present, and the future. The celebration of these festivals was basic in Cherokee life, even as it was in all Indian life, and constituted the logical and motivational basis of the social order.

In his book entitled "Moon Up and Moon Down," John Alden Knight (1942) has outlined the feeding activities of fish as related to the height of the tides. A regular "solunar" rhythm exists, he says, and the higher tides at new moon and full moon are directly cor-

related with good fishing because the fish are biting and feeding at those times. Thus activities of the fisherman would in turn be influenced by the recurrence of good fishing in accordance with the phases of the moon. Some marine animals appear in great abundance once or twice a year in accordance with special phases of the moon. One such animal is the palolo worm which appears in great numbers in the waters off Samoa during the last quarter of the November moon. Here breeding and feeding go hand in hand in the rhythms of nature as large numbers of fish find sudden accessions to the food supply.

So it was possible, in the human world, to correlate activities of animals with periods of hunting and fishing which would be symbolized in feasts. The regular sequence of new-moon feasts among the Cherokees was, so far as we are able to judge, connected with the rhythms of human breeding and feeding. The monthly friendship dances of today still commemorate the cleansing of menstrual taboos, which are imposed by clan sanctions and relate to the monthly feasts of an earlier period. The shedding of blood, from whatsoever cause, invokes sanctions of uncleanliness which must be given recognition. The avenger of blood could not slay the fugitive who reached a city of refuge, or a "white town" because it would produce an uncleanness. The special clan that killed a particular animal in the hunt had to be absolved from blood revenge by the animal's clan relatives by special rituals.

Among the early Cherokees the year was divided into two sequences. The first, for winter, began with the Great New Moon feast of October and the second with the New Moon feast of April, and included the summer months. The two important New Moon festivals were each seventh in a continuous series reckoning from the other and each began a new season and a new year.

Each of the two main festivals of April and October were celebrated with hunts, dances, lustrations, divinations, and a feast. Each was succeeded a short time afterward by a festival in which new fire was made to renew the life of the tribe for the new season. The principal purpose of all new-moon feasts seemed to have been to purify from uncleanness and to protect against harmful forces. They celebrated renewal of life and life's friendships after segregation for impurities and uncleannesses.

There were six major new-moon feasts pointed out as of special significance, and which were as follows:

1. The First New Moon of Spring, celebrated when the grass began to grow in April and possibly represented by the Corn Dance of today.
2. The New Moon of August when the corn first became fit to eat, the roasting-ears time of today.

3. The Green Corn Feast of September when the corn crop was harvested; still celebrated.
4. The Great New Moon of October, which was called the Great Medicine Feast since at that time the leaves of many curative plants fell into the streams and imparted their properties to the water.
5. The Cementation of Reconciliation Festival at the end of October which involved cleaning of all houses, the use of new utensils, forgetting of differences between people and cases of blood revenge, donning of new clothes and exchange of clothes, pledging of eternal friendship and solidarity, and making of new fire (probably represented today by the "Woman Gathering Wood" Dance).
6. The Exalted or Bounding Bush Feast, held in December, characterized by the waving of pine boughs; thought to survive in the Pigeon Dance of later times.

THE DANCE OF LIFE

Dancing is of primary importance in the traditional Cherokee culture. It is difficult to gather up all its varied meanings into one sentence, but it is possible to say that in the dance rhythms all the essential life activities are memorialized and the continuity of the race is maintained. The so-called Friendship Dance, for example, gives one the impression that for the Cherokee all the world is a ballroom and all the men and women merely dancers, each with his exits and his entrances. This is in a way a community opera in which the drama and the music induce a state of emotional exaltation which commemorates the ancestors and assures them of the loyalty of the present generation to the principles of the race. In the cheerfulness of the occasion those who mourn find comfort. In the participation in community of demonstration the young as well as the old find a primary life satisfaction. In the dance the familiarity with joking clan relatives is carried on freely so that on such occasions the young people may find their mates in the proper clans.

Three musical instruments are employed: the skin drum, the tortoise-shell legging rattle, and the gourd hand rattle. The drum consists of a barrel fastened with wooden hoops and with a groundhog skin stretched across the top. The skin must be moistened at times from the inside for proper tonal effects. Usually a little warming at the fire will lessen the tautness of the skin. The diameter at the top of the drum is 6 inches and at the bottom 8 inches, and the length is about 12 inches. The beater is of carved wood and about 8 inches long.

In making a tortoise-shell legging rattle five terrapins of approximately the same size are caught and boiled and the flesh scraped out four days later. Small gravel or pebbles are put in each shell and the ends of the hinged parts are tied up with strings and set before the fire until they harden shut. The tops are perforated with small holes and strings put through them. Four terrapin shells are then

placed together on a piece of groundhog skin or buckskin about one yard square in size and the fifth tortoise shell placed on top of the other four and tied with them to the skin. Thongs of skin are used for tying one of these combination rattles to each leg.

The hand rattles are made from gourds. A small hole is bored at each end of the gourd and a slender piece of wood a foot long is run through the oval or egg-shaped gourd. The typical gourd shell is about 4 inches long and about 3 inches in diameter and contains small pebbles to make the rattling sound.

Dance teams are organized in the different communities—at Big Cove, Birdtown, and elsewhere, especially for Friendship Dances. Each team has a "caller" who calls forth the names of those who are to lead each song step, and directs the sequence with the proper signals. The caller endeavors to pick out the best and most effective singers to lead the songs. The number of songs in each dance averages about four, and the song consists in the repetition of a single melodic theme to the accompaniment of archaic words. An alternation of slow and fast tempos can be noted, with the faster tempos predominating at the close. Dances may be held as often as once a week, generally in the evenings.

The action and speech simulates and refers to basic life activities such as playing the game of Cherokee ball, planting and tilling the soil, curing and preventing disease, hunting various wild animals, and joking with familiar clan relatives. Clapping the hands together is a common feature of the Friendship Dances and expresses the happiness and the good time being enjoyed by all the participants. Solo dances are sometimes given in which the dancer sings and tells a story as he dances, occasionally poking fun at his familiar clan relatives.

The names of the principal dances of the Cherokees and the significance of each is given below.

Name of Dance	*Significance*
Ant Dance	Imitates the movements of ants
Ball Dance	Magic for obtaining victory in ball game
Bear Dance	Imitative of the bear
Beaver Dance	Imitative of killing beaver
Buffalo Dance	Imitative of killing buffalo
Bugah Dance	Buffoonery
Chicken Dance	Mimetic of birds
Coat Dance	Buying a wife
Corn Dance	Corn planting
Eagle Dance	Victory in war
Friendship Dance	Promotes social intercourse
Green Corn Dance	Celebrates the harvest of corn
Groundhog Dance	Hunting the groundhog
Horse Dance	Mimetic of the horse
Knee-deep Dance	Mimetic of knee-deep spring frog
Medicine Dance	Physic dance for health

Name of Dance	*Significance*
Partridge Dance	Mimetic of quail movements
Pheasant Dance	Mimetic of pheasant drumming
Pigeon Dance	Hunting of pigeons by hawks
Raccoon Dance	Hunting raccoon
Round Dance	Dance around the fire
Snakelike Dance	Magic power from the snake
War Dance	Magical protection in war
Woman Gathering Wood Dance	New-fire making

CHEROKEE INSPIRATION: THE ORAL TRADITION

An idea or a feeling grandly expressed lives forever and gives immortality to the words that enshrine it.—Viscount Bryce.

Speech can be looked upon as a system of signals or symbols, not only of ideas but also of sentiments, feelings, and emotions. The first words and the nursery songs that are learned orally at the parent's knee form the basis of all subsequent language learning and stay with the individual to the very end of his life. Nothing can be more important to the preservation of a race and its culture than the continued oral transmission of ideas, principles, and sentiments within the domestic household, from generation to generation.

This is particularly true of the religious and moral sentiments, those ultimate realities with which language, in its most exalted use, is particularly concerned. Hence many religious systems have evolved ritual or liturgical languages which commemorate the religious sentiments in fixed linguistic forms and which stand in contrast thereby to everyday language with its multitude of vulgar innovations and neologisms. In India the Vedic language represents an even more intensive conservatism of speech wherein a liturgical language, Sanskrit, has preserved in Vedic texts the remnants of a still earlier liturgical form. In his work on the Swimmer manuscript, Olbrechts (1932, pp. 160–165) has discussed the liturgical language of the Cherokee sacred prayers or formulas. In a matrilineal clan society, such as that of the Cherokees, the transmission of both oral and written liturgical material is from mother or mother's brother to the daughter and son.

So it is that, in the same way that we of the Western civilization attempt to learn the elements of Latin and Greek in our youth for the better preservation of those ideas, sentiments, and values most intrinsic to our culture, the Cherokee student learns the ritual language of the prayers or formulas that in part have been preserved in written form through the good offices of Sequoia's syllabary and given literary recognition by Mooney and Olbrechts, in their printed texts with English translations. Thus the mentality of the Cherokee and the values of Cherokee traditional culture are made manifest and enter into the

modern inheritance of a pattern of world cultural and racial pluralism. The inspirational works or formulas are accompanied by a collection of narrational commentaries, or the so-called "myths" of the Cherokee, assembled by James Mooney (1891, 1900.)

THE PRAYERS OR FORMULAS

The Cherokee ancestors believed that the earth was flat and that the sun sets through a hole in the ground in the west every night and rises through a hole in the ground in the east every morning. Four ropes are attached to the four corners of the earth to hold it up, stretching horizontally outward. At the edge of the earth there is "something hammerlike" which keeps pounding on the ground constantly. When people die their souls must go through this gauntlet and the good succeed but the evil are crushed by the hammer. Heaven is beyond the edge of the earth and is like this world, only more beautiful, with all sorts of fruits and deer meat in plenty. It is also very light there. The moon has a path like the sun and goes down through one hole in the earth and rises through another. A different version has the sun and moon passing around the edge of the four-cornered earth, when invisible in the sky. There are seven worlds above the flat one on which men dwell, and correspondingly there are seven suns and seven moons which go through each world like ours. There are also thought to be seven sets of stars. When one's soul reaches the seventh heaven or world it dies of old age.

The various natural forces and elements of the world are personified. Fire is regarded as a mother, grandmother, or the old mother (i. e., ancestress). Cure of many diseases is secured by use of the heat of fire and by charcoal and ashes. The moon is the most important heavenly body and is personalized as a man, an elder brother or grandparent. The Cherokee are said to have had a high regard for James Mooney because of his last name. The sun is personalized as a female and generally reckoned as a maternal grandmother, the source of the blood of the clan. The Cherokee mother sings lullabies before daybreak to her child in which she invokes the dawn and the rising sun, in terms of mythical words and ideas. Wind, clouds, lightning, snow, and thunder are also personalized. Control of the weather is a foremost object of Cherokee prayers. All the above-mentioned elements of nature are thought of as causes of disease in man and as requiring placation in removing the disease.

Although the major part of the Cherokee tradition has always been a matter of oral transmission, the invention of a syllabary by Sequoia about 1824 furnished a medium of writing for preservation of the mantic and magical formulas of the conjurers. The existence of these documents was first called to the world's attention by James Mooney in the late nineteenth century (1891).

The magical formulas consist of prayers or conjurations for curing disease, for securing game and fish, for prognostication, for protection against supernatural influences, for long life, for weather control, and for attracting the affections of a woman. Most of the formulas are composed of two parts, one part dealing with actual technique and a second part dealing with the incantation to secure the desired result. It is doubtful whether the native practitioner of the magical arts ever made any distinction between the two different elements or between the formulas devoted to one purpose and those devoted to another. For to him the fundamental pattern of events and the means of controlling the events is the same, namely, the merging on a temporary basis of the suppliant's personality with some stronger personality in the universe which has the magical powers to accomplish the end desired. The undesirable things are magically separated from the desirable and the latter are then assimilated to the self.

The philosophy of the formulas may best be understood by taking an example from Mooney's published Cherokee love charms (1891, pp. 376–377). The following is the text of the formula.

Concerning Living Humanity (Love)

Ku! Listen! In Alahi' yi you repose, O Terrible Woman, O you have drawn near to hearken. There in Elahiyi you are at rest, O White Woman. No one is ever lonely when with you. You are most beautiful. Instantly and at once you have rendered me a white man. No one is ever lonely when with me. Now you have made the path white for me. It shall never be dreary. Now you have put me into it. It shall never become blue. You have brought down to me from above the white road. There in mid-earth (mid-surface) you have placed me. I shall stand erect upon the earth. No one is ever lonely when with me. I am very handsome. You have put me into the white house. I shall be in as it moves about and no one with me shall ever be lonely. Verily I shall never become blue. Instantly you have caused it to be so with me.

And now there in Elahiyi you have rendered the woman blue. Now you have made the path blue for her. Let her be completely veiled in loneliness. Put her upon the blue road. And now bring her down. Place her standing upon the earth. Where her feet are now and wherever she may go, let loneliness leave its mark upon her. Let her be marked out for loneliness where she stands.

Ha! I belong to the (Wolf) Clan, that one alone which was allotted into for you. No one is ever lonely with me. I am handsome. Let her put her soul (into) the very center of my soul, never to turn away. Grant that in the midst of men she shall never think of them. I belong to the one clan alone which was allotted for you when the seven clans were established.

Where (other) men live it is lonely. They are very loathesome. The common polecat has made them so like himself that they are fit only to be with him. They are very loathesome. Even the crow has made them so like himself that they are fit only for his company. They are very loathesome. The miserable rain-crow has made them so like himself that they are fit only to be with him.

The seven clans all alike make one feel very lonely in their company. They are not even good looking. They go about clothed with mere refuse. They even go about covered with dung. But I—I was ordained to be a white man. I stand

with my face toward the Sun Land. No one is ever lonely with me. I am very handsome. I shall certainly never become blue. I am covered by the everlasting white house wherever I go. No one is ever lonely with me. Your soul has come into the very center of my soul, never to turn away. I ---------- take your soul. Sge!

In the first paragraph there is established a solidarity between certain benevolent spirits and the reciter of the formula, while a preliminary statement of the reciter's own attractiveness and charm is made. The second paragraph sets up barriers of avoidance between the woman the reciter desires to conquer and the rest of humanity, with blueness and loneliness assigned as her lot until she recognizes her true interest, which is with the reciter of the charm. In the third paragraph the reciter begins to set up a bond of familiarity between himself and the woman desired in the course of which he names himself and his clan and reminds her that she has been allotted to his clan in marriage from the beginning of the world, so that he alone of that clan is suitable for her as a mate. In the fourth paragraph he creates a barrier of avoidance between himself and the rest of mankind, comparing them to noxious and repulsive animals. The fifth paragraph ends the prayer with a reiteration of the assertions of the first paragraph, the charms and attractiveness of the reciter, and concludes with a statement of solidarity by identification with the woman of his choice.

The use of such a love charm is most frequently at midnight and the man sings his formula in a low voice while facing in the direction of the girl's house. This will make her dream about him and become lonesome for him unless she has fortified herself, on going to bed, with counter spells. The next time she meets him she will be irresistibly drawn toward him and become attached by strong and permanent bonds.

After he has gained her favors, however, his labors are not over. He must retain her only by constant spells, especially if she be at all attractive on her own account and liable to the magical spells of male rivals. In order to retain a mate a man must affirm the strength of the bonds existing between himself and his wife by a magical formula and anointing her breast, while sleeping, with his spittle. Sometimes, despite his best efforts his mate will be attracted away from him by the superior magic of a rival. To overcome this reverse and recall the woman the man uses a prayer reaffirming his attractiveness and allying himself with the all-powerful grandmother fire.

The rival who is intent on detaching a man from his mate makes use of negative love formulas. These are of two types: (1) Designed to separate a man and wife preparatory to uniting the wife with himself through his own attractiveness; and (2) to render a man unattractive so that no woman will want him. In the case of separating a man

and wife the wording of the formula likens each unto a noxious animal so that repulsion is set up between the conjugal pair. The wife will then leave her husband or vice versa, unless counterspells are resorted to.

At times the love spell fails to move the object of attention and the reciter's love interest is then turned to hatred and a desire for revenge. He may practice a spell of unattractiveness on her and make her repulsive to all men. Or he may continue to ply her with love spells until she makes a clown of herself through her overdemonstration of passion toward him. Thus he attains revenge on her.

FORMULAS AND DISEASE

Disease and its causes have always been a moot problem for mankind. About the simplest explanation would be that of Pandora's Box in which the disobedience of a command brought sorrows and disease on man through feminine curiosity. The Cherokees, like other races, found it necessary to deal with disease both from the psychosomatic approach as well as from the practical or herbal approach. As in the case of the ancient Aryan Atharva-Veda the Cherokee formulas enable the apothecary to confront the many ills to which the flesh is heir.

The suffering caused by disease is associated in the Cherokee mind with the suffering caused by the anger of some other personality, whether mental or physical anguish. Disease is the requital for the anguish caused some other personality for actions, conscious or unconscious, on the part of an individual. In a sense then, disease is a form of conflict in which the symptoms are the equivalent of the blows exchanged by the boxers in a pugilistic contest. The animal spirits, as Olbrechts says (1932, p. 19), such as the Little Deer, the White Bear, and others, are the tireless and valiant defenders of their particular animal clan and mete out justice or take vengeance by sending disease to neglectful and disrespectful hunters. In other words, all disease is from due cause and this cause must be searched out and compensated for before the disease can be cured.

Diseases of one class are sent by medicine men to other people and are made to display symptoms calculated to inspire the wrong remedy. These are spoken of as "ordeal" diseases and are sent by conjurers to each other "as a joke" or to test their knowledge and aptitude in warding off attacks.

The curative methods pursued by the medicine man, as well as the matter of materia medica, are treated at length by Olbrechts (1932, pp. 60–77, and ff.). Suffice it to say here that the treatments were often well conceived and well administered in terms of the theory of disease herein presented. Many examples of curative formulas are given by Olbrechts in the work cited.

THE MEANING OF THE MYTHS

The Cherokee myths collected by Mooney do not give a full story of how the tribe originated. Rather they are extremely fragmentary remnants that have survived from a much more complete account now lost. The myths explain the ways of the past and the motivations of behavior characteristic of the traditional life. In a sense the myths are rationalizations of the life of the ancestors and justifications of the world as we now see it, in terms of the continuity of life.

The various species of animals are pictured in the myths as having clans just like the Cherokee, and townhouses, towns, and other social forms like men. Each of the animal clans is pictured with its own clan council which made decisions of importance regarding the future of the species. Fire and tobacco are pictured as having been acquired by stealing animals at the behest of the clan councils. There seems to be some identification of important conjurers with the various animal clans. The animals play tricks on each other just as the conjurers do. All the animal clans, however, seem to be involved in a perpetual state of war or blood revenge against man because he slays them or otherwise menaces their welfare.

Plants are regarded as the friends of man because they furnish the basis for cures of disease and also because they yield food for man. Corn, or maize, is especially revered and the myths clustering about the old woman of the corn are highly regarded and important.

Certain other beings exist in the cosmos who may help or hinder human purposes depending upon the magic power wielded by the human being. Such beings are: (1) The Man of the Whirlwind who stirs up tornadoes and dangerous winds; (2) the Rainmaker who brings or withholds rain; (3) the Cloud People who often come to visit and commune with humans; (4) the Red Man of Lightning; (5) the Thunder Men who make known their presence during the storm; (6) the Snow Man; (7) the Hot and Cold Weather Man who dispenses temperature changes; (8) the Rainbow Man; (9) the Hail Man; (10) the Frost Man; (11) the Waterfall Man; and (12) the Long Man of the River who incarnates the power of running water.

The dramatis personae of the myths are involved in frequent quarrels with each other and with man, and the struggle for power between the various conjurers is reflected in the myths in various ways. Killing and revenge for killing, clan sanctioned, are basic themes. Conflicts may also arise through a stealing of something valuable which requires compensation. Blood revenge was of primary importance in the older days but now seems to have subsided into conjuring "wars" and other such sublimated conflicts.

The joking or trickster element in the myths may be regarded as another phase of the conflict relationship. In the myths the rabbit tricks the otter, opossum, turkey, wolf, flint, and the deer. The wolf

is very gullible and is tricked not only by the rabbit but also by the terrapin and the groundhog. The terrapin is tricked by the turkey and the partridge. The tricks and practical jokes between the animals are quite frequently reciprocated and the animal tricked returns with interest the tricks of the trickster. The favorite mode of trickery is for the trickster to lure the unsuspecting butt of the joke into a situation wherein he is made to appear ridiculous and loses something of value. In incidents of this nature the bear loses his tail, the otter his coat, the deer his sharp teeth, and the opossum his furry tail.

The trickster element is highly suggestive of the joking that goes on between relatives today and the teasing of persons in the grandparent clan relationship to one's self which leads to the intimate relationships of marriage.

Fundamentally the purpose of the myths is to explain the present in terms of the past as the following story well indicates.

THE STORY OF THE CREATION OF MAN

At first there was a Great Spirit or "apportioner" living in this world called by a name which means "He has prepared." This name came about because of the fact that he had already prepared or created the sun, the moon, and the earth.

One day while walking about on the earth the Great Spirit became lonely and thought to himself, I will make a human being to live with me temporarily. As he walked on his way he came to a place where there was a mass of pale soil caused by a fallen tree with upturned roots. The soil being thin and sandy and just right for the purpose, he took some of it and molded a human being and breathed the breath of life into him. As the man stood up and walked the Great Spirit saw that he was so hairy from the rootlets of the fallen tree and so pale from the nature of the soil from which he was made that displeasure with his creation took hold of him.

He decided to try again and walked on to another place where another fallen tree had exposed its roots with a mass of black soil. He then took of this earth and created another man. But he was displeased when he saw the black color of the man, too dark to be of good appearance. So he walked on and came to another fallen tree, which in falling, had exposed a mass of red clay. From this earth the Great Spirit made a third human being whose skin was light red in color and very smooth. And this time the Great Spirit was greatly pleased with his creation.

He then stood up the three human beings in a row, the white man, the black man, and the red man, and commanded them to stand and be blessed. And as he did so he prepared each of them for his occupation in the future. He created a book and a bundle of roots. He offered the book first to the red man who refused it, and then to the

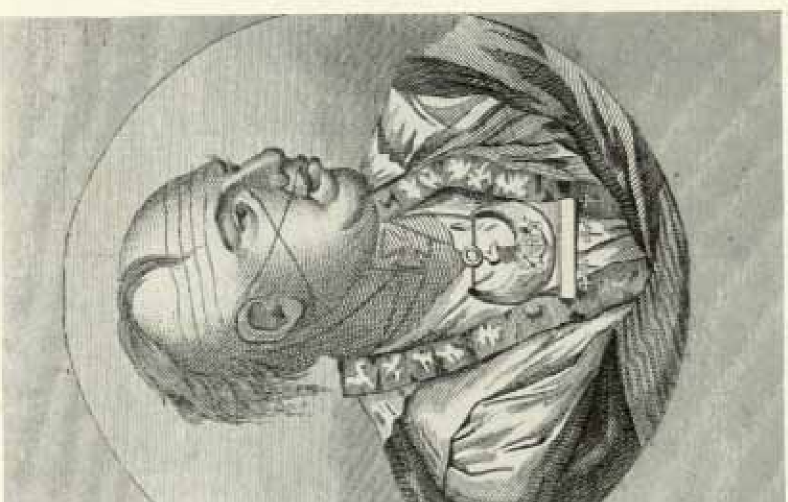
black man who also refused it; finally to the white man who accepted the book. The Great Spirit then offered the bundle of roots to the black man who refused it, and next to the red man, who accepted it. That is why the Indians have become wise in the use of roots for medicines and the white men in the use of books.

THE TOWN LIFE

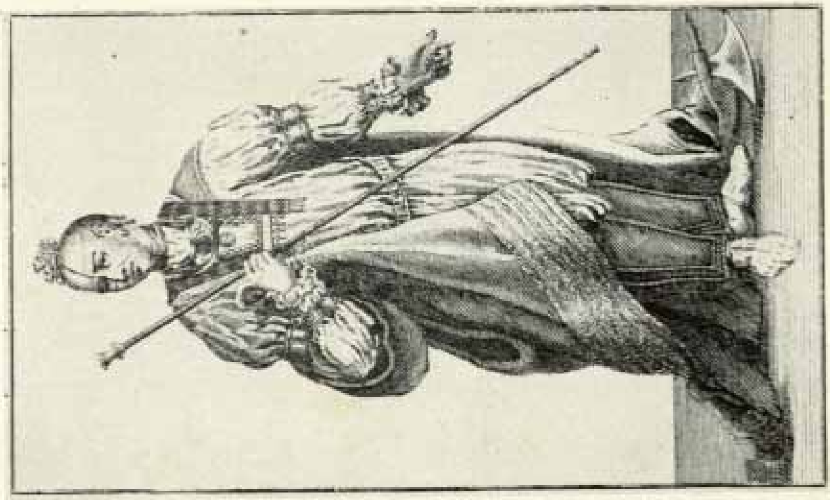
From the earliest times the Cherokees have lived in settlements or towns. The five towns of the Qualla Boundary today are Birdtown, Yellow Hill, Painttown, Wolftown, and Big Cove. Yellow Hill and Birdtown are located in the valley of the Oconaluftee while Big Cove is on the Raven Fork branch, Painttown on Wright's Creek branch, and Wolftown on Soco Creek branch. Each of these towns consisted originally of a number of log cabins strung out at intervals of from a quarter to a half mile apart. In the case of Big Cove two divisions are noticed, an upper Big Cove proper or Raven and the lower Big Cove or Calico. The town of Big Cove itself had in 1932 about 50 families of which possibly half a dozen were white families. Each of the families possessed about 30 or 40 acres of hillside or woodland and of this area perhaps six acres would be cultivated and planted with corn, beans, and potatoes. The stock was and is scant, consisting of a horse, cow, a few hogs, and some chickens.

The five towns mentioned above, together with a sixth consisting of Graham County households, are organized as the Eastern Band of Cherokees with a chief elected every four years, vice chief, and town delegates who compose a band council. Town unity is evidenced in cooperative societies called gadugi, funeral societies, poor-aid societies, town ball team, and town dance team. The towns differ in their clan composition. The Wolf Clan predominates in Wolftown, Painttown, Yellow Hill, and Birdtown, and disputes first place with the Deer Clan in Big Cove. The Wolf Clan is not found in any degree in Graham County. The Deer Clan claims the most members in Big Cove and is numerous in Graham County. The Bird Clan is most numerous in Graham County and ranks second in Wolftown, Painttown, and Yellow Hill. The Paint Clan predominates in Painttown, the Blue Clan is found mostly in Big Cove, the Potato Clan is most numerous to the westward, and the Twister Clan is strongest in Birdtown and Yellow Hill.

Stated in another way, clan distributions by towns show: 57 percent of Big Cove consists of Deer and Wolf; 60 percent of Yellow Hill, Wolf and Bird; 50 percent of Wolftown and Painttown, Wolf and Bird; 65 percent of Birdtown, Wolf and Twister; and 73 percent of Graham County, Bird and Deer. On the whole the less thickly settled areas of Graham County and Big Cove show a greater predominance



1. Outacite, Chief of the Cherokees, one of the Cherokees who visited London in 1762 with Henry Timberlake.



2. Austenaco, "Great Warrior," another of the Cherokees who visited London in 1762.

Cunne Shote, "The Stalking Turkey." From painting by F. Parsons, 1762.

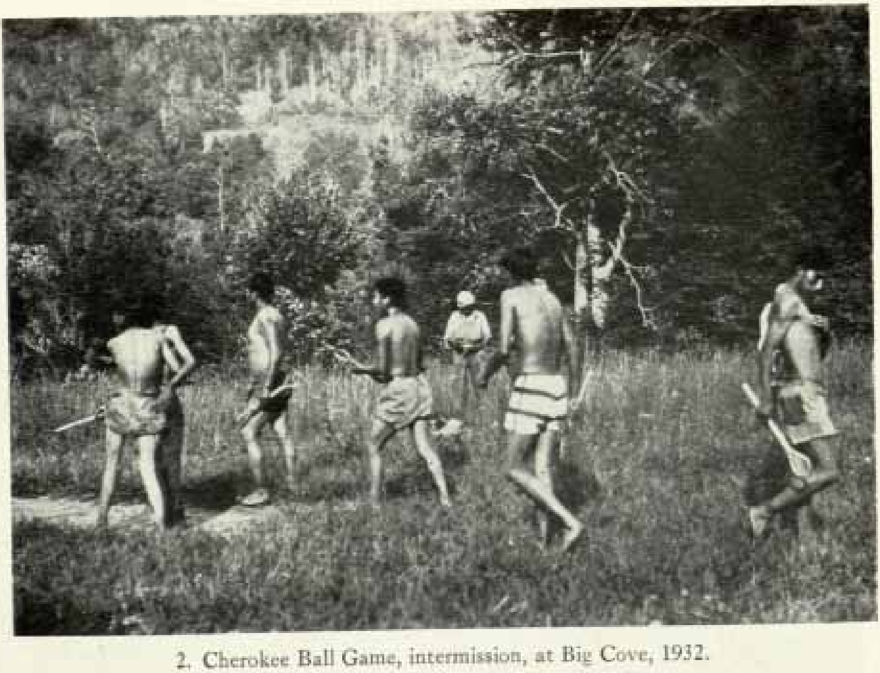
1. Ayâsta's daughter, typical fullblood Cherokee girl. 1888.

2. Tsiskwa-kaluya, or "Bird Chopper," son of the celebrated chief, Junaluska. 1888.

1. Cherokee Eagle Dance at Big Cove, 1932.

2. Group of Cherokees dancing the Horse Dance at the reservation, Cherokee, N. C., during the 31st annual Cherokee Indian fair, October 1948. (State Department photo, O'Donnell.)

1. Four women of Big Cove, 1932.



2. Cherokee Ball Game, intermission, at Big Cove, 1932.

1. Arts and crafts have long been a part of Cherokee culture and have provided opportunities for income. The Cherokee Historical Association has been instrumental in increasing production through its arts and crafts school and in reviving old Cherokee arts and crafts such as beadwork. (Photo courtesy Cherokee Historical Association, ca. 1956.)

2. The Cherokee have long been famous for their baskets and these basket weavers shown above practice their art in the Cherokee Historical Association's re-created 200-year-old Oconaluftee Indian village. (Photo courtesy Cherokee Historical Association, ca. 1956.)

1. A maker of blowguns and blowgun darts, Hayes Lossiah is shown practicing this ancient Cherokee Indian art in Oconaluftee Indian village. (Photo courtesy Cherokee Historical Association, ca. 1956.)

2. This Cherokee woman is demonstrating fingerweaving in Oconaluftee Indian village. (Photo courtesy Cherokee Historical Association, ca. 1956.)

1. This Cherokee Indian boy is explaining how in ancient times the Cherokee trapped fish for their food with such implements as this handmade fish trap in Oconaluftee Indian village. (Photo courtesy Cherokee Historical Association, ca. 1956.)

2. The log structure shown is one of several progressive types of structure depicted in Oconaluftee village. (Photo courtesy Cherokee Historical Association, ca. 1956.)

of one or two clans over the others than do the more densely populated Painttown and Yellow Hill. Examination of the record of marriages between clanspeople indicates that the chance propinquity of residence has little to do with choice of mate.

Intertown rivalry is expressed in the ball game. Great stress is laid on magical power or the lack of it as the sole detriment to the winning or losing of ball games. These games, together with the ball dances, resolve themselves into a rivalry between teams of conjurers in the opposing towns. The magical rites surrounding the ball game are extensive and esoteric but include a weakening of the opponents through trickster joking of familiar clansmen in the opponent's town. Extraordinary measures are resorted to in order to obtain the more powerful conjurers for one's ball team. In fact the entire community has been known to turn out to hoe the fields and perform work on the conjurer's fields in order to show their good will and regard for the conjurer's abilities. The conjurer prays and divines the future. If he finds the opponents stronger than the home team, he takes magical measures to strengthen the latter.

The life in Cherokee towns in early times has been described in great detail in the Payne-Butrick manuscripts. The number of dwellings varied from a dozen to 200, depending upon the importance of the settlement. Townsites were usually on small creeks near the mouth, while larger streams were used for water travel and fishing. Stockades surrounded those settlements whose exposed position rendered it necessary. In the center of the town stood the town house or council house on a level area adjacent to the stream. The council house was 7-sided and in arrangement and use served as a temple for the Indians. Within the council house was an altar of clay at which the sacred new fire was kindled at certain specific times.

Houses within the village were built with posts and wickerwork plastered with clay and with a bark or thatched roof. There were also hothouses for sweat baths and for cold-weather habitation. Storehouses were used to hold stored food. There was a dance square in front of the council house at which important ceremonies were held. Nearby were ball grounds for the ball play and chunkey yards for the chunkey game.

Towns were classified as white towns and red towns, depending upon their traditional ceremonial affiliation. There was a complete hierarchy of so-called white or peace officials and a similar hierarchy of red or war officials.

CHEROKEE PERSONALITIES

The preservation of Cherokee culture and traditions is largely an affair involving personalities, particularly the medicine men. In John

Howard Payne's time (1830) information regarding the traditions was gleaned by the missionary, D. S. Butrick, from Nutsawi Pinelog, Awayu, Corn Tassel, Deer-in-the-water, Nettle, Nutsawi Saddler, Rain, Raven, Thomas Smith, T. Smith, Jr., Shortarrow, Situegi, Terrapin Head, and Toleta.

In Mooney's time (1890–1910), the principal informants were Swimmer, John Axe, Suyeta, Catawba-killer, Chief N. J. Smith, Salali, Jessan Ayasta, and James and David Blythe.

In recent years of the twentieth century there were Will West Long, Deliski Climbing Bear, Morgan Calhoun, and others. The tendency of medicine-making to run in families was noted by Olbrechts (1932, p. 106).

A detailed study of the matrilineal pedigrees among the Cherokees would reveal much of the background of the prominent personalities of the band. This is true both of the earlier period and the later history of this group. The science of human genetics is only in its infancy, yet a brilliant future may be forecast for it in the study of groups like the Eastern Cherokee. The tracing of clan descents, together with historical notices of the personalities and the lineages achieving continued distinction in the Cherokee tribe, is of the greatest importance. Whether the distinction was socially inspired or biologically transmitted is of little account in our present state of knowledge. The important thing is to trace the genealogy of achievement within the group.

The famous Atakullakulla or Little Carpenter was a nephew of Old Hop of Chote, who was principal chief in the early eighteenth century. Little Carpenter was noted as a man of superior abilities who was peace chief of the tribe through many difficult years. One of his sisters was said to have been the mother of the famous Nancy Ward, who was described by William Martin as "One of the most superior women I ever saw." Since Nancy Ward is described as having been of the Wolf Clan, we may assume that her mother and Little Carpenter were also of this clan and possibly Old Hop also. Little Carpenter's son, Dragging Canoe, was another famous Cherokee leader. Also of the Wolf Clan was Charles R. Hicks, principal chief, and son of Nancy, a daughter of Chief Broom, and a white man, Nathan Hicks.

Still another lineage development is suggested in the case of Old Tassel, principal chief of Chote, and of the Twister Clan, a lineage noted for its pride and haughtiness. John Watts was a nephew of Old Tassel and son of a white trader, John Watts, and a sister of Old Tassel. He was a headman of the Cherokees and a chief of the Chickamaugas. It is said that Nathaniel Gist, a Pennsylvania German, married another of the sisters of Old Tassel and became the father of George Gist, the famous Sequoia, inventer of the Cherokee

syllabary. Two other distinguished nephews of Old Tassel were Tolluntiskee, a principal chief, and his brother, John Jolly, also a principal chief.

The Wolf Clan, the line of Little Carpenter as we have seen, has also given in more recent times the famous medicine woman, Ayasta, mother of Will West Long, Climbing Bean Calhoun, Lawyer Calhoun, Morgan Calhoun, and John Calhoun. Of these, Will West Long and Morgan Calhoun were famous medicine men of the Wolf Clan at Big Cove. The famous Swimmer, Mooney's formula informant, was of the Wolf Clan and married a Blue Clan woman. His daughter Mary had a son Uweti who had a son, Luke Swimmer, living in the reservation in 1932.

Yonaguska or Drowning Bear was a peace chief and the best orator of his time. He married twice, in both cases women of the Wolf Clan. His son Julio married Ensi of the Deer Clan and had a son Faidil Skiti or Waving Ears, who was a householder in Big Cove in 1932.

From this and other examples, it may be seen that descent can be traced back to the period of the middle nineteenth century and beyond. The continuity of descent afforded by the clan traditions of superior achievement, especially in the cases of the Wolf and the Twister Clans, doubtless accompanies the transmission of formulary lore and other cultural items. Thus it is made to appear that a tribal society such as the Eastern Cherokee is essentially made up of contending lineage groups (clans) each of which carries its own placement status within the society. The personalities produced by the lineage are but facets of the clan and the social standing of the clan. This is because behavior in a primitive society is always conditioned by lineage affiliations and by the prestige attaching thereto.

CONCLUSION

We have examined a number of facets of the Cherokee tribe operating in relation to its natural environment. In this brief paper the idea has been stressed that culture is mainly an ecological adaptation of a race to its environment and is designed to enable survival and expansion of the biological heritage of that race. In other words the culture is not regarded as operating, per se, in a vacuum. It is thought of as inseparable from the natural ecology of the race or people under consideration. The people are primary objects of consideration, their culture secondary.

The first principle of social continuity of the generations is illustrated by the clan or matrilineal lineage. Next, attention is called to the principle of rhythms in nature and the commemoration of these rhythms in the ancient monthly feasts. These in turn are shown to be the likely antecedents to the modern Cherokee dances which commem-

orate the rhythmic recurrence of needs just as did the ancient monthly feasts.

Then, turning to the Cherokee prayers or sacred formulas, which are in some cases hundreds of years old, it was found that they lend force to social continuity through their conservation and commemoration of traditional values, both orally and in writing. The prayers are in turn buttressed by the myths or stories that illustrate the thinking of the ancestors and explain the present in terms of the past.

The town or community life of the Cherokees shows its roots in the clan lineage system and its relation to the civil and military needs of a primitive people. Out of this lineal emphasis of the community life emerges a view of the Cherokee personality, a product of lineage and social status, but permissive nonetheless of special individual achievement.

The final conclusion is that Cherokee life today is a going concern and gives no evidence of dying out or disappearing through absorption within the non-Indian society that surrounds it. Commemoration and innovation are the two forces still constituting the cycle of life as far as the stream of Cherokee existence is concerned.

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Dried Meat—Early Man's Travel Ration [1]

By Edward N. Wentworth
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Chesterton, Ind.

Primitive man originated three methods of meat preservation—freezing, salting, and drying. Later on, according to skills and latitude, he developed further offshoots of each through refrigeration, spicing, and smoking. Some tribes that lived near salt springs, dead seas, or ocean flats discovered that salt was a good preservative, while the subarctic tribes naturally learned the efficacy of cold. Drying came from experience on the edges of the desert or in mountain altitudes where the air was light and arid. When the atmosphere proved too humid for the sun- and wind-drying process, these methods were supplemented by fire, either in outside frames or in the hut, and the smoke from the wood or brush imparted distinctive flavors.

Drying as a method of preservation was just as natural a discovery as were the other two. Any meat left on a carcass by a predator or hunter would dry quickly in the regions were humans first emerged from the anthropoid. Possibly this location was Asia or Africa; and most probably it was north of the Himalaya Mountains. Perhaps the method of drying was worked out independently in several locations. For example, archeologist William A. Ritchie of the State of New York has found extensive sites in Cayuga County, which radio-carbon dating by Dr. W. F. Libby of the Atomic Energy Commission shows to have been in existence about 3500 B. C. Apparently large racks for meat and fish drying were erected, and numerous remains of bones (principally deer) were present—either whole or cracked for the marrow. Dried meat has been found in the ancient Sumerian sites, on the lower Egyptian Nile, and in the extreme northern and eastern edge of Mongolia. In a few cases it can be determined definitely that the meat was dried before storing. Perhaps the first tradition in Europe was learned from the experiences of Genghis Khan, Tamerlane, and other "Hun" invaders. In their first expedition, the Mongols ran short of the cattle they drove en route, but they apparently

[1] Reprinted by permission from Agricultural History, vol. 30, January 1956.

had enough dried meat in their haversacks to last until they could find additional food in the civilized settlements.

In the days before wheeled transportation, it was very important to carry meat in some form that would not spoil and yet could be conveniently borne by travelers on foot or horseback. Even before recorded history began, swarms of warriors, traders, and travelers were traversing the trade routes along the Mediterranean Sea—the famed "Course of Empire." Wild food animals disappeared rapidly, and farmers that dwelt along the highways could not raise enough cereals or domestic livestock to meet the needs of the villages already in the course of development. Ultimately, market centers grew up where pastoral tribes, hunters, and farmers, operating in areas lying off the trade routes, could bring their meats and grains for sale in a form the wayfarer could use. Jerky was a prime market product.

The practice of meat drying undoubtedly came to this continent by the great migration across the Bering Strait several millennia ago. It was the most convenient method of preserving meats, at a minimum weight, that the Asiatic tribes reaching North America then knew. No one can date the calendar for this event, but it was at least 40 to 60 centuries ago. Possibly the method of desiccation with which this continent was acquainted had originated in several places but, because it was so uniform among all the primitive tribes in America, it seems likely that it sprang from one source.

In the Western Hemisphere, dehydration of meat was practiced all the way from the Arctic Circle to Patagonia. On the east coast of South America, numerous Brazilian and Paraguayan tribes, including those in the swamp areas, dried their seasonal meats over smoke. The Portuguese explorers called this meat *xarque*; the Spanish explorers, *char-qui;* and the English, *jerky*. In North America the term *jerky* was confined principally to the United States, with only slight usage in Canada—probably adopted from the fur traders.[2] However, Charles J. Lovell calls attention to the fact that references to pemmican were in the literature of Canada as early as 1743 and 1772.[3] The Mexicans used still another word, *tasajo*, which may be nearer the original Indian sound, but now it cannot be identified.

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[2] V. Stefansson to author, February 16, 1955.

[3] Charles J. Lovell to author, February 16, 1955, quotes James Ishman's Observations on Hudson's Bay, 1743, p. 156, Toronto, 1949, where it is called "Pimmegan," and the Cumberland House Journal of the Hudson's Bay Company, September 23, 1777, which lists 2,924 pounds of beat meat, 1,720 pounds of "Fatt," and 100 pounds of "Pimmacon." The first citation in print in England is in the Oxford Dictionary in 1801, from Alexander Mackenzie, the great Canadian explorer, and the first citation from an American source was from the Lewis and Clark expedition in 1804, though the dictionary purports to include only words that first entered the English language in the United States.

In the fifteenth century dried meats were known traditionally by the Celts in Wales, Ireland, and Scotland, as used by their warrior forebears 8 or 10 centuries earlier. The Basques in the Pyrenees, as well as the French races of old Provence, were familiar with the product during the ascendency of Rome. Earlier still, the ancient races of lake dwellers in the Balkans, Switzerland, and islolated regions of the Alpine mountain chains, left remnants of dried meats around their ancient dwellings that indicated their use of the product.

In his study of the American Indian, Clark Wissler divided the North American continent according to basic meats consumed.[4] Throughout the arctic and subarctic regions the chief dependence was placed on the flesh of the caribou, although in the northeast musk oxen were occasionally substituted. The salmon area extended as far south as San Francisco and eastward to the crest of the Sierras. The heart of the continent, however, depended on the bison, which even today contributes the best flavored jerky produced under conditions of sun and wind drying. In eastern Canada and New England, deer and moose, with an occasional elk, furnished the foundation; while along the Atlantic coast to the south, and in the Gulf region, deer and an infrequent bear seemed most important.

The first historical reference to jerky in the Western Hemisphere was furnished by Castañeda, who prepared the records of the Coronado expedition (1540–1542). Two standard translations exist, the older being by George Parker Winship:

They dry the flesh [of the bison] in the sun, cutting it thin like a leaf and, when dry, they grind it like meal to keep it, and make a seasoup of it to eat. A handful thrown into the pot swells up so as to increase very much. They season it with fat, which they always try to secure when they kill a cow [bison].[5]

The other standard translation, by Hammond and Rey, renders, "seasoup" as "mash" and romanticizes the "pot" by calling it an "olla."[6] Some students have tried to assume that Castañeda referred to pemmican rather than jerky because of his allusion to fat, but it seems rather obvious that he was discussing fat added during cooking or eating. Pemmican itself seldom required added fat to improve its appetite appeal, as it usually consisted of 35 to 50 percent fat and on the northern plains it might contain as much as 60 to 80 percent.

The chief problem was to gather enough meat during the hunting season to warrant drying. Both the plains Indians and trappers relied on the bison, but the forest-dwelling tribes also sought caribou, moose, and deer. Indian attempts to catch numbers of salmon during

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[4] Clark Wissler, The American Indian, 2d ed., pp. 2–3, New York, 1922.

[5] George Parker Winship, The Coronado Expedition, 1540–1542, Fourteenth Ann. Rep. Bur. Amer. Ethnol., Pt. I, pp. 527–528, 1896.

[6] George P. Hammond and Agapito Rey, Narratives of the Coronado Expedition, 1540–1542, pp. 262, Albuquerque, 1940.

the seasonal runs have been well described by explorers and anthropologists. But not many are familiar with methods used by the tribal hunters of the Mississippi Valley before the horse age, who dwelt on the borders of the bison range. They hunted the bison afoot, a difficult and dangerous procedure.

Back in 1700 Nicholas Perrot, French commandant of the Northwest, described an even earlier buffalo hunt among the Illinois tribe.[7] Long before daylight a hunting party of young braves started out in three groups. One section went to the right, another to the left, and the third served as gap closers, dividing into two parts—able to support the right or left groups as they needed re-enforcement. The bison was more than a match for single hunters who approached on foot.

A long section or file was formed on each side, and after traveling about a league toward the bed grounds of the herd, some of the party remained to await daylight. After another league had been covered, a second party was detached, while the rest marched another half league and waited there. When the dew had dried, they closed the opening between the right and left groups and encircled the entire area, setting fire to the dried herbage. At this moment, the old men and boys from the tribal village joined them, and the completed fires on four sides surrounded the game. A few of the bison would try to break through the burning barriers, but the hunters could usually turn single animals back to their companions in the fiery enclosure. Perrot reports that sometimes a single village would obtain as many as 1,500 animals.

Bison killed during the summer when the animals were fat and their coats thin proved the best. The flesh was then of the finest quality and the pelts were easiest to remove and dress. The meat was cut along the muscle fibers instead of across them as we commonly do, so the flavors inherent in the juice could be preserved while dehydrating. However, the slices were cut into as thin strips as stone knives would permit. Our American Indians were Stone Age men when Europeans first reached here, except for a limited number of tribes which had access to impure natural lead or copper ores. These metals were beaten into knives with hammers and then ground along the edges.

The flesh was dried as rapidly as possible in the sun and wind or, if too humid, in the smoke of the fire inside the lodge. This process actually mummified the meat and made it quite tough. Meat dry enough to last in damp, warm climates was difficult to chew. Hence it was usually pounded into small fragments and placed in skin bags

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[7] Emma Helen Blair, ed., The Indian tribes of the upper Mississippi Valley, pp. 121–122, Cleveland, 1911, contains translation of Nicholas Perrot's "Memoirs of the Manners, Customs and Religion of the Savages of North America," originally published by Jules Tailham, Leipzig and Paris, 1864.

(christened by the French Canadians *parflèches*) to make it convenient for travel or storage. Pulverizing was customarily accomplished by use of stone hammers or wooden clubs against stone. Many fragments of rocks were thus included in the "beat meat" or "pounded meat," as the fur trade came to call it. When fully dried, a bison cow was estimated to yield 45 pounds of dried meat which was quite a saving in weight in comparison with the original carcass.

The meat-drying operation was a community and tribal affair. In 1843, Thomas J. Farnham reported quite vividly a picture of meat drying by the Kaw tribe on the Pawnee Fork of the Arkansas River in Kansas, near present-day Larned:

> Their wigwams were constructed of bushes inserted into the ground, twisted together at the top, and covered with the buffalo hides which they had been gathering for their winter lodges. Meat was drying in every direction. It had been cut into long narrow strips, wound around sticks standing upright in the ground, or laid over a rick of wicker work, under which slow fires are kept burning. . . . They make a yearly hunt to this region in the spring, lay in a large quantity of dried meat, return to their own territory in harvest time . . . and thus prepare for a long and merry winter. They take with them, on these hunting excursions, all the horses and mules belonging to the tribe, which can be spared from the labor of their fields upon the Konzas River, go south until they meet the buffalo, build their distant wigwams, and commence their labor. This is divided in the following way between the males, females, and children; the men kill the game; the women dress and dry the meat, and tan the hides . . .; the younger shoots of the tribe during the day are engaged in watering and guarding the horses and mules that have been used in the hunt—changing their stakes from one spot to another of fresh grass, and crouching along the heights around the camp to notice the approach of foes and sound the alarm. . . . Unless driven from their game by the Pawnees, or some other tribe at enmity with them, they load every animal with meat and hides about the first of August, and commence the march back to their fields, fathers, and wigwams on the Konzas River.[8]

Not much has been written about *half-dry* meat. Stefansson states that this is the favorite form of preparation, when the caribou are fat, over Canada from Lake Athabaska northward.[9] First the carcass is split down the back and the side is boned out. The choicest lean for making this preparation is taken from the hams and tenderloins. Some persons, principally traders, do not wish to have too much fat, so the excess is stripped off. Then the boneless side or "rib blanket" is hung like clothes on a wash line. A rawhide or other rope is used for suspension, or the meat may be spread over the branch of a tree. If the flesh is laid on the ground it must be turned at frequent intervals. The intention is to have the meat dry on the outside, but on the inside it still retains considerable moisture. Where the

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[8] Thomas J. Farnham, Travels in the great western prairies (2 vols.), vol. 1, pp. 63–67, London, 1843.

[9] Stefansson to author, January 26, 1955.

sun strikes it, a sort of glaze is formed which is airtight, and the fur trader was very fond of the resultant flavor. Stefansson remarks that the outside "skin" protects it through the months of hot weather, and the half-dry meat is highly appetizing.

The usual method of cooking is to roast the sides by the fire, but the half-dry meat is also excellent if boiled. Since tooth decay is normally an affliction of starch, sugar, and cereal eaters, there was no trouble in chewing this meat among tribes north of the Mandan country. Of course, traders from England, France, New England, and eastern Canada, with teeth already decayed, did have some difficulty in chewing. However, the natives never faced that problem and Stefansson states that meals of good half-dry boned caribou ribs, properly roasted, are the most delicious he has ever eaten.

During World War II the author was on the advisory staff of the Quartermaster General (with various explorers and geographers like Stefansson and Earl Parker Hansen), and had opportunity to learn several interesting criticisms of dehydrated meats. One of the first objections came from the members of our own committee, who felt that the meat did not "taste right." It was prepared at low temperatures and with a minimum of light and air. Sun drying permits the development of flavors arising from the natural enzymes in the meat, as well as from the crusting, or membrane, which appears on the outside during the drying process.

Some people less practiced in the use of jerky and pemmican complained that the sun-dried product had a "fishy flavor." Others expressed the opinion that the taste was due to the fats rather than to the proteins. Not much scientific research has been conducted on the relationships between the amino-acid composition of various proteins and their flavors. However, it is known that when the fats are completely removed, there seems to be little difference in taste between the flesh of various orders, genera, or species.

Sun drying required thin slices so as to obtain rapid removal of water under the hot sun and the circulation of dry air. There are two kinds of reactions in the proteins; one due to the enzymes natural in the meat and the other from enzymes of the micro-organisms. The action of the enzymes of the meat takes place normally, and produces the "aged" flavors to which we are accustomed. On the other hand, undesirable flavors may be developed by enzymes of organisms that act on amino-acids and the derivatives, converting them into highly odorous substances such as amines, mercaptans, and skatole.

This strong flavor in carelessly handled meat dried in the more humid regions provides one of the reasons why jerky has never found an important outlet in the civilized areas. In more recent times a second cause of unpopularity was the time required in the home to

soak and cook it before it was usable. During the early 1940's, an attempt was made to manufacture so-called "dehydrated meat," which was of very good quality, but on account of the war and the employment of so many homemakers in defense industries, it was not possible for them to obtain the time to dehydrate it and prepare it for the table.

With further reference to enzyme action, it should be noted that neither the naturally occurring enzymes found in the meat nor those caused by micro-organisms can act if the water content of the meat is reduced rapidly. When the percentage of water is dropped to 6 to 8, enzyme action is extremely slow, and by the time it is reduced to 2 or 3 percent, it is stopped. Thus dehydrated meat, during this period, as prepared for military and civilian personnel, had the water content carried down to 3 or 4 percent as quickly as possible.

It proved very difficult to pulverize half-dry meat evenly for storage in the *parflêches* of the frontier, and both condition and flavor were often affected adversely when exposed granular fragments had different water contents. Since the chief part of the off-flavors that come in the proteins arise from outside action after the meat is ground, when it was dehydrated for wartime use the temperature was raised to 165° to 170° to "pasteurize" it. There are some enzymes in the flesh that, even at that temperature, may still be active, but the primary purpose is to destroy vegetative forms of life that act on the product through the elaboration of their own enzymes.

In the packing house, during World War II, the meat to be dehydrated was ground just as in hamburger or sausage. One of the large companies dried the product through a tunnel with a current of air passing over it, and another used a louver process. A third dried the ground meat in open pans and then transferred it to a vacuum. The latter process took care of the final drying, as well as any undesirable volatile products. [10]

The chief factor in developing the "fishy" taste in sun-dried jerky, to which inexperienced people objected, came from the fats. In sun and wind drying, unsaturated fatty acids tend to oxidize, producing substances that contribute to their distaste. Of the unsaturated fatty acids whose oxidation produces unrelished flavors, the two most important are linoleic and linolenic (characteristic of linseed oil and very important in the skin health of mammals). The higher the temperature of the process, the more these oxidized fatty acids develop and the more pronounced the "fishy" flavor.

To most people, a degree of "fishy" taste is not so bad. The rarer flavors of aged cheese and the epicurean delights of well-hung game arise through similar aging, or proteolytic conditions. However, during World War II housewives were not accustomed to these flavors,

[10] Byron T. Shinn to author, February 18, 1955.

so processes were used that held them in check. Also a small amount of salt (1 to 2 percent) was added to increase the appeal to the average consumer. In spite of the most superior techniques, the dehydrated meat never became popular. In the military service, helicopters, airplanes, and parachutes made possible the delivery of canned meats to which the military personnel in isolated posts was accustomed. At such posts as radar stations along and over the Himalayan hump, well within the enemy lines, delivery by air was almost regular.

An early discovery of prehistoric days was that dried meat was so difficult to swallow that it could not be eaten in a hurry, and dipping it in water made it even more tasteless than before. However, when the dried meat was dipped in melted fat, or even in oils that were liquid at ordinary temperatures, the ease of swallowing was greatly improved. Where the fats were too hard at normal temperatures, melting was often impossible during the chase or in the proximity of enemies, so that hunter or warrior introduced pieces of fat into his mouth at the same time that he bit off a chunk of jerky. This practice may have led to the manufacture of pemmican.

Hodge states that the word "pemmican" means more than the simple thought of fat—it also implies its manufacture.[11] He translates the Cree Indian word *pimiy* as meaning "he makes grease." The Indians boiled the crude fat in water and skimmed off the supernatant oil. However, it may be going wide of the mark to derive the word pemmican from the Cree language.

Catlin and other early travelers report the collection and cracking of buffalo bones, which were broken and boiled to extract the marrow fat which the tribes prized highly.[12] The marrow from the long bones, when cracked, could be easily extracted by physical methods, but the fat from the cell cavities at the end of the bones (or any other bones that had a spongy structure) was usually obtained by crushing and boiling. Furthermore, Catlin states that the fat was put into bison bladders, which had been distended, for storage and later consumption. He says that marrow fat after cooling became quite hard "like tallow," and possessed the appearance and very nearly the flavor of richest yellow butter. A second motive in keeping the marrow fat separate was that it required more careful handling to prevent rancidity—it would not keep as well as ordinary tallow. At feasts, chunks of the marrow fat were cut off and placed in a tray or bowl with the jerky, so both could be eaten together. He suggests that this was a good substitute for bread and butter, and might even be considered the dietary equivalent of that food for the tribesmen.

[11] Frederick W. Hodge, ed., Handbook of American Indians north of Mexico, Pt. 2, p. 223, Washington, 1910.

[12] George Catlin, The manners, customs and condition of the North American Indians, p. 116, London, 1841.

There was never enough marrow fat to make the amounts of pemmican which the Indians and frontiersmen required, so this type was known as *sweet* pemmican.[13] The ordinary pemmican was made by adding the fat from the hump of the bison, from under the skin, or from the body cavity. The latter was the hardest, and was preferred to the fat nearer the exterior of the body. Both caribou and buffalo pemmicans were formed by the addition of their own fats. Their range was treeless, and the natives had to hunt as fast as their quarry moved. Most of the time it was impossible to dry the meat and make the pemmican while the hunt was in progress, so the meat was stripped off the animals as fast as possible and cached each day. When enough was secured, it was dried, assembled, and the pemmican was manufactured.

In some cases, as a variant, wild cherries (pits and everything) were dried, pulverized, and mixed with the pounded meat. Thornapples were also used, as well as June berries and chokecherries, and, still farther north, "sarvis" berries. While these introduced special flavors, most of the trappers and explorers preferred the simple jerky and fat. However, in the winter camps some squaws were said to like more variety, and it was in part to satisfy the feminine tastes among Indians that berries were added. Also it may have been a white man's idea. Stefansson states that at the height of pemmican's use by whites around 1820, from 1 to 5 percent of it was of the flavored or holiday sort (salt, raisins, dried berries, sugar, etc.), the cake variant of the "bread of the wilderness."[14] In many cases where the fruit pemmican was prepared for the men on long or difficult expeditions, the simple dried-meat and fat type was prepared for the dogs used for transportation. After a few weeks' experience, almost without exception, the men exchanged their ration for the "dog pemmican," and the dogs got the "cake" variety.

For fish pemmican in the northwest area, salmon was dried and soaked and then pounded fine in stone mortars. These dried fish could be stored in baskets, or fish fats could be added to make standard-type pemmican.[15] In either case it was considered an emergency food, since most of the tribes (especially those of the interior) preferred the product made from bison or deer meat. The sturgeon provided the principal fish oil, although in some cases seal fat was used.

The Eskimos did not produce jerky, although they were familiar with the Indian product south of them. Their substitute was known as akutok and was based on caribou meat, which was sliced thin and wind dried until an outside crust was formed.[16] The inside, though,

[13] Hodge, ibid., pp. 223, 224.

[14] Vilhjalmur Stefansson, Not by bread alone, p. 182, New York, 1946.

[15] Wissler, The American Indian, p. 9.

[16] Stefansson to author, February 16, 1955; Not by bread alone, p. 37, n.

was merely half dry. The resultant meat did not grind satisfactorily to form jerky, as only an occasional piece was dry enough to be suitable. Consequently they chewed their meat instead of grinding it, and spat it out to be dried.[17]

In the old days when pemmican was being manufactured it was poured into the bag, and watch was kept to flatten the sides to a thickness of 6 to 7 inches—thereby giving it more of a brick shape when it was cooled. This aided in stacking and storing it, and in general made it convenient to handle. Gradually these bags were standardized for the fur trade at about the size of an old-fashioned bed pillow, and would weigh, when filled, from 80 to 90 pounds. In this form the bags were known as "pieces of pemmican." Each bag was of buffalo rawhide, the hair side out. When filled, the mouth was sewed shut and all the seams were greased with fat, which was applied when cool enough to congeal. This excluded air from the contents, and prevented water from reaching the interior—if a canoe was upset, for example.

The French fur traders and trappers, as stated previously, christened these rawhide bags *parflêches*, and specified slightly different shapes. They required that they be roughly cylindrical and taper toward the bottom. Usually they were fringed on one side, and were used for storage rather than for shipment.[18]

Around the turn of the twentieth century the rawhide bags were also called *taureaux* (bulls). Alexander Henry reported receiving in the Red River country of Dakota four *taureaux* of pemmican per canoe, each load weighing over 300 pounds. These *taureaux* were also rawhide bags whose contents totaled about 80 pounds. Sometimes the name *taureaux* was transferred to the same amount of pemmican when it was packed differently. The best quality of pemmican came from the upper Red River in Dakota, and when circumstances prevented Henry from getting other food he wrote:

> We now were obliged to eat pemmican, and had a few bags which had been lying all summer in a heap covered with a leathern tent. I was apprehensive that it was spoiled from the complaints made by my friends about the bad quality of Lower Red River pemmican, but was surprised to find every bag excellent. This was clear proof to me that the bad pemmican [of which they spoke] came from another quarter—I suspect Portage-la-Prairie [west of modern Winnipeg and not on the Red River].[19]

Pemmican was a summer food, used in hot weather by Indians, traders, trappers, and explorers. Contrary to usual modern dietitians'

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[17] Hodge, ibid., pp. 223, 224.

[18] Robert H. Lowie, The Crow Indians, p. 79, New York, 1935.

[19] Elliott Coues, The Red River of the North *in* New lights on the early history of the greater Northwest. The manuscript journals of Alexander Henry and of David Thompson, vol. 1, p. 276, New York, 1897.

teachings, the percentage of fat desired was as high in summer as in winter. A convenient method of figuring the proportion of fat is by the calories furnished from it in proportion to the calories coming from the lean. Most Americans tasting pemmican for the first time prefer 50–50, or at most 60–40. But for the hard-working *coureurs-de-bois* 70–30 was too small, and 80–20 was preferred. When Earl Parker Hansen, the tropical explorer, went to Liberia a few years ago, Armour and Company manufactured both 70–30 and 80–20 varieties for him, but in a few days he came to the conclusion that only the latter suited his needs. Similarly, for cold climates, R. E. Priestley, favored an even higher proportion, 60 percent of fat by weight, which probably provided more than 90 percent of the calories.[20]

The problem of bulk was another question leading the way from jerky to pemmican. The original strips of dried meat were never flat enough to pack well and the "beat meat" was too fluffy. When ready for manufacture into pemmican, the bag, bladder, or other membrane receptacle, was filled loosely (like feathers in a pillow), and melted tallow, about the temperature of lard for frying doughnuts (365° F.), was poured into the container.[21]

An excellent illustration of the importance of this reduced bulk occurred during the Gold Rush in California. The hordes of prospectors soon exhausted the game supply, the surplus from the Mexican- and Spanish-owned ranches, and the animals that could be driven from nearby territories like New Mexico and the Midwest. So important amounts of Oregon jerky and pemmican (especially the former) were shipped by vessel to San Francisco or transported by pack animals to the northern California mining regions.

The food value of pemmican is surprising. Considered from the standpoint of calories the maximum of energy that can be crammed into a pound of digestible food is around 4,000 to 4,200 calories—the amount in a pound of pure lard.[22] Pemmican often yielded 3,200 to 3,500 calories, depending on the ratio of fat. Three-quarters of a pound of pemmican was needed for the day's ration, although the hard-working *coureurs-de-bois* of the fur brigade often consumed a pound and a half to two pounds, when making long portages.

These French Canadians (especially those working for the Hudson's Bay Company) carried their pemmican by the "piece." Since a piece of pemmican varied from 80 to 90 pounds in weight, the Hudson's Bay porters carried one, two, or three "pieces"—80 to 90, 160

[20] Raymond E. Priestley, Antarctic adventure, p. 344, New York, 1915.

[21] V. Stefansson, "Pemmican," Activities Report—Research and Development Associates, Food and Container Institute, Inc., vol. 3, pp. 243–244n, 1951. His principal work on pemmican is in Not by bread alone, pp. 185–187.

[22] Shinn to author, February 18, 1955.

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to 180, or 240 to 270 pounds. In addition, they were "allowed" to carry anything like their own equipment, such as their blankets, hatchet, pipe, tobacco, mosquito net, spare clothes, and even a present for the wife.[23] "Three-piece" men were rare, famous from Edmonton to the Arctic Ocean, and well-nigh Dominion heroes.

One of the fears expressed regarding a pemmican diet arose at the beginning of World War II, when the military and naval physicians worried about the development of ketosis in the average soldier or sailor—especially if he received only a fat and protein diet without carbohydrates to serve as a source of quickly available glycogen (animal sugar as it exists in the blood). When the available supply of glycogen gets low, one undergoes a form of nerve poisoning by the ketones, which are one of the products of fat metabolism and which are very active chemically since they characteristically have only an atom of oxygen to one of carbon and are really "predatory" on the nervous system. Peary and other Arctic explorers offset this by using a supplement of ship's biscuit, but the hard-working trappers and voyagers seemed to have grown into adjustment to the high-fat low-carbohydrate diet as a matter of long conditioning.

While some military subjects on an experimental pemmican diet during World War II developed the odor of ketones on their breath, apparently the only ones who believed themselves seriously affected were those who had been informed of such a possibility in advance.[24] Ketosis, in the extreme, is what causes athletes to collapse at the end of a strenuous race, but it is quickly overcome by the introduction of glucose into the circulation. Under ordinary military conditions, where one would choose in an emergency between the consumption of pemmican or the possibility of starvation, pemmican seems to be far the more intelligent selection. Men accustomed to eating it would scarcely exchange such food for anything else, as noted later.

A second worry arose over scurvy. This last disease is caused by a deficiency of vitamin C in the diet. Nearly a century ago it threatened winter life on the frontier, and was not a disease expected solely at sea or in the barren north. Col. Philippe Regis de Trobriand struggled against it among his troops in Dakota in the winter of 1867–68. He begged for cattle for fresh meat as early in the fall as September for, he said, "some cases of scurvy have already broken out in the garrison as a result of using salted meat and being without vegetables too long." [25] Many times authorities believed that scurvy was

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[23] Stefansson to author, February 16, 1955.

[24] Interview of Col. E. C. Mattick by author, January 28, 1942.

[25] Phillipe St. Regis de Trobriand, Military life in Dakota, ed. by Lucile M. Kane, p. 71, St. Paul, 1951.

caused by lack of exercise and by filth, but by March, de Trobriand was convinced that it was due to something lacking in the food. He blamed the "limitation of fare which, because of the absence of fresh vegetables, eggs, fowl, veal, mutton, and even game, had reduced us to a diet that brings scurvy to the soldiers and takes the edge off the appetites of the officers." [26]

Meat may lack the concentrations of vitamin C to bring instant therapeutic response, but by de Trobriand's time commanders in the field knew that it would bring early relief, and when used in advance would prevent the appearance of the disease. A half-century later, Dr. Alfred Hess presented a paper on scurvy before the American Medical Association in New York.[27] He stated that he used fresh lemons, limes, grated oranges, and grated raw vegetables, but on meat alone Stefansson obtained the same results. Both diets required four days for recovery. Furthermore, they were found to be equally quick acting in cases of scurvy when the patients were gloomy in spirit, too weak to stand, and had pain in every joint.

Another decade was required after de Trobriand to give proper credit to pemmican on these points. A serious outbreak of scurvy took place among the members of the Arctic expedition of Sir George Nares in 1875–76 and a committee was appointed by the British admiralty to conduct his court-martial. The most effective witness was Rear Adm. Sir Leopold McClintock, who had been the outstanding personage to emerge from the numerous searches for the lost Sir John Franklin expedition of the late 1840's.[28] He testified that he used lime juice (the standard remedy of that date) on only one expedition, and that whenever he could use fresh meat—and he stated emphatically that he considered the dried meat in pemmican equally as efficient as fresh—he had no trouble with scurvy.

During World War II some authorities objected to the assumed high percentage of protein in pemmican, and recommended the addition of carbohydrates. Protein requires more water in human metabolism than starches and sugars. In fact the water requirement is more than seven times as great in protein. But starches and sugars cannot rebuild the muscular tissue and human vigor declines, while the energy-releasing foods accumulate uselessly because the human machine is running down. The fat in pemmican is particularly important in this connection for it releases relatively large amounts of water,

[26] Ibid., p. 238.

[27] Stefansson quotes Hess in Not by bread alone, p. 171.

[28] Report of the Committee Appointed by the Lords Commissioners of the Admiralty to Enquire into the Causes of the Outbreak of Scurvy in the Recent Arctic Expedition—presented to both Houses of Parliament—London, 1877. Admiral McClintock's testimony was given January 20, 1877, on p. 110 ff., questions on pp. 3248–3399.

about 1.1 grams of metabolic water to each gram of fat. Popular knowledge of this phenomenon comes from the fat of the camel's hump, the water tank of the "ship of the desert." Hence, plane crews bailed out on the arid plains, or sailors cast out in a life boat can live much longer on pemmican because the fat conserves the body water and the protein rebuilds the body tissue. If lost for a short time carbohydrates are satisfactory, but if the time is longer protein must be in the ration for survival. If one has room enough for starchy products there is a slightly greater amount of metabolic water formed per calorie of energy from starch than is formed per calorie of energy from fat. However, the difference is very small, and the fat and protein combination is a much more compact unit of energy than is the starch and protein combination.[29]

Pemmican was not planned to be a regular food supplanting all others, but was really an explorer's, adventurer's, or traveler's ration. It was intended for hungry men, not for epicures, gourmets, or connoisseurs. The remarkable thing about it was that it could be used so long, be completely nutritive, and still appeal to the man using it. It creates no appetite when first placed in the mouth, but the longer it stays, the better it tastes, and the longer one eats it the more he appreciates it. After living on it for months at a time, on several polar trips, Admiral Peary wrote:

> It is the most satisfying food that I know. I recall innumerable marches in bitter temperatures when men and dogs had worked to the limit and I reached the place for camp feeling as if I could eat my weight of anything. When the pemmican ration was dealt out, and I saw my little half-pound lump, about as large as the bottom third of an ordinary drinking glass, I have often felt a sullen rage that life should contain such situations. By the time I had finished the last morsel, I would not have walked around the completed igloo for anything or everything that the St. Regis, the Blackstone, or the Palace Hotel could have put before me.[30]

In a similar vein Raymond R. Priestley, who was a member of the scientific staff of the first Shackleton Expedition, 1907–09, and the second Scott Expedition, 1910–13, is equally full of praise:

> Under ordinary circumstances, when one first starts on a journey, one's full allowance is seldom eaten, but, as time passes and the work and the keen air take effect, one becomes hungrier and hungrier, until the sledging allowance of pemmican is not sufficient to satisfy the cravings aroused. It is then that pemmican is truly appreciated at its full worth. Nothing else is comparable with it. I have taken all sorts of delicacies on short trips when the food allowance is elastic, I have picked up similar delicacies at depots along the line of march, and I have even taken a small plum-pudding or a piece of wedding-cake for a

[29] Shinn to author, February 18, 1955.

[30] Admiral Robert E. Peary, The secrets of polar travel, pp. 77–79, New York, 1917.

Christmas treat, but on every such occasion I would willingly have given either of these luxuries for half its weight of the regulation pemmican.[31]

Stefansson caps it all by writing:

Pemmican . . . has been found to continue tasting good to those with good appetites, even when no food but pemmican has been used for weeks on end. . . . So it is about pemmican as the Scots are said to remark about whisky—there is no bad pemmican, but some are better than others.[32]

That this statement applies to a man with his heart in his work rather than to one with play in his heart is obvious, but which man of the two converted our "wide-open spaces" into our modern economic scene?

[31] Priestley, Antarctic adventure, p. 344.

[32] Stefansson, "Pemmican," p. 251.

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