Annual Report of the Board of Regents

of the

SMITHSONIAN INSTITUTION

PUBLICATION 4232

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

1955

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LIST OF PLATES

THE SMITHSONIAN INSTITUTION

June 30, 1955

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

Members of the Institution:

DWIGHT D. EISENHOWER, President of the United States.
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EARL WARREN, Chief Justice of the United States.
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CHARLES E. WILSON, Secretary of Defense.
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ARTHUR E. SUMMERFIELD, Postmaster General.
DOUGLAS MCKAY, Secretary of the Interior.
EZRA TAFT BENSON, Secretary of Agriculture.
SINCLAIR WEEKS, Secretary of Commerce.
JAMES P. MITCHELL, Secretary of Labor.
OVETA CULP HOBBY, Secretary of Health, Education, and Welfare.

Regents of the Institution:

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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.
CLARENCE CANNON, Member of the House of Representatives.
OVERTON BROOKS, Member of the House of Representatives.
JOHN M. VORYS, Member of the House of Representatives.
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ARTHUR H. COMPTON, citizen of Missouri.
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JEROME C. HUNSAKER, citizen of Massachusetts.

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Assistant chief, editorial and publications division.—JOHN S. LEA.

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Chief, supply division.—ANTHONY W. WILDING.

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

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Exhibits specialist.—J. E. ANGLIM.

Exhibits workers.—T. G. BAKER, DON H. BERKEBILE, R. O. HOWER, BENJAMIN LAWLESS, W. T. MARINETTI, EDWARD W. NORMANDIN, JR., MORRIS M. PEARSON, GEORGE STUART.

Chief, office of correspondence and records.—HELENA M. WEISS.

DEPARTMENT OF ANTHROPOLOGY:

Frank M. Setzler, head curator; A. J. Andrews, exhibits specialist; Mrs. Arthur M. Greenwood, Smithsonian fellow in anthropology; W. W. Taylor, Jr., collaborator in anthropology.

Division of Archeology: Waldo R. Wedel, curator; Clifford Evans, Jr., associate curator; George S. Metcalf, museum aid; Mrs. Betty J. Meggers, research associate.

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

Division of Physical Anthropology: T. Dale Stewart, curator; M. T. Newman, associate curator; W. J. Tobin, research associate.

Associate in Anthropology: Neil M. Judd.

DEPARTMENT OF ZOOLOGY:

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

Division of Mammals: D. H. Johnson, acting curator; H. W. Setzer, Charles O. Hanley, Jr., associate curators; J. W. Paradiso, museum aide; A. Brazier Howell, collaborator; Gerrit S. Miller, Jr., associate.

Division of Birds: Herbert Friedmann, curator; H. G. Deignan, associate curator; Gorman M. Bond, museum aide; Alexander Wetmore, research associate and custodian of alcoholic and skeleton collections.

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

Division of Fishes: Leonard P. Schultz, curator; E. A. Lachner, associate curator; Robert H. Kanazawa, museum aide.

Division of Insects: J. F. Gates Clarke, curator; O. L. Cartwright, W. D. Field, Grace E. Glance, associate curators; Sophy Parfin, junior entomologist; W. L. Jellison, M. A. Carriker, R. E. Snodgrass, C. F. W. Muesebeck, collaborators.

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

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

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

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

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

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Associates in Zoology: T. S. Palmer, W. B. Marshall, A. G. Böving, C. R. Shoemaker.

Collaborator in Zoology: R. S. Clark.

Collaborator in Biology: D. C. Graham.

DEPARTMENT OF BOTANY (NATIONAL HERBARIUM):

Jason R. Swallen, head curator.

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

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

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

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

DEPARTMENT OF GEOLOGY:

W. F. Foshag, head curator; J. H. Benn, museum geologist; L. B. Isham, scientific illustrator.

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

Division of Invertebrate Paleontology and Paleobotany: Gustav A. Cooper, curator; A. R. Loeblich, Jr., David Nicol, associate curators; Robert J. Main, Jr., Mrs. Vera M. Gabbert, museum aides; J. Brookes Knight, Mrs. Helen N. Loeblich, research associates in paleontology.

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

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

Division of Vertebrate Paleontology: C. L. Gazin, curator; D. H. Dunkle, associate curator; F. L. Pearce, G. D. Guadagni, F. O. Griffith, III, exhibits workers.

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

Associate in Paleontology: R. S. Bassler.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Frank A. Taylor, head curator.

Division of Engineering: R. P. Multhauf, curator; William E. Bridges, Museum aide.

Section of Civil and Mechanical Engineering: R. P. Multhauf, in charge.

Section of Tools: R. P. Multhauf, in charge.

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

Section of Electricity: K. M. Perry, 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; Edward C. Kendall, associate curator; E. A. Avery, museum aide; F. L. Lewton, research associate.

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

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

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

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

Division of Medicine and Public Health: George B. Griffenhagen, associate curator; Alvin E. Goins, museum aide.

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

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

DEPARTMENT OF HISTORY:

Mendel L. Peterson, acting head curator.

Divisions of Military History and Naval History: M. L. Peterson, curator; J. R. Sirlouis, assistant curator; Craddock R. Goins, Jr., junior historian.

Division of Civil History: Margaret W. Brown, associate curator; Frank E. Klapthor, museum aide.

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

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

BUREAU OF AMERICAN ETHNOLOGY

Director.—MATTHEW W. STIRLING.

Associate Director.—FRANK H. H. ROBERTS, JR.

Anthropologists.—H. B. COLLINS, JR., PHILIP DRUCKER.

Collaborators.—FRANCES DENSMORE, JOHN R. SWANTON, A. J. WARING, JR., R. J. SQUIER, R. F. HEIZER, SISTER M. INEZ HILGER, RALPH S. SOLECKI.

Research associate.—JOHN P. HARRINGTON.

Scientific illustrator.—E. G. SCHUMACHER.

RIVER BASIN SURVEYS.—FRANK H. H. ROBERTS, JR., *Director.*

ASTROPHYSICAL OBSERVATORY

Director.—LOYAL B. ALDRICH.

DIVISION OF ASTROPHYSICAL RESEARCH:

Chief.—[Vacancy.]

Astrophysicist.—FREDERICK A. GREELEY.

Instrument makers.—D. G. TALBERT, J. H. HARRISON.

Research associate.—CHARLES G. ABBOT.

Table Mountain, Calif., field station.—ALFRED G. FROILAND, STANLEY L. ALDRICH, physicists.

Calama, Chile, field station.—JAMES E. ZIMMERMAN, physicist; JOHN A. PORA, physical science aide.

DIVISION OF RADIATION AND ORGANISMS:

Chief.—R. B. WITHROW.

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

Biochemist.—JOHN B. WOLFF.

NATIONAL COLLECTION OF FINE ARTS

Director.—THOMAS M. BEGGS.

Curator of ceramics.—P. V. GARDNER.

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

Exhibits preparator.—ROWLAND LYON.

FREER GALLERY OF ART

Director.—A. G. WENLEY.

Assistant Director.—JOHN A. POPE.

Assistant to the Director.—BURNS A. STUBBS.

Associate in Near Eastern art.—RICHARD ETTINGHAUSEN.

Associate in technical research.—RUTHERFORD J. GETTENS.

Assistant in research.—HAROLD P. STERN.

Research associate.—GRACE DUNHAM GUEST.

Honorary research associate.—MAX LOEHR.

Consultant to the Director.—KATHERINE N. RHOADES.

NATIONAL AIR MUSEUM

Advisory Board:
LEONARD CARMICHAEL, *Chairman.*
MAJ. GEN. GEORGE W. MUNDY, *U. S. Air Force.*
REAR ADM. APOLLO SOUCEK, *U. S. Navy.*
GROVER LOENING.
WILLIAM B. STOUT.
Head curator.—PAUL E. GARBER.
Associate curator.—R. C. STROBELL.
Manager, National Air Museum Facility.—W. M. MALE.
Museum aides.—STANLEY POTTER, WINTHROP S. SHAW.

NATIONAL ZOOLOGICAL PARK

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

CANAL ZONE BIOLOGICAL AREA

Resident Manager.—JAMES ZETEK.

INTERNATIONAL EXCHANGE SERVICE

Chief.—D. G. WILLIAMS.

NATIONAL GALLERY OF ART

Trustees:
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JOHN FOSTER DULLES, Secretary of State.
GEORGE M. HUMPHREY, Secretary of the Treasury.
LEONARD CARMICHAEL, Secretary of the Smithsonian Institution.
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Secretary-Treasurer.—HUNTINGTON CAIRNS.
Director.—DAVID E. FINLEY.
Administrator.—ERNEST R. FEIDLER.
General Counsel.—HUNTINGTON CAIRNS.
Chief Curator.—JOHN WALKER.
Assistant Director.—MACGILL JAMES.

NATIONAL AIR MUSEUM

Advisory Board:
Leonard Carmichael, Chairman.
Maj. Gen. Donald W. M..., U. S. Air Force.
Rear Adm. ..., U. S. Navy.
Grover Loening.
William B. Stout.
Head curator—Paul E. Garber.
Associate curator—R. C. Strobell.
Manager, National Air Museum Facility—Walter M. Male.
Museum aide—Stanley Potter, Winthrop S. Shaw.

NATIONAL ZOOLOGICAL PARK

Director—William M. Mann.
Assistant Director—Ernest P. Walker.
Head animal keeper—Frank O. Lowe.

CANAL ZONE BIOLOGICAL AREA

Resident Manager—James Zetek.

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.
Samuel H. Kress.
Ferdinand Lammot Belin.
Duncan Phillips.
Chester Dale.
Paul Mellon.
President—Samuel H. Kress.
Vice President—Ferdinand Lammot Belin.
Secretary-Treasurer—Huntington Cairns.
Director—David E. Finley.
Administrator—Ernest R. Feidler.
General Counsel—Huntington Cairns.
Chief Curator—John Walker.
Assistant Director—Macgill James.

Report of the Secretary of the Smithsonian Institution

LEONARD CARMICHAEL

For the Year Ended June 30, 1955

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, 1955.

GENERAL STATEMENT

The period covered by this report has been an active and fruitful one for the Smithsonian Institution.

It was noted in last year's report that much time has been devoted to preliminary planning for the new buildings so urgently needed to make the museums of the Smithsonian comparable to the modern national museums of other great nations. The Institution's collections are probably the largest in the world, but because of the inadequacy of its present buildings these collections can now be presented to the public in only most limited ways.

Building Program Gains Congressional Support

It is a great satisfaction to be able to report that legislation providing for the planning and erection of a new museum building for the Smithsonian Institution was enacted during the first session of the 84th Congress. The bill, authorizing a $36-million Museum of History and Technology, was signed by President Eisenhower on June 28, 1955. Subsequently, Congress appropriated $2,288,000 for the immediate planning of this great new museum, bringing it even further toward the realm of actuality. During the discussion of this legislation on the floor of the House of Representatives, many favorable statements were made about the place of the Smithsonian Institution in our national life. All of us at the Smithsonian are indeed grateful for the hard work done by so many people in connection with this legislation, which clears the great hurdle from the path toward providing adequate and fitting housing for many of the Nation's priceless treasures. Certainly it is the greatest event for the Smithsonian Institution since the erection of the Natural History Building half a century ago.

The new Museum of History and Technology will house all the national collections that record and illustrate the political, cultural, industrial, scientific, and military development of the United States. For the most part the materials to be exhibited in this new museum are those now on display or stored in the Arts and Industries Building. Some collections now temporarily housed in the Natural History Building will also find a place in the new building.

The new museum as we plan it will be both a museum of United States history and a museum of science, engineering, and industry. This combination is especially appropriate for a nation in which the industrial revolution achieved a most luxuriant flowering—matching the earlier American Revolution that gave our country its freedom and its unique institutions.

The Museum of History and Technology will be the Nation's history book of objects. In it the main elements of our national progress will be represented and related. To replace the clutter of cases and machines that crowd the old Arts and Industries Building, we plan a series of modern halls highlighting the principal periods of our history from colonial days to the present. Each main hall will illustrate the dominant character of a particular period (the exploration of the West, for example) against a background of the times. This story of our national development will be told with original documents, machines, costumes, inventions, home furnishings, weapons, the personal effects of famous Americans, and many other classes of authentic objects.

Connected with these main halls will be others in which the exhibits will amplify the themes of the main halls with subjects that might include Agriculture and Trade in the Colonies, Transportation to the Frontier, and others. Many halls will illustrate the development of particular devices or subjects, such as automobiles, mining, medicine, costumes, manufactures, engineering, and science. Here will be demonstrated the painstaking study, work, management, and trials that have been the lifeblood of our Nation's progress. Likewise will be shown the Smithsonian's world-famous collections of stamps and coins, guns, watercraft models, and all the others that have made the Institution a mecca for scholars, collectors, and hobbyists, the country over.

The site chosen for the new building is the Mall area of Washington 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. Naturally much difficult and prolonged work lies ahead before such a monumental task can be consummated, but it is our earnest hope that the final planning of this new building may be done in 1956 and that construction may begin in 1957.

Other Buildings Planned

By the use of private funds given to the Institution specifically for the purpose, preliminary architectural studies were made during the year for the projected new National Air Museum. The proposed site for this museum is between 9th and 12th Streets, SW., on the south side of Independence Avenue, where it would be closely associated with other Smithsonian buildings. No final estimates have yet been given of the new Air Museum's cost or of the time when it may be most appropriate to ask for public or private funds for its erection.

This new building is urgently needed. The airplane is in many respects a product of the genius of the American people. The Smithsonian collections in this great field, beginning with the Wright brothers' "Kitty Hawk" itself, are unrivaled in the world. Today many of the most important treasures of the Smithsonian collection of aircraft and associated objects are crated and held in storage. They are thus not available either for the public or even for the use of engineers and patent authorities. As soon as possible it is important to find means, public or private, or both, for the erection of a suitable building for this great collection.

The National Collection of Fine Arts is now also most inadequately provided for in an incongruous setting in the Natural History Building. As was especially emphasized in last year's report, a new Smithsonian Institution Gallery of Art to house the great historical paintings in this collection, the National Portrait Gallery, and the work of deserving living artists is most urgently needed. The collections that will be displayed in the proposed new gallery would include painting, sculpture, ceramics, and other forms of decorative art.

Authorization to construct wings on the Natural History Building was approved by Congress in 1932, but it has never been implemented by an appropriation. Our superlative study collections in natural history are crowded from attic to basement and have extensively invaded the exhibition halls. To be of the greatest use to the Nation, these collections must continue to grow, for only in this way can they become more complete and thus more useful in the scientific and economic researches conducted by many other agencies. Room for expansion is urgently needed for all the collections in anthropology, geology, and zoology. Also far below our needs is laboratory space for the scientists and aides working on these collections, and for the visiting specialists who so freely and generously assist in this work. The over-all situation is such that the addition of wings on the Natural History Building must hold high priority in the Institution's building program.

Exhibits Modernization in Full Swing

During the year further progress was made in the renovation of major exhibits at the Smithsonian Institution, under the long-range modernization program authorized by Congress. President and Mrs. Dwight D. Eisenhower honored the Smithsonian by coming to the Institution on May 24. On that occasion Mrs. Eisenhower officially opened the new First Ladies Hall at special ceremonies in the Arts and Industries Building. This hall displays in authentic settings gowns worn by each of the ladies in the history of the country who have served as Presidential hostesses. In creating the new settings the designers wherever possible have combined real architectural details taken from the White House in its various renovations with furniture and fixtures owned by or associated with both the White House and the First Ladies. The dresses are thus seen in the type of surroundings in which they were worn. All the objects, for example, in the room in which Martha Washington's dress is displayed, belonged to President Washington. A large and beautiful mirror on exhibit in this room which belonged to President Washington has been at the Smithsonian Institution for more than 60 years, but never before has it been on display. The amazing success of this new hall is attested by the crowds of visitors that it attracts.

In the Natural History Building a modernized hall illustrating the life of various Indian tribes of California, southwestern United States, and Latin America was formally opened on June 2, as a feature of the program of the 50th Annual Convention of the American Association of Museums held in Washington. These exhibits, numbering more than 50 in all, use mainly materials long in the possession of the Smithsonian but present them in such an attractive way that the visitors may learn easily and quickly how these primitive peoples actually lived. They stress the remarkable ingenuity of the American Indians in utilizing the natural resources of such different environments as seacoasts, deserts, grasslands, jungles, and mountain valleys to provide food, clothing, shelter, and materials for arts and crafts. The ability of the primitive Indian to wrest a living from the most uninviting environments is a striking characteristic. The wide range of Indian skills in handicrafts is represented in displays of California Indian baskets (some of the world's finest basketwork), Navaho weaving and silverwork, Pueblo Indian decorated pottery, colorful weavings of Guatemalan Indians, religious wood carvings of the San Blas Cuna in Panamá, and paintings on guanaco skins worn as robes by Tehuelche Indians in Argentina. Included are nine large, dramatically lighted groups of life-size Indian figures engaged in typical tribal activities. Another shows Navaho weavers and silversmiths

at work. Still others illustrate the preparation of acorn meal by Hupa Indians of northern California, the processing of cassava by Carib Indians in British Guiana, and Tehuelche horsemen packing their belongings in moving camp. Five dioramas portray the life of other Indian tribes. One of them recreates in miniature a village of Lucayan Indians in the Bahamas in which the natives are excitedly viewing the approach of Columbus's ships. Another diorama represents a simple hunting camp of the sparsely clothed, poorly housed Yahgan Indians of Tierra del Fuego, the southernmost people of the world. Themes of wide popular interest are interpreted in other exhibits—such as the process of shrinking human heads employed by Jivaro warriors of the Ecuadorian jungles, the construction of a Pueblo Indian apartment house, and the use of shells for money in native California.

A companion hall will soon be started interpreting the lives of the Eskimo and the Indians of Canada and of the United States east of the Rocky Mountains. Progress was made during the year on a new hall in which selected portions of the magnificent bird collection of the Smithsonian can be displayed. Work has also been done on the new North American mammal hall, on a hall that will show the development of power machinery, and on another hall that will illustrate the cultural history of the United States. Although some of the exhibits in these halls will be moved to the new building, it is especially important to prepare them as soon as possible, because the labor involved in each such presentation is very time-consuming, and only by having modern exhibits ready to be installed in the new building can maximum use be made of the improved facilities of such a structure as soon as it is opened.

During the year the public comfort rooms of the Natural History Building, which had not been generally repaired since 1910, were modernized. The steam supply lines of the Arts and Industries Building and of the Freer Gallery of Art were replaced. This latter building for the first time since its erection was thoroughly cleaned inside and repainted. More than half of the exhibit halls of the Arts and Industries Building were repainted. Some of the paint in these rooms had peeled from the plaster, and in other places it was seriously stained. The bright new colors of present-day paints have done much to improve the visibility of exhibits and the attractiveness of the building.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, in accordance with the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States

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

THE BOARD OF REGENTS

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 death of a valued member of the Board of Regents. Former Justice of the Supreme Court Owen Josephus Roberts died on May 17, 1955. Justice Roberts had been a Regent only since July 23, 1953, and on account of illness had been able to attend only one meeting of the Board. The death of this eminent jurist and public servant was a severe loss to the Institution.

The Board is honored to welcome as a new member the Honorable Overton Brooks of Louisiana to succeed the Honorable Leroy Johnson. It is my pleasure also to record the reappointment to the Board of the Honorable Clarence Cannon, the Honorable John M. Vorys, the Honorable Clinton P. Anderson, the Honorable Leverett Saltonstall, and Dr. Jerome C. Hunsaker.

The annual informal dinner meeting of the Board was held in the main hall of the Smithsonian Building on the evening of January 13, 1955, amid various exhibits showing phases of the work being carried on at present. Brief illustrated talks on their special fields of research and activities were made by three staff members: Frederick M. Bayer, Dr. George S. Switzer, and Archibald Wenley.

The regular annual meeting of the Board was held on January 14, 1955. 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 the House of Representatives: Clarence Cannon, John M. Vorys, Overton Brooks; citizen members: Vannevar Bush, Arthur H. Compton, Robert V. Fleming, 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 167.

APPROPRIATIONS

Funds appropriated to the Institution for the fiscal year ended June 30, 1955, total $3,048,146, obligated as follows:

Management	$63, 830
United States National Museum	1, 154, 232
Bureau of American Ethnology	58, 730
Astrophysical Observatory	110, 680
National Collection of Fine Arts	44, 523
National Air Museum	86, 119
International Exchange Service	79, 376
Canal Zone Biological Area	8, 473
Maintenance and operation of buildings	1, 121, 697
Other general services	320, 846
Total	3, 048, 146

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	$648, 000
From the National Park Service, Department of the Interior, for the River Basin Surveys	52, 700

VISITORS

Visitors to the Smithsonian group of buildings during the year reached a record total of 3,895,017, nearly a quarter of a million more than the previous year. April 1955 was the month of largest attendance, with 585,916; May 1955 was second, with 551,820; August 1954 third, with 490,035. Largest attendance for a single day was 55,096 for May 7, 1955. Table 1 gives a summary of the attendance records for the five buildings. These figures, when added to the 3,476,584 estimated visitors at the National Zoological Park and 814,932 recorded at the National Gallery of Art, make a total number of visitors at the Smithsonian Institution of 8,186,533.

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Many visiting scientists and scholars from Federal departments, universities, and research organizations all over the world have come to the Smithsonian Institution during the past year. We were especially honored by a visit on November 5, 1954, from Mrs. Dwight D. Eisenhower and Her Majesty, Queen Elizabeth, the Queen Mother.

TABLE 1.—*Visitors to certain Smithsonian buildings during the year ended June 30, 1955*

Year and month	Smithsonian Building	Arts and Industries Building	Natural History Building	Aircraft Building	Freer Building	Tota
1954						
July	74, 040	230, 332	89, 726	54, 289	9, 505	457, 892
August	88, 610	230, 958	98, 239	61, 231	10, 997	490, 035
September	48, 842	133, 332	55, 912	34, 721	7, 256	280, 063
October	37, 042	102, 130	59, 197	25, 835	5, 491	229, 695
November	31, 748	85, 346	54, 394	25, 976	4, 470	201, 934
December	19, 418	45, 168	32, 916	15, 359	2, 942	115, 802
1955						
January	21, 745	50, 459	44, 924	18, 182	4, 305	139, 615
February	26, 674	58, 848	41, 154	19, 151	4, 396	150, 023
March	35, 373	109, 107	60, 722	27, 790	4, 734	237, 726
April	100, 687	251, 946	129, 425	92, 040	11, 818	585, 916
May	104, 462	237, 728	132, 295	65, 849	11, 486	551, 820
June	76, 620	206, 963	106, 389	53, 618	10, 906	454, 496
Total	665, 261	1, 742, 317	905, 292	494, 041	88, 306	3, 895, 017

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, 1954–55*

Year and month	Number of groups	Number of children
1954		
July	95	2, 986
August	91	2, 211
September	63	2, 065
October	245	7, 703
November	301	9, 958
December	139	3, 829
1955		
January	201	5, 693
February	277	8, 415
March	752	23, 960
April	1, 742	71, 376
May	2, 468	116, 032
June	942	33, 967
Total	7, 316	288, 195

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-second Arthur lecture was delivered in the auditorium of the Natural History Building on the evening of April 27, 1955, by Sir Harold Spencer Jones, Astronomer Royal of Great Britain. This lecture, on the subject "Solar Activity and Its Terrestrial Effects," will be published in full in the general appendix of the Annual Report of the Board of Regents of the Smithsonian Institution for 1955.

Dr. Konrad Z. Lorenz, director of the Research Institute for Comparative Ethology, Max-Planck Institute, Bulden, Westfalen, Germany, delivered a lecture in the auditorium of the Freer Gallery of Art on the evening of November 17, 1954, on "Evolution of Behavior Patterns in Animals." This was one of a series of lectures that this distinguished foreign scientist delivered in America that season.

Dr. Sumner McKnight Crosby, professor of the history of art at Yale University and curator of medieval art at the Yale Art Gallery, lectured on "Excavations in the Abbey Church at St.-Denis" in the Freer Gallery auditorium on the evening of February 3, 1955, under the joint sponsorship of the Smithsonian Institution and the Archaeological Institute of America. Dr. Crosby's lecture was accompanied by a colorful film showing the church as it is today, the technique of excavation, the reconstruction of the earlier buildings, and the important results.

AWARD OF LANGLEY MEDAL

The Langley gold medal, established in 1908 in memory of the late Secretary Samuel Pierpont Langley "for specially meritorious investigations in connection with the science of aerodromics and its application to aviation," was awarded by the Institution on April 14, 1955, to Dr. Jerome Clarke Hunsaker, chairman of the National Advisory Committee for Aeronautics and professor emeritus of aeronautical engineering at the Massachusetts Institute of Technology. Although Dr. Hunsaker is a member of the Smithsonian Board of Regents, he did not know of the award until the presentation was made, at a private reception and dinner held in the great hall of the Smithsonian Building, by the Honorable Earl Warren, Chief Justice of the United States, acting in his capacity as Chancellor of the Smithsonian Institution. The occasion also marked the fortieth anniversary of the founding of the National Advisory Committee for Aeronautics. The citation accompanying the presentation reads as follows:

> In recognition of your unique and superlatively important contributions to aeronautics as a distinguished designer of aircraft, as the creator of a great

center for instruction in aeronautical engineering, and as the scientific genius under whose leadership the present-day National Advisory Committee for Aeronautics has become the world's greatest scientific aeronautical research organization.

The Langley medal has previously been presented seven times: to Wilbur and Orville Wright in 1910, to Glenn H. Curtiss in 1913, to Gustave Eiffel in 1913, to Col. Charles A. Lindbergh in 1927, to Rear Adm. Richard E. Byrd in 1929, to Charles E. Manly (posthumously) in 1929, and to Dr. Joseph S. Ames in 1935.

DR. ABBOT HONORED

Dr. Charles Greeley Abbot, retired Secretary of the Smithsonian Institution and one of the nation's most eminent astrophysicists, was honored by a reception in the great hall of the Smithsonian Building on the afternoon of May 31, 1955—his eighty-third birthday. This also marked the sixtieth anniversary of Dr. Abbot's association with the Institution. In connection with the occasion, a bronze bust of Dr. Abbot by Alicia Neathery, Washington sculptress, was unveiled. It is now on permanent view in the Smithsonian Building.

FUNDS FOR THE INSTITUTION

At its January 1955 meeting, the Board of Regents gave careful consideration to the problem of what can be done to call public attention to the Smithsonian Institution as the beneficiary for large or small gifts of money to advance the "increase and diffusion of knowledge" in the areas covered by the Smithsonian. Since that time certain general statements concerning the needs of the Institution have been prepared, and through the kindness of various members of the Board of Regents, the Secretary has had an opportunity to present the need for generous additional endowments to a number of individuals and groups who may be in a position to help the Smithsonian Institution in this important material way. Only a beginning has been made on this program. It is urged that in the present year and in future years everyone interested in the Smithsonian will do everything possible to assist in providing substantial increases in the Institution's endowments for general or specific purposes. One of the suggested possibilities is that a single donor or group of donors may wish to present to the people of the United States through the Smithsonian Institution a memorial museum building for the National Collection of Fine Arts and other related materials.

As shown in last year's report, the Institution continues to receive subventions from Federal agencies and nongovernmental organizations. Work assisted by such grants includes studies and publications in anthropology, zoology, botany, geology, psychology, and the gen-

eral scientific programs of the Institution at Barro Colorado Island. A list of such grants made during the year is given in the Financial Report of the Executive Committee, at the end of this report.

BIO-SCIENCES INFORMATION EXCHANGE

By a cooperative arrangement with all branches of the armed forces and with other Federal agencies, the Smithsonian Institution continued to administer the Bio-Sciences Information Exchange under the directorship of Dr. Stella L. Deignan.

The Exchange is charged with the responsibility of "preventing the unknowing duplication of research support by the several Government agencies concerned." In carrying out this responsibility, it has developed techniques that maintain a rapid interchange of concise information on the support of research in the bio-sciences and on its content in both broad and specific subject areas. The Exchange reports that it has been able to supply adequate information in response to every request it has received from its sponsors. The body of information, at first confined almost entirely to medical research, now contains sizable components in basic biology, psychology, and mental health. An increasingly close liaison with nongovernmental granting agencies has been developed. During 1955 the active projects registered exceeded 9,000, bringing the present total to more than 19,000 projects.

ORGANIZATION AND STAFF

A number of important personnel changes affecting Smithsonian staff members occurred during the year. Loyal B. Aldrich retired on June 30, 1955, after 46 years with the Astrophysical Observatory of the Smithsonian Institution, since 1945 as its director. In his place Dr. Fred L. Whipple was appointed, effective July 1. At the time of his appointment Dr. Whipple was chairman of the department of astronomy at Harvard University. At the same time, headquarters of the Astrophysical Observatory were changed to Cambridge, Mass., where its astronomers will work in close proximity to Harvard's program of solar research. Some administrative and mechanical work will continue in the laboratories and shops of the Astrophysical Observatory in Washington, and the two field observatories in Chile and Table Mountain, Calif., will be maintained.

On September 13, 1954, by transfer from the U. S. Department of Agriculture, Dr. J. F. Gates Clarke assumed the position formerly held by Dr. Edward A. Chapin as curator of insects in the United States National Museum.

John D. Howard, Smithsonian Treasurer, retired effective December 31, 1954, and Thomas F. Clark, chief of the fiscal division, was

named to succeed him. Mr. Clark will also continue as chief of that division.

From time to time the Smithsonian endeavors to recognize the aid and encouragement received from the Institution's outstanding collaborators and benefactors by conferring upon such persons honorary status. A new class of such appointments—Fellows of the Smithsonian Institution—was established during the year, and the first Fellow to be named was Mrs. Arthur M. Greenwood, of Marlboro, Mass., in recognition of her generous and important contributions to the National Museum's collections of American colonial material and an entire seventeenth-century house.

Other honorary appointments made during the year were as follows: Drs. Robert J. Squier and Robert F. Heizer, both of the University of California, as collaborators in connection with the Smithsonian Institution–National Geographic Society's archeological expedition to southern Mexico; Dr. Helen Tappan Loeblich, of Washington, D. C., as honorary research associate, with particular reference to her achievements in the field of Cretaceous Foraminifera and her active participation in the work of the National Museum's department of geology; Dr. Betty J. Meggers, of Washington, D. C., as honorary research associate in recognition of her close and continuing participation in the scientific work, exhibits, and other activities of the National Museum's division of archeology; Dr. William J. Tobin, of Washington, D. C., as honorary research associate for his valued scientific contributions and his active participation in the work of the National Museum's division of physical anthropology; and Sister Inez M. Hilger, of St. Cloud, Minn., in recognition of her many years of collaboration with the Bureau of American Ethnology and her valued contributions to the study of the American Indian.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE INSTITUTION

National Museum.—The year saw a large increase in numbers of specimens added to the Museum collections, due to receipt of several million fossil foraminiferans from Europe. In all, approximately 7,600,000 specimens were received, bringing the total catalog entries in the National Museum to 42,864,645. Some of the year's outstanding accessions included: In anthropology, a wood, cloth, and basketry figure of a human being recovered from a Peruvian grave (A. D. 1100), ethnological objects from Iraq, Afghanistan, and Ethiopia, and an entire 2-story, 4-room colonial house from Massachusetts; in zoology, collections of mammals from Korea, Pakistan, and Panama, birds from Panama, large collections of fishes from the Gilbert Islands, Liberia, and the southeastern United States, the W. M. Mann collection of ants, 3,200 polychaete worms, mostly from New England, and

400 corals from the Great Barrier Reef; in botany, plant collections from Mexico, Central and South America, and Iraq; in geology, several gifts of rare minerals and gems, 35 specimens of meteorites, 2,000 Silurian and Devonian fossils from Canada, about 3,500,000 mounted foraminiferan specimens, 600 rare Paleocene and Eocene mammals from Wyoming, and about 750 otoliths of Eocene teleostean fishes from England; in engineering and industries, an early Curtis steam turbine, the Dodrill-GMR mechanical heart, and important electrocardiograph equipment; and in history, much desirable material needed to complete the settings for the First Ladies Hall, including the loan of a piano used in the White House during the administration of John Quincy Adams.

Members of the staff conducted fieldwork in Ecuador, Mexico, the Belgian Congo, Panama, the Caribbean, and many parts of the United States. Several studied collections in other museums in America and in Europe.

In the Museum's program of exhibit modernization, two new halls were formally opened to the public during the year—the First Ladies Hall and the American Indian Hall. Construction work was begun on the hall depicting colonial life in North America, and the renovation of the hall devoted to birds saw good progress.

Bureau of American Ethnology.—The Bureau staff continued their researches in archeology and ethnology: Dr. Stirling his Panamanian studies, Dr. Collins his archeological work in the Canadian Arctic, and Dr. Drucker his field researches of the La Venta culture in Mexico. Dr. Roberts continued as Director of the River Basin Surveys.

Astrophysical Observatory.—Solar radiation studies were continued at the Observatory's two field observing stations—Montezuma in northern Chile and Table Mountain in southern California. Volume 7 of the Annals of the Astrophysical Observatory was published in July 1954. Cooperative work with the U. S. Weather Bureau was continued. In the division of radiation and organisms studies were made on the photocontrol of the processes of plant growth and on the mechanism of action of the plant hormone auxin in the control of growth.

National Collection of Fine Arts.—The Smithsonian Art Commission met on December 7, 1954, and accepted two oil paintings for the National Collection of Fine Arts, one oil painting of President Eisenhower for the National Portrait Gallery, and one pastel for the Smithsonian Institution. The Gallery sponsored 14 special exhibitions during the year. The Smithsonian Traveling Exhibition Service circulated 68 exhibitions, 57 in the United States and 11 abroad.

Freer Gallery of Art.—Purchases for the Freer Gallery collections included Chinese bronzes, lacquerwork, paintings, and pottery; Per-

sian jade, metalwork, and paintings; Japanese lacquerwork, paintings, and pottery; Indian paintings; Iraqi illustrated manuscript; and Turkish pottery. The first number of Ars Orientalis was published during the year. The Gallery sponsored again a series of illustrated lectures by distinguished scholars on various phases of Oriental art.

National Air Museum.—By the end of the year the task of moving the Museum's stored materials from Park Ridge, Ill., to Suitland, Md., was virtually completed. The Museum participated in celebrating the fortieth anniversary of the founding of the National Advisory Committee for Aeronautics, a feature of which was the awarding of the Langley medal to Dr. Jerome C. Hunsaker. Added to the aeronautical collections during the year were 117 specimens in 31 separate accessions, including the midget racing airplane *Buster* (formerly named *Chief Oshkosh*), built in 1931 and flown in more than 50 races. Nearly 22,000 photographs pertaining to aeronautics were added to the Museum's library of reference materials during the year.

National Zoological Park.—The Zoo accessioned 2,347 individual animals during the year, and 1,917 were removed by death, exchange, or return to depositors. The net count of animals at the close of the year was 3,410. Noteworthy among the accessions were a pair of baby gorillas, several young chimpanzees, and two Goeldi's marmosets; emperor, Adelie, and Humboldt's penguins; two examples of the rare Mona Island iguana and a horn-nosed iguana; and a domestic donkey. In all, 280 creatures were born or hatched at the Zoo during the year—77 mammals, 141 birds, and 62 reptiles. Visitors totaled approximately 3,476,000.

Canal Zone Biological Area.—More than 600 visitors came to Barro Colorado Island during the year; 43 of these were scientists who used the facilities of the station to further their various researches, particularly in biology and photography.

International Exchange Service.—As the United States official agency for the exchange of governmental, scientific, and literary publications between this country and other nations, the International Exchange Service handled during the year 1,146,972 packages of such publications, weighing 812,960 pounds—slightly more than last year. Consignments were made to all countries except China, North Korea, Outer Mongolia, the Communist-controlled areas of Viet Nam and Laos, and the Haiphong Enclave.

National Gallery of Art.—The Gallery received 842 accessions during the year, by gift, loan, or deposit. Gifts included paintings by Stuart, Raeburn, Renoir, Romney, R. Peale, Pater, Blake, Carriera, and Goya; sculptures by Renoir, Ward, and Daumier; and about 400 prints. Six special exhibits were held, and 13 traveling exhibitions of prints from the Rosenwald Collection were circulated to other gal-

leries and museums. Exhibitions from the "Index of American Design" were given 60 bookings in 20 States and the District of Columbia. About 41,000 persons attended the Gallery's "Picture of the Week" talks, and 10,000 persons attended the 44 Sunday lectures in the auditorium. The Sunday evening concerts in the west and east garden courts were continued.

Library.—A total of 71,179 publications were received by the Smithsonian library during the year. Approximately 650 new exchanges were arranged. More than 150 individual donors sent gifts of desirable books and periodicals. At the close of the year the holdings of the Smithsonian library and all its branches aggregated 951,409 volumes, including 585,592 in the Smithsonian Deposit in the Library of Congress but excluding incomplete volumes of serials and many thousands of reprints and separates from serials.

Publications.—Seventy publications were issued under the Smithsonian imprint during the year (see Report on Publications, p. 160, for full list). Outstanding among these were "The Material Culture of Pueblo Bonito," by Neil M. Judd; "The Black Flies (Diptera, Simuliidae) of Guatemala and Their Role as Vectors of Onchocerciasis," by Herbert T. Dalmat; "Check List of North American Recent Mammals," by Gerrit S. Miller, Jr., and Remington Kellogg; "Frogs of Southeastern Brazil," by Doris M. Cochran; "The Horse in Blackfoot Indian Culture," by John C. Ewers; "A Ceramic Study of Virginia Archeology," by Clifford Evans; Volume 7 of the Annals of the Astrophysical Observatory; "Masters of the Air," by Glenn O. Blough; and Volume 1 of the new series Ars Orientalis. In all, 428,286 pieces of printed matter were distributed during the year—192,108 copies of publications and 226,178 miscellaneous items.

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, 1955:

COLLECTIONS

During the year 7,596,646 specimens were added to the national collections and distributed among the six departments as follows: Anthropology, 34,450; zoology, 363,500; botany, 58,526; geology, 7,056,121; engineering and industries, 5,609; and history, 78,440. This increase is markedly greater than last year and results from the collection in Europe during the year of several million minute fossils known as Foraminifera. The other accessions for the most part 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 42,864,645.

Anthropology.—A unique gift to the division of archeology was a figure of a human being made from wood, cloth, and basketry, recovered from a grave along the central coast of Peru and dating from about A. D. 1100. This unusual object was presented by Mrs. Virginia Morris Pollak as a gift from the Arther Morris Collection. A series of large archeological collections taken from excavation projects in various parts of the Missouri Basin has been transferred to the Museum by the River Basin Surveys. A willow-splint figure of a quadruped, probably prehistoric, from a cave in Grand Canyon, was presented by Dr. J. D. Jennings, University of Utah.

The division of ethnology received from Ralph Solecki numerous ethnological objects which he collected from his native employees and their relatives among the Shirwani Kurds of Kurdistan while he was conducting archeological work in Iraq. Also accessioned were 28 items of Afghan material culture, consisting of pottery, basketry, weaving, and quilted clothing, a Khyber knife, and Mohammedan cult objects, collected in 1954 by the donor, Miss May Wilder, from villagers and country folk in Afghanistan. Another gift was a well-documented collection of 34 miscellaneous ethnographical specimens

from the Anuak, a Sudanese tribe living in the environs of the Akobo River, collected by the donor, Miss Joan Yilek, prior to 1953 at Pokwo, Ethiopia, while she was stationed there as a missionary. Most extraordinary was the gift by Dr. and Mrs. Arthur M. Greenwood of Marlboro, Mass., of an entire 2-story, 4-room house built in Everett, Mass., in 1678. The hand-hewn timbers of this early American home were dismanteled and reassembled for future exhibition. W. Dan Quattlebaum, Pasadena, Calif., presented two outstanding examples of eighteenth-century glass, consisting of an engraved glass bowl blown in 1789 at John Frederick Amelung's New Bremen Glassworks in Frederick County, Md., and a decanter of about 1795 bearing an engraved American eagle.

The division of physical anthropology had an opportunity through collaborative studies to restore a badly crushed human skull that had been recovered by Dr. Fred Wendorf near Midland, Tex. This skull was found associated with Folsom-type projectile points. Dr. T. Dale Stewart, curator of physical anthropology, who restored the skull, arranged with Dr. F. J. McClure, of the National Institute of Dental Research, to test the skull and associated Pleistocene animal bones for the amount of fluorine. On the basis of these tests and the excavation record, its age is considered to be about 12,000 years.

Zoology.—The armed forces research teams operating in various parts of the world continued to make major contributions to the mammal collections. Specimens of Korean mammals, including the Museum's first collection from Quelpart Island, were transferred through the Hemorrhagic Fever Commission from the Army Medical Service Graduate School. A transfer from Naval Medical Research Unit No. 3 at Cairo included about 350 specimens from Egypt and the Sudan. The U. S. Army, through the 25th Preventive Medicine Survey Detachment, transferred a collection of specimens obtained by Capt. Gordon Field and C. M. Keenan in Panama and the Canal Zone. Dr. Robert K. Enders contributed three separate collections of small mammals from Pakistan, the Island of Saipan in the Marianas, and Wyoming. An especially fine collection of dog and wolf skulls was included among specimens excavated from an aboriginal site on Southampton Island by Dr. Henry B. Collins, Bureau of American Ethnology, on the National Geographic Society-Smithsonian Institution-National Museum of Canada Expedition.

Most noteworthy among the accessions recorded by the division of birds was a gift of 1,255 bird skins from the "Benson Grubstakers" (a group of young men living in Panama who are interested in natural history) and the Panama Canal Natural History Society. A gift from Maj. Gen. G. R. Meyer of 119 sets of eggs with full data, largely from the Canal Zone, added important information to that

already available on the breeding dates of Panamanian birds. A deposit made by the Smithsonian Institution comprised 959 skins, 54 skeletons, 2 alcoholic specimens, and 1 set of eggs collected by Dr. A. Wetmore. The National Geographic Society presented a geographically important collection of 131 birds obtained in French Equatorial Africa by Walter A. Weber.

A considerable number of valuable herpetological specimens were accessioned as gifts: A type and 18 paratypes of a new species of frog taken in Jamaica by Dr. W. Gardner Lynn; 119 reptiles and amphibians from Virginia, including a type and paratypes of a new species of salamander, from Richard L. Hoffman; 8 reptiles from Puttur, Chittoor District, South India, including a genus and three species not formerly contained in the Museum collection, presented by Rev. Erwin Chell. A transfer from the Naval Medical Research Unit No. 3 at Cairo, yielded 390 Egyptian reptiles and amphibians.

The largest collection of fishes received during the year consisted of 2,341 specimens from fresh-water streams in the southeastern United States collected for the Museum by Dr. Ernest A. Lachner and Frank J. Schwartz. Another large gift was composed of 1,813 reef fishes collected in the Gilbert Islands by the donor, John Randall. Additional gifts included the holotype of a new scorpaenid fish from the eastern Pacific from John E. Fitch; and the holotype of a new *Monocentris* from Mas-a-Tierra Island from Dr. Edwyn P. Reed, Valparaiso, Chile. The U. S. Fish and Wildlife Service transferred to the Museum the most important Atlantic collection received in several years consisting of 983 fishes obtained by George C. Miller in Liberia. Through exchanges with other institutions the Museum received 6 paratypes of cyprinids from Mexico through Dr. José Alvarez, Escuela Nacional de Ciencias Biológicas; the paratype of a frogfish from the Chicago Natural History Museum through Loren P. Woods; and 3 paratypes of a Mexican catfish from the Instituto Mexicano de Recursos Naturales Renovables, through Dr. Jorge Caranza.

One of the most valuable acquisitions of insects received was the W. M. Mann collection consisting of 136,288 specimens of which over 116,000 are ants. Approximately 700 types and hundreds of species of ants from many areas in the world not previously represented in Washington were included in this group. Among the important transfers from the U. S. Department of Agriculture was the S. W. Bromley collection of well over 35,000 insect specimens. This accession, rich in material representative of the dipterous family Asilidae, places the Museum high on the list of institutions possessing extensive collections of these flies. Another transfer included 34,258 entomological specimens from the Department's Laboratory of Forest Insects, New Haven, Conn. Over 9,000 medically important black flies were

received as a transfer from the U. S. Department of Health, Education, and Welfare.

Two notable gifts greatly enhanced the collection of polychaete worms maintained by the division of marine invertebrates; 3,645 specimens, mostly from New England, including 3 holotypes and 3 paratypes, from Dr. Marian Pettibone, University of New Hampshire, and more than 200 identified specimens from the Gold Coast, Africa, received from the Rijksmuseum van Natuurlijke Historie, Leiden, through Dr. L. B. Holthuis. Twelve lots of octocorals were received from His Imperial Majesty's collections, laboratory of the Imperial Household, Tokyo, Japan. Other noteworthy gifts to the collections were 7 remarkable fossil sea-pens presented by H. G. Kugler, Pointe-à-Pierre, Trinidad, and 3 large balanoglossid worms from Grand Isle, La., given by Dr. Harry J. Bennett, Louisiana State University. Three exchanges from Dr. Alejandro Villalobos F., Universidad Nacional A. de México, netted 54 isopod and decapod crustaceans, of which 34 were paratype specimens. Among the transfers was one from the Fish and Wildlife Service, U. S. Department of the Interior, which included more than 1,019 crustaceans and other invertebrates collected in the Gulf of Mexico by the exploratory fishing vessel *Oregon* under the direction of Stewart Springer.

The division of mollusks received types of seven new species of nudibranch mollusks described and presented by J. M. Ostergaard. Thirty-four specimens of gastropods from the Gulf of Mexico, including the types of three new species, were donated by Daniel Steger. As in the past, Jeanne S. Schwengel gave many fine specimens to the Museum, including a specimen of the rare cowrie, *Cypraea armeniaca*, from South Australia. Of the year's five accessions of helminths two are worthy of special mention because they brought types of two new species, *Onchocotyle somniosi*, a trematode, described by the donor, Dr. David Causey, and *Gigantobilharzia huttoni* presented by the author, Dr. W. Henry Leigh.

The most important accession of corals comprises 400 specimens from the Great Barrier Reef off Queensland, Australia, collected and donated by Dr. John W. Wells, Cornell University.

Botany.—Two significant collections were obtained for the Museum by staff members: 2,850 specimens, largely grasses, in the states of San Luis Potosí and Chiapas, Mexico, collected by Dr. Ernest R. Sohns, and 3,445 specimens from Big Pine Key, Fla., and Isle of Pines, Cuba, obtained by E. P. Killip, research associate.

Among the numerous collections received as gifts, with names requested, one is especially noteworthy, 588 plants from the Herbário "Barbosa Rodrigues," Itajaí, Santa Catarina, Brazil. The Ohio State University presented 4,084 plants of Guatemala collected by W. A.

Kellerman many years ago, including numerous historically important specimens. E. C. Leonard of the department staff donated his private herbarium consisting of approximately 9,300 specimens accumulated over a period of many years.

Transfers from other Government agencies yielded several fine collections: From the Agricultural Research Service, U. S. Department of Agriculture, 983 specimens collected by Richard Evans Schultes in Colombia; 5,066 specimens collected in India, Afghanistan, and Iran by Walter Koelz; and a historic set of 575 central European cryptogams, the Kryptogamae Germaniae Exsiccatae. From the U. S. Geological Survey, 1,360 plants of Alaska with a request for identifications; and 1,105 plants of Micronesia collected by F. R. Fosberg. The National Research Council, through the Pacific Science Board, transferred 532 plants of the Caroline Islands collected by S. F. Glassman.

Important exchanges included 2,009 plants of Mexico, Central America, and South America, from the Academy of Natural Sciences of Philadelphia collected by the late F. W. Pennell.

Geology.—Outstanding gifts to the mineral collections are examples of the rare minerals hurlburtite and bismutotantalite from Prof. E. Tavora; rare iron and manganese phosphates from Finland from Dr. Mary Mrose; a superb specimen of crystallized wolframite from Korea from C. S. Whetzel; the rare uranium mineral kasolite, Hahns Peak, Colo., from C. R. Reddington; and a combination of the rare minerals schallerite and hedyphane, Franklin, N. J., from J. S. Albanese.

Included in the exhibition material added to the Roebling collection were a group of large flawless axinite crystals of smoky lavender color on actinolite from Madera County, Calif., a large benitoite crystal in neptunite from San Benito County, Calif., and a bastnaesite crystal from Madagascar weighing 11 pounds. A mass of native lead weighing 80 pounds is one of the largest masses of this rare mineral found at Langban, Sweden. A sharp dodecahedral crystal of grossularite of an unusual pink color is one of the largest crystals of this mineral known.

Among the outstanding exhibition specimens added to the Canfield collection were a rich nodule of precious turquoise from the mines at Villa Grove, Colo., a rare group of tourmaline crystals of bronze-green color from Brazil, and a fine exhibition group of apophyllite on prehnite from a newly discovered occurrence near Centreville, Va.

Gifts to the gem collection included a pink pearl from East Pakistan presented by the former Prime Minister of Pakistan, Mohammed Ali, and an outstanding collection from W. F. Ingram, of 33 cut tourmalines weighing 118 carats, selected to show the color range

of this gem stone. An uncommon specimen received for the ore collection was the limb bone of a dinosaur partially replaced by unarinite, from the Atchison, Topeka & Santa Fe Railway Co. through T. O. Evans.

During the past year Dr. S. H. Perry donated 35 specimens of meteorites. Among them was a stone of the Sylacauga fall, weighing 1,682 grams. Another individual of this fall became celebrated as the first known case of a meteorite striking a person.

The support of the Walcott fund again permitted staff members to obtain important accessions in invertebrate paleontology and paleobotany. Specimens numbering 15,000 of Paleozoic invertebrates were collected by Dr. G. A. Cooper and Robert Main, and a very large group of Mesozoic and Tertiary Foraminifera from the classic localities of Europe was obtained by Drs. A. R. Loeblich, Jr., and Helen Tappan Loeblich.

Particular mention is made of the gift of 2,000 specimens of Silurian and Devonian fossils from little-known areas in New Brunswick, Nova Scotia, and Quebec, received from Dr. Arthur Boucot, and 800 Triassic invertebrate fossils from the Italian Alps from Dr. Franco Rasetti. Important foraminiferal donations included 275 type specimens from the Cretaceous rocks of Cuba and Trinidad presented by Dr. P. Bronnimann, and 320 slides of type Recent Foraminifera and 305 foraminiferal slides from the North Atlantic from Dr. Fred Phleger. Another very valuable gift presented by Drs. A. R. Loeblich, Jr., and Helen Tappan Loeblich consisted of 1,000 micro-samples and 3,500,000 specimens of mounted Foraminifera with many types from the Cretaceous of Texas.

Through the income of the Walcott fund a collection of about 600 specimens of rare Paleocene and Eocene mammals was obtained by Dr. C. L. Gazin and F. L. Pearce from southern Wyoming. Of particular interest were an excellent skull and some skeletal material of the large pantodont mammal *Coryphodon* and two well-preserved skulls of the condylarth mammal *Meniscotherium*. Under the same fund Dr. D. H. Dunkle collected fossil fish and reptile remains from Devonian, Triassic, and Cretaceous rocks of Utah, Idaho, and Wyoming. An outstanding gift was a nearly complete skull of the large saber-toothed cat *Smilodon fatalis* collected from the Pleistocene deposits of Texas by George Klett and presented to the Museum through James E. Conkin. A remarkable collection of about 750 otoliths of teleostean fishes from the Eocene lower Barton beds of Hampshire, England, representing 22 genera and 28 species, was given by Dr. F. C. Stinton.

Engineering and Industries.—A turbine reputed to be the first built by Charles Curtis, America's best-known pioneer steam-turbine in-

ventor, was presented by the Stevens Institute of Technology. Original radio apparatus was received from the widow of Edwin Armstrong, comprising his regenerative receiver made about 1912, three superheterodyne receivers, a superregenerative circuit, and what is considered the oldest surviving frequency-modulation receiver.

The Dodrill-GMR mechanical heart, the first to be used successfully for the complete bypass of the human heart during surgery, was presented by the General Motors Corporation through C. L. McCuen of the Research Laboratories Division. The Rockefeller Institute for Medical Research gave the first Einthoven string galvanometer made in the United States for an electrocardiograph. This was made in 1914 by Charles F. Hindle for Dr. Alfred E. Cohn. The electrocardiograph used by Dr. Frank E. Wilson, a pioneer in the field of electrocardiography, was presented by the University of Michigan.

Several hundred drawings, mostly of the details of early Bessemer-process steel plants made by the distinguished engineer Alexander Lyman Holley, were the gift of the Rensselaer Polytechnic Institute.

An elaborately carved roller cotton gin from India was received from Mrs. Stanley M. Walker. A pink brocaded taffeta christening blanket, known to have been used in 1827, was presented by Faith Bradford, and a commemorative linen, "We Offer Peace, Ready for War," was given in the name of Sibyl Avery Perkins, deceased, by her daughter, Mrs. Robert C. Johnson, Jr.

An unusual board section of curly yellow buckeye showing beautiful blue stain markings was presented by Ray E. Cottrell of the Wood Collectors Society. Fifty microscope mounts of woods of the family Celastraceae were received from John A. Boole, Jr., and 20 woods and 20 corresponding mounts of the genus *Garrya*, through Prof. J. E. Adams, from the University of North Carolina.

A linoleum block print, "Le Coup de Vent," by Felix Vallotton (1865–1925), an important figure in the revival of the woodcut, was purchased through the Dahlgreen fund.

Two etchings by Giovanni Baptista Piranesi (1720–1778), "Veduta del Palazzo dell' Academia" and "Veduta sul Monte Quirinale del Palazzo Eccelentissima," were received as Smithsonian Institution deposits. Eight etchings illustrating Homer's Odyssey, by the well-known Polish artist Sigmund Lipinsky (1873–1940), were presented by Mrs. Elinita K. Burgess Lipinsky.

History.—A very interesting specimen received in the division of civil history was a piano used in the White House during the administration of President John Quincy Adams. This piano, on loan from the Juilliard School of Music in New York, is a very early one of American make, bearing the type of label used between 1822 and 1829 by Alphaeus Babcock who worked in Boston.

A large collection of vases, andirons, and other ornamental pieces donated by Mrs. W. Murray Crane of New York City helped to complete the exhibition of almost every setting in the First Ladies Hall. As a loan the Museum received from B. Woodruff Weaver two gold sofas which were missing from the White House suite of furniture previously acquired. These sofas were sold at auction by the White House in 1902 to a private party. They were purchased by the Barnes family of Washington.

Mrs. Dwight D. Eisenhower presented the gloves, evening purse, jewelry, and slippers that she wore with her inaugural dress. These accessories complement this unit for exhibition. Two fans and a blue-and-white Chinese porcelain vase belonging to Mrs. Herbert Hoover were presented by Mrs. Herbert Hoover, Jr. A hickory walking stick, inlaid in silver and bearing the name of Abraham Lincoln, was given by Samuel J. Prescott.

A gift to the division of military history from Joseph Cummings Chase contained 79 portraits of World War I officers and enlisted men, and one portrait of an enlisted man in service during the Korean conflict.

Outstanding among the accessions in the division of numismatics was the gift from Mrs. William D. (Gorgas) Wrightson, comprising 43 award medals and decorations given to Dr. William Crawford Gorgas, 1854–1920, Sanitation Engineer for the Panama Canal Commission and later Surgeon General of the United States.

The Post Office Department continued as the principal means whereby the philatelic collections are kept up to date, forwarding one specimen of each new stamp distributed by the Universal Postal Union. Three shipments of approximately 3,000 stamps were transferred. The Treasury Department through the cooperation of T. Coleman Andrews, Commissioner of Internal Revenue, transferred an additional 49,642 specimens of United States revenue stamps and proofs.

Among gifts from private donors, especial mention is made of two additional collections of great value from Ernest Lowenstein. One collection comprised four volumes of Honduras airmails, replete with rarities, and the other consisted of a 3-volume collection of Paraguay airmails.

EXPLORATION, FIELDWORK, AND RELATED TRAVEL

During November 1954, Frank M. Setzler, head curator, department of anthropology, and C. Malcolm Watkins, associate curator, division of ethnology, excavated a number of test pits at Marlborough Point, Stafford County, Va., to obtain evidence of the former location of houses, taverns, and industries of this long-abandoned colonial town. The acquisition of such information will supplement existing knowl-

edge of the origins of Virginia and its subsequent influence in the settlement of the country west of the Allegheny Mountains.

From August 15 to August 30, 1954, Dr. Clifford Evans, associate curator, division of archeology, examined collections at Belém and Rio de Janeiro and attended as official delegate the 31st International Congress of Americanists at São Paulo, Brazil. New acquisitions in the Museo National and the Museo de Anthropología at Lima and the Regional Museum at Cuzco, Peru, were examined during the first week of September. Archeological investigations involving stratigraphic technique and survey were undertaken from September 8 to November 1, 1954, in the Guayas Basin, Guayaquil, Ecuador, to establish sufficient evidence to evaluate the previously collected materials in the museum of Sr. Emilio Estrada.

The study of early Virginia pottery in the collections of the National Park Service at Jamestown and Williamsburg by C. M. Watkins, associate curator, division of ethnology, was continued during March and April 1955. Mr. Watkins also made two trips to New England and New York to obtain materials and data for incorporation in the Cultural History Hall.

Dr. Waldo R. Wedel, curator, division of archeology, was detailed to represent the U. S. National Museum in conferences with River Basin Surveys personnel at Lincoln, Nebr., relative to the division of archeological specimens collected in the Missouri River Basin since 1946. Specimens from important archeological and historical sites in North and South Dakota, Nebraska, and Wyoming have been received on the basis of the arrangements concluded at Lincoln, and other needed material from Montana, Wyoming, and Kansas will be forwarded for incorporation in the national collections.

From September 20, 1954, to January 21, 1955, Dr. T. D. Stewart, curator, division of physical anthropology, was detailed to the Army Graves Registration Service to conduct research on skeletal aging of American war casualties returned from North Korea at the 8204th A. U., Jono Area, Kukura, Kyushu, Japan. Since in all instances the age at death is known, it will be possible when analysis of these records is completed to set up more accurate standards for determining the age of unidentified skeletons.

Dr. Ernest R. Sohns, associate curator, division of grasses, conducted botanical fieldwork in the state of San Luis Potosí, Mexico, from August 29 to October 16, 1954. Grasses were collected in the Sierra de Alvarez, Sierra de San Miguelito, Sierra de Cuates, Sierra de Guadalcázar, Sierra Madre Oriental, Sierra de Catorce, and Sierra de Mexiquitic, as well as at intermediate localities. At the request of Dr. Juan Leonard, general secretary, El Centro de Investigaciones Antropológicas de México, Dr. Sohns was detailed to accompany

an expedition to the unexplored region of southeast Chiapas, near Lake Miramar, for the purpose of participating in a coordinated exploratory program. Fieldwork was carried on from March 15 to April 1, 1955, and some 648 botanical specimens were obtained.

The last five days in December 1954 were devoted by Dr. Robert P. Multhauf, curator, division of engineering, to the inspection of display and lighting techniques in the Metropolitan Museum of Art, the American Museum of Natural History, and the International Business Machines Co., for utilization where suitable in the Power Hall. The collections of the Henry Ford Museum in the fields of power machinery, electrical apparatus, machine tools, and transportation were examined late in March 1955, and the Edison Institute in Greenfield Village, Dearborn, Mich., was visited. Dr. Multhauf also represented the Smithsonian Institution at the 75th anniversary meeting of the American Society of Mechanical Engineers during June 1955.

George Griffenhagen, associate curator, division of medicine and public health, in January 1955 consulted with representatives of Merck & Co., Rahway, N. J., relative to a proposed vitamin exhibit. In February 1955 he inspected the Apothecaries Hall in the Charleston (S. C.) Museum, La Pharmacie Française and the Cabildo (State Historical Museum) at New Orleans, La., to examine the types of early pharmaceutical equipment, the materia medica collections, and archival records. During June 1955 he inspected a number of pharmaceutical and medical exhibits housed in institutions in New York and Philadelphia. All these visits were made to obtain suggestions and assistance in the planning of the Hall of Health.

Edward C. Kendall, associate curator, division of crafts and industries, during the last week of September and the early part of October 1954, visited a number of New England museums, chiefly at Hartford, Worcester, Salem, Durham, Boston, Burlington, Bennington, Ithaca, and Corning, to examine handicraft tools, agricultural implements, and historical materials.

Grace L. Rogers, assistant curator, crafts and industries, during December 1954 visited the Henry Ford Museum at Greenfield Village, Mich., to obtain detailed data relative to textile machines, particularly the Scholfield wool-carding machine, and the sewing machines, as well as to inspect the exhibition and storage techniques for textile fabrics. She also observed exhibition techniques at the Detroit Institute of Arts and the Detroit Historical Museum. During the first week of March 1955 Miss Rogers examined the collection of textile machinery at Old Slater Mill, Pawtucket, R. I., historical papers on the Rhode Island Historical Society at Providence, the textile collection in the Rhode Island School of Design, the handwoven textiles in the Essex Institute at Salem, and the collections of the Connecticut

Valley Historical Society and Old Sturbridge Village for ideas applicable to the improvement of our textile exhibits.

Jacob Kainen, curator, division of graphic arts, made a critical study of six color prints made in 1744 by John Baptist Jackson in the print department of the Boston Museum of Fine Arts to determine the number of wood blocks used in making the prints, and gathered additional data for the descriptive catalog of Jackson's color prints.

A survey of the paleobotanical materials in the collections of the American Museum of Natural History, including specimens formerly exhibited, was made by Dr. G. A. Cooper, curator, division of invertebrate paleontology and paleobotany, in November 1954. During April 1955 Dr. Cooper obtained collections of invertebrate fossils from the Porterfield Quarry near Saltville, Va., and from the reef and interreef beds at Blacksburg, Va. A short field trip, financed by the income from the Walcott bequest, was made by Dr. Cooper during May 1955, when invertebrate fossils were collected from the Middle Devonian near Hamilton, N. Y., and from Ordovician rocks north and east of Utica, N. Y. During June 1955, he studied the preparation techniques and the displays of fossil marine invertebrates in the Museum of the University of Michigan and the Chicago Natural History Museum. The Laudon collection at the University of Wisconsin was examined and conferences were held with Dr. A. K. Miller of the State University of Iowa on problems related to the stratigraphy of the Permian of the Glass Mountains in Texas.

The rather poor representation in the national collections of Foraminifera from the Miocene deposits of northern Florida and from the upper and lower Cretaceous of Texas and Oklahoma was materially improved by fieldwork undertaken by Dr. A. R. Loeblich, associate curator, division of invertebrate paleontology, and Prof. Eugenia Montanaro Gallitelli of the University of Modena, Italy, during January 1955 under the Walcott fund. From April 24 to May 12, 1955, Dr. Loeblich was engaged in making a reconnaissance collection of Foraminifera from nearly every major stratigraphic level on Trinidad Island and in studying faunal assemblages in the geological laboratory of Trinidad Leasehold, Ltd.

Dr. David Nicol, associate curator, division of invertebrate paleontology, examined pelecypod material, particularly *Conocardium*, in the collections of the American Museum of Natural History and the Museum of Comparative Zoology during late December 1954.

Under the income of the Walcott bequest, Dr. D. H. Dunkle, associate curator, division of vertebrate paleontology, was engaged in fieldwork from July 24 to September 12, 1954. Prospecting in the exposures of Middle Cretaceous Mowry shale south of Cody, Wyo., was carried on for 12 days, and he then proceeded to Logan, Utah, for

collecting in the Lower Devonian Water Canyon formation. After five days in this area, Dr. Dunkle moved his camp and obtained an extremely important collection of marine Lower Triassic fishes from the Woodside formation in Paris Canyon. Subsequently the occurrences of fossil fishes in the upper half of the Triassic Chinle formation in Big Indian Wash near Monticello, Colo., were investigated. On the return trip to Washington stops were made at Upper Cretaceous Niobrara Chalk exposures at Sharon Springs, Oakley, and near Hays, Kans., to ascertain the possibility of securing needed materials for the exhibition program. Museum officials of the University of Oklahoma were consulted relative to the possibility of acquiring an exhibition specimen of the large pelycosaurian reptile *Cotylorhynchus*.

Inasmuch as additional fish display material is needed for the lower vertebrate hall now in the planning stage, Dr. Dunkle, assisted by Don Guadagni, exhibits preparator, proceeded by Museum truck on May 18, 1955, from Washington to western Kansas. Enroute arrangements for the exchange of European fossil fishes were completed with the Carnegie Museum in Pittsburgh, and a small collection of fish remains was made in excavations in the Upper Devonian along the new Ohio Turnpike right-of-way. On arrival at Hays, Kans., George F. Sternberg guided the party to the Haverfield Ranch in southwestern Gove County where camp was established. Collections of fish were obtained from exposures of the Smoky Hill member of the Niobrara formation.

Through the generosity of Dr. Stuart H. Perry, of Adrian, Mich., in providing travel funds, E. P. Henderson, associate curator, division of mineralogy and petrology, was enabled to examine the meteorite collections of the British Museum (Natural History) at London, as well as those at the universities of Bonn and Munich in Germany. More than 450 meteorites were reviewed at the Institute de Mineralogie et Petrographie, Université de Strasbourg, France. At Vienna, Austria, he examined the meteorite collection in the Naturhistorischen Hofmuseum, which is regarded as the best in Europe. He devoted approximately a week to the examination of the collection of the Laboratorido Astrofisico, Castel Gondolfo, Specola Vaticana, near Rome, Italy, and subsequently examined the meteorites housed in the Muséum National d'Histoire Naturelle at Paris, France, and those not represented in our national collections were listed. This trip covered the period from August 20 to October 30, 1954.

The generosity of Mr. and Mrs. Bruce Bredin, of Greenville, Del., enabled the Smithsonian Institution to undertake a field investigation of the plant mites and other types of the smaller animal life of central Africa. The field party, which assembled at Leopoldville, Belgian Congo, April 8–11, 1955, consisted of Dr. Waldo L. Schmitt, head

curator of zoology, leader of the expedition, Dr. Edward W. Baker, acarologist, on detail from the U. S. Department of Agriculture, and Dr. Roy Lyman Sexton, physician, of Washington, D. C., as medical consultant and photographer, assisted by his son, Roy Lyman Sexton, Jr., as microphotographic specialist. Traveling by auto and truck, except for a short plane flight from Leopoldville to Stanleyville, they spent some 50 days in the Belgian Congo and the mandate territory of Ruanda-Urundi; 4 days in Uganda on the way to the head of navigation on the Nile at Juda; and 19 days in the Sudan and Egypt, the descent of the Nile being made by steamer and by train around the cataracts. The expedition concluded its travel at Cairo on June 17, 1955, the collections having been forwarded by train from Kampala, Uganda, to the port of Mombassa, British East Africa, for shipment to Washington. Through the courtesy of the Institute des Parcs Nationaux in Brussels and particularly its president, Dr. Victor van Straelen, permission was given for photographing many of the larger big-game mammals inhabiting the Garamba, Albert, and Kagera National Parks on the route of the expedition. Scientifically profitable visits were made also to the leading geological, medical, and agricultural research stations operated by the government, including those at Leopoldville, Yangambi, Nioka, Lwiro, and Bukavu.

At the end of December 1954, Dr. Alexander Wetmore, research associate, returned to Panama to continue the ornithological survey of the Republic. Until late in January he was located at the Juan Mina field station of the Gorgas Memorial Laboratory for Tropical Medicine on the Río Chagres, a short distance below Madden Dam, an area on the Caribbean drainage, which, through the formation of Gatún Lake, has become especially favorable for birds that choose a freshwater habitat, as well as those that frequent forest.

Late in January, accompanied by Mrs. Wetmore, Dr. Wetmore drove by jeep to El Volcán in the mountains of western Chiriquí to remain until the end of March. The Finca Palo Santo of Don Pablo Brackney was again made available for a base, and from here he worked into the lower Temperate Zone on Cerro Picacho on the Continental Divide and also covered the lower and middle slopes of the great Chiriquí Volcano. In February the party located at the finca of Alois Hartmann at Santa Clara, visited also last year, and from here it was possible, through use of a jeep, to make valuable collections across to the Panamanian-Costa Rican frontier near El Sereno. Here the forest on the Panamanian side still remains only on the hills and in the steeper valleys, as in the more accessible areas timber has been cut. Studies made later from the small settlement of Cerro Punta, located at 6,100 feet elevation toward the Continental Divide, were especially interesting since this place gave access to high, heavily

forested valleys in the true Temperate Zone. Here quetzals, jays, and a variety of little-known, high-mountain birds ranged through trees grown heavily with moss and dense undergrowth constantly wet from misty rain. Morning temperatures ranged down to 45° F.

Following this, a few days were devoted to Cerro Chame, a low, isolated mountain on the coast below Bejuco, and a day each to the La Jagua marshes, near Pacora, and the high ridge of the Cerro Azul, beyond Tocumen. The latter mountain is especially interesting as the haunt of an unusual species of hummingbird, known first from its discovery by E. A. Goldman during investigations for the Smithsonian in 1912, and named *Goldmania violiceps.*

The field investigations concluded with two days on Barro Colorado Island, the Smithsonian biological station in Gatún Lake, the time being devoted mainly to observation from cayuco along the island shoreline. The work, during which Armageddon Hartmann served again as assistant, was completed on April 5. During the 3-month period notes were secured on approximately 400 species of birds.

During the last week of September 1954, Dr. David H. Johnson, acting curator, division of mammals, devoted a week at the Chicago Natural History Museum to the study of types and other specimens of mammals in that collection from Formosa, Borneo, and Siam. On the recommendation of the Commission on Hemorrhagic Fever, Armed Forces Epidemiological Board, military air transportation to London and return was furnished on March 29, 1955, to Dr. Johnson for the purpose of studying the types and other related specimens from northeastern Asia in the collections of the British Museum (Natural History). This commission requested Dr. Johnson, with the assistance of Lt. J. Knox Jones, to undertake a review of Korean mammals collected by Army field teams between 1952 and 1954.

From March 27 to April 8, 1955, Dr. Charles O. Handley, Jr., assistant curator, division of mammals, was engaged in comparative studies of foxes, bats, and marsupials in the collections of the Museum of Comparative Zoology and the American Museum of Natural History for the purpose of advancing completion of revisionary studies.

Dr. Ernest A. Lachner, associate curator, division of fishes, assisted by Frank Schwartz of the University of Pittsburgh, collected in the interval between September 9 and 14, 1954, several thousand fishes in furtherance of his projected study of the fresh-water fishes of the mountain streams of Virginia, the Carolinas, and Georgia.

Dr. J. F. Gates Clarke, curator, division of insects, left Washington on May 25, 1955, for an extended field trip to the Pacific Northwest, financed by a grant-in-aid from the American Philosophical Society. This research project involved the collection of larvae of small moths

of the genera *Depressaria* and *Agoropterix*, as well as experimental observations on their host specificity and host relationships. Fieldwork was commenced in Wyoming and carried on subsequently in Utah, Idaho, Oregon, Washington, Montana, North Dakota, and Minnesota.

Frederick M. Bayer, associate curator, division of marine invertebrates, under a cooperative arrangement with the Marine Laboratory of the University of Miami, conducted a search from August 20 to September 14, 1954, for a reef among the Florida Keys suitable for reproduction, in part at least, as a coral reef group in the projected Hall of Ocean Life. An unusually luxuriant, actively growing *Acropora* reef with conspicuous sea-fans and other gorgonians was located, and will furnish all the materials needed for an instructive display. Underwater pictures were taken of the reef and some material was collected for use in the preparation of this exhibit. On June 21, 1955, Mr. Bayer was detailed to join an expedition to the Palau Islands sponsored jointly by the George Vanderbilt Foundation and the Office of Naval Research.

Mendel L. Peterson, acting head curator, department of history, participated in a cruise sponsored by Edwin A. Link, of Binghamton, N. Y., to the Bahamas, Haiti, and Cuba from May 1 to July 7, 1955. The objective of this cruise was to investigate Spanish wreck sites on Silver Bank and to retrace the probable route followed by Columbus in the Bahamas during his first voyage to America, as well as to investigate the marking and decoration of muzzle-loading cannon. Photographs and measurements were taken of cannon in the old forts at Nassau in the Bahamas, at Turks Island, at the Citadelle of Henri Christophe at Port au Prince, and those in Morro Castle and the Cabana Fortress in Havana, Cuba.

Between December 12 and 16, 1954, Margaret W. Brown, associate curator, division of civil history, visited New York City and vicinity for consultations relative to the installation of materials in the First Ladies Hall. Franklin R. Bruns, Jr., associate curator, division of philately, participated during the past year in first-day ceremonies for postage-stamp issues and in exhibitions containing portions of the national postage stamp collections at Chicago, New York, and Philadelphia.

To obtain three bison for display in the North American Mammal Hall, W. L. Brown, chief taxidermist, proceeded on October 11, 1954, from Washington to the National Bison Range at Moiese, Mont., where arrangements had been made with the National Park Service for skins of three suitable surplus animals. Subsequently, Mr. Brown traveled to Amidon, Slope County, and to Bismarck, N. Dak., to obtain Rocky Mountain and columnar cedars, willow, dwarf juniper, sagebrush, and grasses for use as background materials in this exhibit.

John E. Anglim, exhibits specialist, visited the Chicago Natural History Museum for the purpose of studying the exhibition techniques employed in the newly completed bird, invertebrate paleontology, gem, mineral, and mammal halls. Discussions were held with the exhibits preparators and the respective curators. Several trips were also made to the Museum of Science and Industry at Chicago, between June 19 and June 27, 1955.

EXHIBITION

The program for modernization of exhibits initiated during the preceding year was continued in 1955 by a Congressional allotment of $360,000. Contracts were awarded and work commenced on the completion of the North American Mammal and Bird Halls and on the construction of the Cultural History Hall (Colonial tradition in America) and the Power Machinery Hall.

After many months of planning by Associate Curator C. Malcolm Watkins, with the cooperation of John E. Anglim, chief exhibits preparator, and the Public Buildings Service, construction was begun in Hall 26 on exhibits depicting colonial life in North America. Household furnishings and useful and decorative arts illustrating domestic customs from the earliest settlements along the Atlantic coast to about 1830 will be displayed in 50 cases and 6 period rooms. Two of the latter will be ground-floor rooms of a complete 2-story seventeenth-century house from Everett, Mass., the gift of Dr. and Mrs. Arthur M. Greenwood, of Marlboro, Mass.

An instructive exhibit of "Folk Pottery of Early New England" was installed in an alcove of the ground-floor foyer of the Natural History Building by Mr. Watkins and the exhibits preparators. The redware and stoneware displayed in this special exhibit were selected from the gift collection of Mrs. Lura Woodside Watkins.

On the evening of June 2, 1955, the President of the American Association of Museums, Dr. William M. Milliken, and the Secretary of the Smithsonian Institution, Dr. Leonard Carmichael, formally opened to the public the newly modernized American Indian Hall. This ceremony was scheduled as part of the program of the 50th anniversary meeting of the American Association of Museums. The ethnographic exhibits in the hall range geographically from Tierra del Fuego at the southern tip of South America, through Latin America, to the southwestern United States and California, and display various aspects of the ways of life of these historic Indian cultures. The life-size groups, a legacy from the past, were designed by the talented artist and former head curator of anthropology Dr. William H. Holmes. Five miniature dioramas supplement the life-size family groups and portray the Indians who met Columbus, life in a Yosemite Indian village in autumn when acorns are being collected in the valley below the tower-

ing Yosemite Falls, a sacred ceremony in the Antelope Kiva of the Hopi Indians, terrace farming among the Inca, and a camp scene among the Yahgan Indians, the southernmost people in the world. Wall cases display the basic economy of each culture, such as food, clothing, shelter, and handicrafts.

During the year the exhibits staff of the department of zoology completed the installation of the puma, Alaska wolf, pronghorn antelope, and Virginia deer in the recently constructed display units. For the bison group in this North American Mammal Hall, the Fish and Wildlife Service provided three animals from the National Bison Range.

In the hall devoted to birds, all construction work and one habitat group depicting the bird life of the Antarctic were completed. Five emperor and three Adelie penguins, a skua, a kelp gull, and a snow petrel are included. The paintings on the backgrounds of five additional display units—the hoatzin, Carolina parakeet, bowerbird, honeyguide, and palm chat—were practically finished at the close of the fiscal year. The paintings of flying birds for the ceiling of this hall were reported to be completed and the installation of exhibits in some of the alcove cases was commenced.

A special series of small exhibits of insects was prepared and placed in the foyer of the Natural History Building. Notable among these is an exhibit of Morpho butterflies, showing sexual dimorphism and the contrast between physical and chemical coloration. The display technique developed by Thomas G. Baker of the exhibits staff should be of decided interest to other museums because of its novelty and effectiveness.

Planning for the modernization of the geological exhibits has been resumed. The general plans and layouts of the halls for minerals, invertebrate fossils, and the lower vertebrate fossils have now been determined. Preparation of the giant ground sloth material from Panama has been completed, and two skeletons have been assembled for mounting and installation in the exhibition hall. Changes in the mineral exhibit consist of replacing specimens by finer examples as they are acquired.

The detailed planning of the Power Machinery Hall was completed during the year, the plans and specifications were reviewed, and the preparation of exhibits for installation was in progress. The exhibits in this hall will portray the story of the development of power machinery by using original machines, models, and graphic devices. Several new models of pioneer power machines were constructed by Donald H. Berkebile, modelmaker, in the exhibits workshop. The actual construction of this hall will start shortly after the close of this fiscal year.

An outline of the plans for the Hall of Health was circulated to professionally interested individuals and institutions for their com-

ment. The theme of this hall will be "Man's Knowledge of His Body Then and Now," a comparison of past and present ideas and knowledge of the human body.

Jacob Kainen, curator, and J. Harry Phillips, Jr., aide, division of graphic arts, began a complete revision of the exhibits in the portion of the Smithsonian Building known as the "chapel" with a view to presenting a graphic explanation of the techniques of picture printing and to tracing the development of the important processes employed to reproduce pictures mechanically. The photogravure and rotogravure sections have been completed and the halftone relief process is partially completed. The old built-in display cases have been painted a light gray, and lighting has been installed in the hall for the first time.

In the section of photography material was gathered for exhibits relating to the history of stereophotography and to early motion-picture devices. A series of new exhibits in the northwest gallery relating to the development of the camera shutter, the camera lens, artificial light, and instantaneous photography, and the applications of photography to everyday life, to science and industry, to welfare, and to education are now in the planning stage.

The First Ladies Hall in the Arts and Industries Building was formally opened on May 24, 1955, with the President of the United States and Mrs. Eisenhower participating in the dedication. The eight large display units in this hall are designed to represent different rooms in the White House from its earliest period to the present time. These settings afford the visitor an opportunity to view the dresses in surroundings similar to those in which they were originally worn. Architectural details received from the White House during the recent reconstruction have been incorporated in the rooms. Each room contains from three to six dresses representing a time span of about 20 years, and in consequence a style of background and furnishings typical of the period was selected to create an appropriate setting for all the dresses. Changing styles in White House decoration, from the earliest days to the present, shown in these rooms are actually based on written descriptions of the White House as well as available pictorial evidence.

An exhibit illustrating the history of the United States Marine Corps was dedicated on August 10, 1954, in a section of the Hall of Naval History, by Dr. Leonard Carmichael, Secretary of the Smithsonian, and Gen. Lemuel C. Shepherd, Commandant of the Marine Corps. A colorful parade of the Marine Corps band preceded the dedication. This exhibit reveals the historical development of this organization by means of a series of uniforms, swords, and miscellaneous items owned by notable officers and enlisted men.

A special exhibition, "History Under the Sea," was installed in the foyer of the Natural History Building where it was displayed from July 20 to August 20, and subsequently for about three months in the rotunda of the Arts and Industries Building.

Seventy-six double frames in the philatelic exhibit cases were utilized for display of an exceptionally complete series of United States revenue stamps which were transferred by the Internal Revenue Service. The Commissioner of the Internal Revenue Service, T. Coleman Andrews, made the presentation to Dr. Leonard Carmichael, Secretary of the Smithsonian Institution, on Octover 12, 1954.

VISITORS

During the fiscal year 1955 there were 3,312,870 visitors to the Museum buildings, an increase of 50,730 over the attendance in 1954. The average daily number of visitors was 9,668. Included in this total are 288,195 school children, who arrived in 7,316 separate groups. April 1955 was the month of the largest attendance with 482,058 visitors; May 1955 was the next largest with 474,485; and August 1954 was the third with 417,807. On one day, May 7, 1955, 55,096 visitors were recorded. Attendance records for the buildings show the following number of visitors: Smithsonian Building 665,261; Arts and Industries Building, 1,742,317; and Natural History Building 905,292.

BUILDINGS AND EQUIPMENT

On June 28, 1955, the President of the United States approved the Act of Congress which authorizes and directs the Regents of the Smithsonian Institution to plan and construct a suitable building for a Museum of History and Technology at a cost not to exceed $36,000,-000. It is a gratifying recognition of the value of the collections and exhibits which the staff have developed over the years. When completed, adequate facilities will make possible the long-contemplated effective presentation of objects in these fields.

The outward appearance of the Arts and Industries Building was materially improved by the installation of stainless steel doors, transom, and finished framing at the north entrance. The outmoded doorway was divided into three passageways which not only imparted a somewhat unsightly aspect but also hampered the inflow and exit of visitors. In continuation of the renovation program, the north, east, and south halls in the Arts and Industries Building were painted for the first time in many years.

CHANGES IN ORGANIZATION AND STAFF

Dr. Thomas E. Bowman was appointed assistant curator in the division of marine vertebrates on August 2, 1954.

On September 13, 1954, Dr. J. F. Gates Clarke replaced Dr. E. A. Chapin who retired on January 31, 1954, as curator of the division of insects under a transfer from the Insect Identification and Parasite Introduction Section of the Entomology Research Branch of the U. S. Department of Agriculture.

Dr. Richard E. Blackwelder, associate curator, division of insects, resigned effective October 29, 1954. Dr. R. Tucker Abbott, associate curator, division of mollusks, resigned November 10, 1954, to accept a position at the Academy of Natural Sciences of Philadelphia.

Austin H. Clark, research associate, who retired as curator, division of echinoderms, December 31, 1950, after serving more than 42 years as a member of the staff, died on October 28, 1954, at Washington, D. C.

The department of geology lost, through death, on June 6, 1955, the valuable services and stimulating associations of Dr. John Putnam Marble, research associate in the division of mineralogy and petrology since 1948.

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, 1955, 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

In addition to his administrative duties, Dr. M. W. Stirling, Director of the Bureau, completed the preliminary studies of the archeological collections made in Panama in 1953, and prepared for publication the sections relating to Taboga, Taboguilla, and Uravá Islands, and also that from Almirante Bay on the Panama north coast.

Dr. Frank H. H. Roberts, Jr., Associate Director of the Bureau, was occupied principally with duties pertaining to the management of the River Basin Surveys, of which he is Director (see his report, p. 40). He reviewed and revised a number of manuscripts on the results of excavations at sites in various areas. In the latter part of September Dr. Roberts went to Lincoln, Nebr., to discuss the operations of the field office located there and to talk with the men who were coming in from the field. En route to Lincoln he visited the Department of Anthropology at the University of Michigan where he examined various archeological collections and spoke to a group of students on the problem of Early Man in America. In November he attended the 12th Plains Conference for Archeology held at the Laboratory of Anthropology, University of Nebraska, and took part in discussions on the archeology of the Missouri Basin. During the winter months he devoted a portion of his time to the preparation of a manuscript covering the high points and summarizing the activities of the River Basin Surveys from the beginning of fieldwork in the summer of 1946 to the end of the calendar year 1954. In May he attended the annual meeting of the Society for American Archaeology at Bloomington, Ind., and participated in a symposium on the archeological salvage program. Thence he proceeded to Lincoln where he

spent a week reviewing the activities of the field office and laboratory and assisting in the preparation of plans for the summer field season. Toward the end of June Dr. Roberts again went to the headquarters at Lincoln to assist in the preparations for sending parties to the field and started on an inspection trip through the Missouri Basin in company with Dr. John M. Corbett and Paul Beaubien of the National Park Service. At the end of June the group was at Cherokee, Iowa, where Dr. Reynold J. Ruppe, Jr., of the University of Iowa, was directing a joint party of the University and the Sanford Museum in excavations at an archeological site on Mill Creek.

At the beginning of the fiscal year Dr. Henry B. Collins, anthropologist, was in the Canadian Arctic, conducting archeological work on Southampton Island in Hudson Bay. The expedition was sponsored jointly by the Smithsonian Institution, the National Geographic Society, and the National Museum of Canada. Dr. Collins was assisted by Dr. J. N. Emerson, assistant professor of anthropology, University of Toronto, William E. Taylor, Jr., research assistant, Museum of Anthropology, University of Michigan, and Eugene Ostroff, photographer, of Washington, D. C.

The party left Coral Harbour, Southampton Island, on June 25, traveling by dog team over the sea ice, and camped for the greater part of the summer at Native Point, 40 miles down the coast. This abandoned Eskimo village of 85 stone and sod house ruins was once the principal settlement of the Sadlermiut Eskimos, who became extinct in 1903. Excavation of selected house ruins, graves, and midden areas yielded a valuable collection of cultural and skeletal material of this little-known Eskimo tribe.

One mile from the Sadlermiut site, on an 85-foot elevation and almost a mile from the sea, is a much older site of the Dorset culture, probably 1,000 years or more old. Covering an area of well over 20 acres, this is the largest Dorset site thus far known. Excavations there yielded thousands of artifacts of stone, ivory, and bone, some of them typically Dorset, others representing types that were new to the Dorset culture. The site represents a phase of Dorset culture different in certain respects from any previously reported. Among the new types were several forms of microlithic blades recalling those of the upper Paleolithic and Mesolithic of Eurasia but not previously found in America. Wood was entirely absent at the site, having disintegrated, and the bird and mammal bones and the ivory, bone, and antler artifacts were uniformly patinated and weathered, in striking contrast to the fresh, well-preserved similar material from the Sadlermiut site. This suggests a considerable age for the Dorset site and bears out other indications that the Dorset culture in Canada and Greenland flourished at a time when the climate was milder than today.

Over 45,000 mammal bones were excavated at the Dorset and Sadlermiut sites, and of these some 6,000 were identified in the field. One result was the demonstration of some striking differences in the food economy of the Dorset and Sadlermiut people. Twenty graves containing complete skeletons were excavated, and an additional 15 unassociated skulls were collected. In mid-July a trip was made by Eskimo boat to Coats Island where two Sadlermiut houses were excavated.

A preliminary report illustrating and describing the results of the Southampton investigations was prepared for publication. Another article was prepared describing the current status of Arctic archeology, results accomplished, and problems toward which research should be directed.

Dr. Collins continued to serve as a member of the Research Committee of the Arctic Institute of North America and of the subcommittee responsible for planning and supervising the scientific work of the Point Barrow Laboratory, operated by the Office of Naval Research. He also continued as chairman of the directing committee supervising the work of the *Arctic Bibliography*, which the Arctic Institute is preparing for the Department of Defense, under an Office of Naval Research contract, with funds provided by the Department of the Air Force. Volume 4 of *Arctic Bibliography*, 1,591 pages, was issued by the Government Printing Office in August 1954. It lists and describes the contents of 7,627 publications in all fields of science relating to the Arctic and sub-Arctic regions of America and Eurasia. The material, which is extensively indexed and cross-indexed according to subject and geographical locality, covers papers published in English, Russian, Scandinavian, and other languages. Volume 5 of the bibliography, containing analysis of contents of 5,494 publications, was issued in April 1955. Though all fields of science are included, volume 5 gives special emphasis to health and disease in the Arctic, environmental effects, and anthropology, particularly the native peoples of northern Siberia and Europe. Material for volume 6 was turned over to the printer on June 20, 1955.

On June 6, 1955, Dr. Collins left again for Southampton Island, to continue the excavations begun last year. The work is being sponsored by the National Museum of Canada and the Smithsonian, with a grant received from the American Philosophical Society.

At the beginning of July, Dr. Philip Drucker was at his official station in Washington, D. C., preparing a report on field researches completed during the previous year. The report, entitled "Modern Inter-tribal Organizations on the Northwest Coast," was later submitted to, and accepted by, the Arctic Institute of North America, the foundation that supported the major portion of the research, with

supplementary financial assistance from the American Philosophical Society and the Smithsonian Institution. During the same interval he also completed a theoretical paper on "The Sources of Northwest Coast Culture," for publication in the *New Interpretations of Aboriginal American Culture History*, 75th Anniversary Volume of the Anthropological Society of Washington.

Thanks to the liberal support of the National Geographic Society, it was possible to plan an ample program of archeological research at the important Olmec site of La Venta, Tabasco, Mexico. Plans were drawn up for a cooperative project, in which the National Geographic Society, the Smithsonian Institution, and the University of California were to participate. Dr. Drucker, representing the Smithsonian Institution, and Dr. Robert F. Heizer, of the University of California and honorary research associate of the Smithsonian, were to function as coleaders of the expedition. During the latter part of November and early in December, Dr. Drucker made a preliminary trip to La Venta to obtain clearances from local, civil, and military authorities, recruit labor, select a camp site, and negotiate other details. On January 10 he left Washington to initiate the work, being joined on February 1 by Dr. Heizer and two of the latter's graduate students serving as archeological assistants. An additional member of the party was Ing. Eduardo Contreras S., assistant archeologist and representative of the Instituto Nacional de Antropología e Historia de México. In passing, due tribute must be given the officers of this organization, whose whole-hearted cooperation made the fieldwork possible.

The primary aim of the expedition was to carry out architectonic investigations at La Venta, since in past years National Geographic Society-sponsored parties have recovered a good deal of information on Olmec ceramics and art. Excavations were restricted almost exclusively to the ceremonial enclosure, where tests in previous years had shown a variety of structures to exist. Working through a 3½-month season with a crew of about 50 local laborers, the party excavated a series of structures of the ceremonial enclosure complex. It proved possible to identify a series of constructional phases in each of the individual structures and to work out a correlation of the phases throughout the ceremonial enclosure. From the drift-sand overburden that covered the structures, materials were recovered pertaining to one, or possibly two, post-Olmec occupations of the site. Determination of the cultural affiliations of these later inhabitants is of special interest. Carbon samples from post-Olmec deposits and from various structural phases of the Olmec occupation were collected for the purpose of obtaining accurate C–14 dates of the phases and periods.

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In addition, a series of offerings were found, consisting of objects of pottery, jade, serpentine, hematite, quartz crystal, and other minerals, which add considerably to the stock of available knowledge of Olmec art and technology.

At the end of the fiscal year, Dr. Drucker was at the Museo Nacional de Antropología in Mexico, D. F., studying the collections made during the field season.

RIVER BASIN SURVEYS

(Prepared by FRANK H. H. ROBERTS, Jr., Director)

The River Basin Surveys continued investigations 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 various State and local institutions. Because of a further curtailment of funds the Inter-Agency Salvage Program did not produce as extensive results as in former years. During the fiscal year 1954–55 the work of the River Basin Surveys was financed by a transfer of $52,700 from the National Park Service to the Smithsonian Institution. The funds were entirely for use in the Missouri Basin. An additional carryover of $3,691.44 made a total of $56,391.44 for operations in the area. That amount was approximately 25 percent less than moneys available for the preceding year, which also had suffered a drastic reduction. As a consequence, there was a corresponding progressive decrease in the program.

Field investigations during the year consisted mainly of excavations. On July 1, 1954, three parties were in the field; two were doing intensive digging—one in the Fort Randall area in South Dakota and one in the Garrison Reservoir area in North Dakota, and the third, also operating in the Fort Randall basin, was engaged in test excavations at a number of sites. In each case some reconnaissance work was carried on, but that constituted only a minor activity. At the end of the fiscal year no parties were in the field, but preparations were under way to send out three groups for intensive digging operations in two reservoir areas. Because of lack of funds no paleontological studies were made during the year and none were planned for fiscal 1956.

By June 30, 1955, areas where archeological surveys had been made or excavations carried on since the start of actual fieldwork in the summer of 1946 totaled 243 located in 27 States. In addition, one lock project and four canal areas had also been investigated. As a result some 4,345 sites have been located and recorded. Of that number 852 were recommended for excavation or limited testing. Preliminary appraisal reports were completed for all the reservoirs surveyed, and where additional reconnaissance has resulted in the

discovery of other sites supplemental reports have been prepared. During the course of the year one such report was issued. Since the start of the program 180 reports have been distributed. The difference between that figure and the total number of reservoir areas investigated is in part due to the fact that where several reservoirs form a unit in a single subbasin they are included in one report.

At the end of the fiscal year 324 sites in 44 reservoir basins located in 17 different States had been dug either extensively or in part. In some of the reservoir areas only a single site was excavated while in others a whole series was examined. At least one example of each type of site found in the preliminary surveys has been investigated. In previous years the results of certain phases of that work appeared in technical journals and in Bulletin 154 of the Bureau of American Ethnology. Six manuscript reports on earlier excavation work were completed during the present year and are ready for publication. One major technical report was issued in December as Bulletin 158 of the Bureau of American Ethnology, and a summary statement of the program in the Missouri Basin for the years 1950–51 appeared in April 1955 in the Smithsonian Miscellaneous Collections.

The reservoir projects that have been surveyed for archeological remains as of June 30, 1955, 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, 9; 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, 3; Montana, 1; Nebraska, 1; New Mexico, 1; North Dakota, 4; Oklahoma, 2; Oregon, 3; South Carolina, 1; South Dakota, 3; 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.

Throughout the year the National Park Service, Bureau of Reclamation, Corps of Engineers, and various State and local institutions continued to provide helpful cooperation in the Inter-Agency Salvage Program and furnished valuable assistance to the River Basin Surveys. In several cases mechanical equipment was made available by the construction agency, and at other projects temporary office and laboratory space was provided. Transportation and guides were

furnished in a number of instances. The River Basin Surveys men received helpful assistance from the field personnel of the other agencies, and for that reason their accomplishments were much greater than would otherwise have been the case. As in previous years the National Park Service served as the liaison between the various agencies both in Washington and in the field. It also was mainly responsible for preparing estimates and justifications and procuring funds to support the investigations. The wholehearted cooperation of Park Service personnel greatly aided all phases of the operations.

The main office in Washington continued general supervision over the work, while the field headquarters and laboratory at Lincoln, Nebr., was responsible for the activities in the Missouri Basin. The materials collected by excavating parties in the Missouri Basin were processed at the Lincoln laboratory. During the year there was a general distribution of specimens and materials from the laboratory to the U. S. National Museum and to various State and local agencies. The only activities outside the Missouri Basin pertained to the completion of reports on work done in previous years and a brief check on the status of two construction projects in Tennessee.

Washington office.—The main headquarters of the River Basin Surveys, at the Bureau of American Ethnology, continued under the direction of Dr. Frank H. H. Roberts, Jr. Carl F. Miller, archeologist, was based at that office and from time to time assisted the director in general administrative problems.

At the start of the fiscal year Mr. Miller was in the office continuing his studies on the material obtained at the John H. Kerr (Buggs Island) Reservoir on the Roanoke River in southern Virginia and in the preparation of his report on the results of investigations at that locality. During the fall and winter months he completed a manuscript, "Reevaluation of the Eastern Siouan Problem with Particular Emphasis on the Virginia Branches: the Occaneechi, Saponi, and Tutelo." He also presented papers before several archeological societies and interested study groups. In June, at the request of the Bureau of American Ethnology, he made a brief trip to visit and examine various Archaic and Paleo-Indian sites in Alabama and Tennessee. He made an examination of Russell Cave in Jackson County, Ala., where three and possibly four occupation levels are present. He also visited several Paleo-Indian sites in the vicinity of Decatur and Huntsville, Ala., and studied collections of materials that had been obtained from them. From Alabama Mr. Miller went to Nashville, Tenn., and after conferring with the Corps of Engineers officers in that city proceeded to the Cheatham and Old Hickory projects on the Cumberland River to determine the exact status of the reservoir pools in relation

to the archeological sites in their basins. En route from Tennessee to Washington Mr. Miller stopped in Georgia and picked up materials collected during the course of investigations at the Allatoona Reservoir and brought them to the National Museum. At the end of June Mr. Miller was making preparations to proceed to Montana to conduct excavations in the Tiber Reservoir area on the Marias River.

Columbia Basin and Texas.—The River Basin Surveys did no fieldwork in these areas during the fiscal year, but two technical reports on previous investigations were completed and submitted for publication. Joel L. Shiner, formerly in charge of the River Basin Surveys field headquarters at Eugene, Oreg., and now an archeologist with the National Park Service, turned in a manuscript, "The McNary Reservoir, a Study in Plateau Archeology," based on the results of excavations at nine sites. Edward B. Jelks, who was in charge of the field headquarters at Austin, Tex., before it was transferred to the National Park Service and who is still an archeologist with that organization, completed a report, "Excavations at Texarkana Reservoir, Sulphur River, Texas," detailing the results of the digging at three sites. As his duties at the Lincoln, Nebr., office permitted, Robert L. Stephenson continued work on his "Archeological Investigations in the Whitney Reservoir Area, Hill County, Texas." Mr. Stephenson made the excavations on which it is based before transferring to the Missouri Basin.

Missouri Basin.—Throughout fiscal 1955 the Missouri Basin Project continued to operate from the field headquarters at Lincoln, Nebr. Robert L. Stephenson served as chief of the project from July 1 to September 3, when he was granted leave of absence to complete academic work on an advanced degree at the Department of Anthropology, University of Michigan. After Mr. Stephenson's departure, G. Hubert Smith took over direction of the project as archeologist in charge. Activities during the year were concerned mainly with excavations, the processing of the collections obtained from the digging, analyses and study of the materials, the preparation of general and technical manuscripts on the results, and the publication and dissemination of scientific and popular reports. At the beginning of the fiscal year the Missouri Basin Project had a permanent staff of twelve persons. There were two temporary part-time employees assisting in the laboratory. During July, August, and part of September, 1 temporary assistant archeologist and 24 temporary student and local nonstudent laborers were employed in the field. During the field season three of the regular staff were engaged in excavation activities. The temporary employees were gradually laid off as the excavations and test digging were brought to a close and by the first of October only the permanent staff, a temporary assistant archeologist, and a part-time

office worker were on the rolls. By the first of November it became evident that the funds available for 1955 would not permit the continuance of as large a staff and a reduction in force became necessary. As a result on June 30 the staff had been cut to seven persons.

During the year only three River Basin Surveys field parties operated in the Missouri Basin. Two of them were primarily occupied in conducting full-scale excavations while the third was engaged in making a series of test excavations. The latter and one of the full-scale digging parties worked in the Fort Randall Reservoir area in South Dakota while the other excavating party worked in the Garrison Reservoir area in North Dakota. All three parties were in the field at the start of the fiscal year. At the Fort Randall Reservoir, which has been flooding since the closing of the dam in July 1953, excavations were carried on by a group under the direction of Harold A. Huscher at the Oldham Village site where previous digging had revealed evidence for several components but the relationships were not clear. Because of the rising waters of the reservoir pool and unsatisfactory working conditions, the investigations were brought to a close on July 24. The results of the season's efforts clarified the situation at the Oldham site and will make possible a much more satisfactory story of the occupations there in the period A. D. 1500 to 1700. Shortly after the departure of the field party, the Oldham site went under water and will continue to be flooded throughout the indefinite future.

The second party in the Fort Randall area under Paul L. Cooper continued its intensive sampling operations until September 20. During the season 13 sites ranging from the Woodland to the historic periods were studied. The sites varied from small temporary camps to the remains of extensive earth-lodge villages. Several cultural traditions are represented in the material obtained from them. Mr. Cooper had planned to dig at several additional locations but the rising waters of the reservoir prevented his doing so.

During the period the two field parties from the Missouri Basin Project were engaged in the Fort Randall area, a third party representing the Nebraska State Historical Society, led by Marvin F. Kivett, and working under an agreement with the National Park Service, excavated at Crow Creek Village site. The imposing remains of that former fortified earth-lodge village have been well known to students for many years, but it was not until the summer of 1954 and excavations were under way that the presence of a second village area, also fortified, was established. In the latter, evidence for two occupations, both prehistoric, was found. These are significant because one of them shows definite relationships with cultural materials in Nebraska while the other clearly defines a cultural phase

found during an earlier season at another site in the Fort Randall area and which was not well understood. Important data were also obtained on earth-lodge types. In the vicinity of the village areas two burial mounds were tested and information was obtained on burial customs. The work at that location contributed so much to knowledge of aboriginal occupation in that portion of the Missouri Basin that the Historical Society in cooperation with the National Park Service again sent a party to the site on June 14 where it was continuing excavations at the end of the fiscal year.

In June a party from the University of Kansas led by Dr. Carlyle S. Smith proceeded to the Fort Randall Reservoir area to begin excavations under a cooperative agreement with the National Park Service. The Kansas group started digging at a site near Fort Thompson. By the end of the fiscal year they had cut cross trenches and quadrants in the remains of a large earth lodge approximately 52 feet in diameter and had tested several refuse mounds in a nearby field. The materials recovered by the close of the year indicated that the site had relationships with certain occupations at two sites previously excavated in the Fort Randall area. The party planned to continue its operations through the month of July, and the additional information obtained should make possible a better understanding of aboriginal activities in that immediate district.

The River Basin Surveys did no work in the Oahe Reservoir area during the fiscal year, but a party from the South Dakota State Archeological Commission and the W. H. Over Museum, under a cooperating agreement with the National Park Service, carried on excavations directed by Dr. Wesley R. Hurt at a location known as the Swan Creek site. Three and possibly four occupations were found there. The most recent of them represents the historic period. Parts of two fortification ditches with palisades, earth lodges, and caches, and burials of two types were uncovered. The sites proved to be so important and so complex that Dr. Hurt and his party returned there on June 15 and was continuing its excavations at the close of the fiscal year.

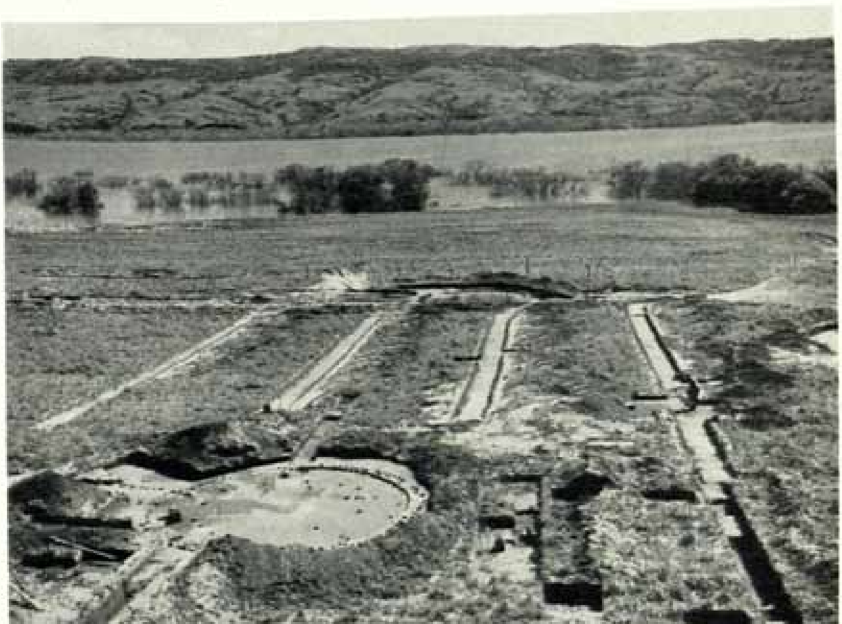
In the Garrison Reservoir area at the beginning of the fiscal year a party from the Missouri Basin Project under G. Hubert Smith and a group from the State Historical Society of North Dakota led by Alan R. Woolworth, operating under an agreement with the National Park Service, were continuing their joint investigations at the sites of Forts Berthold I and II and the remains of the aboriginal village named Like-a-Fishhook. Fort Berthold II had been partially dug by Smith in 1952 and parties from the State Historical Society of North Dakota had carried on studies in the remains of the Indian village during three previous seasons. Toward the close of the 1952 season

the North Dakota party found indications of the remains of Fort Berthold I but had no opportunity to study them. Because of lack of funds nothing was done there in the summer of 1953. The plans for the 1954 season included the clearing of several features at Fort Berthold II, excavation of the remains of Fort Berthold I, and some additional digging in the aboriginal area. When the project was brought to a close on July 10 the remains of the original Fort Berthold trading post were fully exposed and the stockade which surrounded the original Indian village had been found and completely defined. The excavations were greatly accelerated by the use of mechanical equipment. Fort Berthold I was built and occupied from 1845 to 1862 and the adjacent Fort Berthold II, which originally was called Atkinson, was occupied from about 1858 to 1890 by both fur traders and American military forces. Like-a-Fishhook Village was situated between the two trading posts and was built about 1845. It was occupied by groups of Mandan, Hidatsa, and Arikara who had joined forces against the Sioux. Information obtained from the digging of the various features in the area has made possible the preparation of the first complete map showing the extent of the two posts and the village and has added considerable information pertaining to the fur trade and other white and Indian contacts during the period involved. The entire area went under water in the spring of 1955.

From Fort Berthold, Woolworth and the State Historical Society party moved farther upstream and excavated the remains of Kipp's Trading Post. The stockade was outlined and the positions and extent of the log buildings originally within the enclosure were determined. A representative collection of objects characteristic of the period was obtained. This supplemented and broadened the information from test excavations made there by a River Basin Surveys party in the fall of 1951. The site is of particular interest because it was occupied for a short time during the winter of 1826–27 when the period of organized trade on the Upper Missouri was just getting under way and because Kipp's Post seemingly was the immediate predecessor of Fort Union which became the great trade capital for that part of the Plains area. After completing the work at that location, the party made some further investigations at Grandmother's Lodge, a site where some preliminary digging had been done during a previous season. Grandmother's Lodge was the traditional dwelling place of the Mandan or Hidatsa supernatural being who was considered to be the patroness of gardens and crops. Investigation of the remains provided data that can be compared with the legendary story which is one of the important myths of the Indians in that district.

Three detailed technical reports, all pertaining to excavations at sites in the Garrison Reservoir area in North Dakota, were completed

1. Operations of River Basin Surveys. Exposed floor areas being taken from top of tall ladder. Rising waters of Fort Randall Reservoir appear in background.



2. Operations of River Basin Surveys. Portion of the Oldham site as seen from the ladder. Holes in floor of area in left foreground outline former circular earth lodge. Entire site is now under water.

1. Operations of River Basin Surveys. Tracing floor of earth lodge at village site near Chamberlain, S. Dak. Missouri River in background. Area has since been destroyed.

2. Operations of River Basin Surveys. Mechanical equipment was used successfully removing upper part of fill from house pits and for excavating long trenches.

and submitted for publication. Considerable progress was made in the preparation of the reports on the results of investigations in one reservoir area in South Dakota, a second reservoir area in North Dakota, and two reservoir areas in Wyoming. In addition several short articles and papers were written and sent to technical journals. Two major manuscripts were printed and distributed and several short articles were published.

During the year the reduced laboratory staff processed 46,602 specimens from 51 sites in 4 reservoir areas. A total of 6,155 catalog numbers was assigned to the series of specimens. The work in the laboratory also included: reflex copies of records, 7,423; photographic negatives made, 685; photographic prints made, 787; photographic prints mounted, 2,854; manuscript prints mounted, 35; transparencies mounted in glass, 362; drawings, tracings, and maps, 110; specimens drawn for illustration, 81; pottery vessels restored, 2; pottery vessel sections restored, 32. Photographic activity was at a minimum because the position of staff photographer left vacant by the death of the photographer at the end of the preceding fiscal year was not filled. However, the photographic laboratory at the Smithsonian Institution in Washington assisted by performing some of the required work. Drafting and specimen illustrating were also at a minimum because there were not sufficient funds to replace the draftsman-illustrator who resigned in October. The laboratory staff devoted considerable time during the fiscal year to transferring analyzed records and special materials to various permanent repositories. In accordance with the policy adopted at the start of the program, various collections and the data pertaining to them were sent to several State and local agencies as well as to the United States National Museum.

Archeological specimens and records from the following were transferred to the division of archeology, U. S. National Museum: Amherst Reservoir, 12 sites; Baldhill Reservoir, 11 sites; Beaver City Reservoir, 4 sites; Box Butte Reservoir, 1 site; Boysen Reservoir, 1 site; Brewster Reservoir, 1 site; Broncho Reservoir, 6 sites; Buffalo Creek (renamed Bison) Reservoir, 1 site; Cushing Reservoir, 2 sites; Devil's Lake Reservoir, 3 sites; Dickinson Reservoir, 3 sites; Enders Reservoir, 5 sites; Ericson Reservoir, 5 sites; Fort Randall Reservoir, 11 sites; Garrison Reservoir, 117 sites; Heart Butte Reservoir, 1 site; Jamestown Reservoir, 1 site (human bone only); Medicine Creek Reservoir (Harry Strunk Lake), 24 sites; Medicine Lake Reservoir, 5 sites; Mullen Reservoir, 8 sites; Niobrara Basin (a series of 10 small reservoirs), 44 sites; Oahe Reservoir, 8 sites; Red Willow Reservoir, 3 sites; Rock Creek Reservoir, 1 site; Sargent Canal, 4 sites; Tiber Reservoir, 4 sites; sites not in reservoirs: Kansas, 1; Missouri, 1; Montana, 11; Nebraska, 8.

Archeological specimens and records were transferred as follows: From 107 Tuttle Creek Reservoir sites to the Department of Economics and Sociology, Kansas State College. From one site in the Keyhole Reservoir to the Department of Economics and Sociology, University of Wyoming. From one site in the Garrison Reservoir to the Department of Anthropology and Sociology, Montana State University. From 14 sites in the Big Sandy Reservoir to the Department of Anthropology, University of Nebraska. From one site in the Garrison Reservoir to the Nebraska State Historical Society. From 3 sites in the Garrison Reservoir to the North Dakota State Historical Society. Virtually all the material worth preservation from one of the sites, Fort Stevenson, went to Bismarck.

Total number of sites from which archeological specimens were transferred to other organizations in fiscal 1955: 434.

Transfers of archeological specimens made prior to fiscal 1955 and not previously reported: Department of Anthropology, University of Denver, a total of 19 sites representing Bonny, Cherry Creek, Narrows, and Wray reservoirs. Department of Anthropology, University of Nebraska, a total of 11 sites representing Harlan County Reservoir. Museum of Natural History, University of Kansas, a total of 66 sites representing Cedar Bluff, Glen Elder, Kanopolis, Kirwin, Lovewell, Norton, Pioneer, Webster, Wilson, and Wolf Creek reservoirs. Division of archeology, U. S. National Museum, a total of four sites representing Harlan County and Tuttle Creek reservoirs.

Total number of sites from which archeological specimens were transferred prior to fiscal 1955: 100.

As of June 30, 1955, the Missouri Basin Project had transferred to other agencies the archeological specimens from a total of 534 sites. Of these, 513 sites were in 52 reservoirs. Twenty-one sites were not in reservoirs.

In addition to transfers of archeological specimens in site lots, the Missouri Basin Project had, just prior to fiscal 1955, transferred representative series of potsherds to the following agencies: Ceramics Repository, University of Michigan; W. H. Over Museum, University of South Dakota; Museum of Natural History, University of Kansas; Nebraska State Historical Society.

Upper Republican sherds were transferred from Medicine Creek Reservoir sites 25FT13, 17, 39, and 70. Sites 39ST14 and 30, in Oahe Reservoir, furnished sherds of the following wares: Anderson, Foreman, Monroe, and Stanley.

All identified, unworked shell in storage was transferred to the University of Nebraska State Museum in November 1954. Except for specimens in the comparative collection in the Lincoln laboratory, this transfer included all specimens collected prior to 1954. Reser-

voir distribution is as follows: Amherst, 2 sites; Angostura, 11 sites; Baldhill, 7 sites; Beaver City, 1 site; Bixby, 3 sites; Boysen, 2 sites; Buffalo Creek, 1 site; Canyon Ferry, 7 sites; Cushing, 1 site; Edgemont, 1 site; Fort Randall, 35 sites; Garrison, 13 sites; Glendo, 8 sites; Glen Elder, 13 sites; Harlan County, 8 sites; Heart Butte, 3 sites; Kanopolis, 6 sites; Keyhole, 8 sites; Kirwin, 4 sites; Medicine Creek, 14 sites; Medicine Lake, 1 site; Moorhead, 1 site; Niobrara Basin, 7 sites; Oahe, 58 sites; Sheyenne, 2 sites; Tiber, 5 sites; Tuttle Creek, 10 sites; Wilson, 1 site; not in reservoirs, 3 sites.

Total number of sites from which identified, unworked shell was transferred: 236, of which 233 were in 29 reservoirs and 3 were not in reservoirs.

As of June 30, 1955, the Missouri Basin Project had transferred the identified, unworked animal bone from 453 sites to the University of Nebraska State Museum. No such transfers were made during fiscal 1955. Reservoir distribution of previous transfers is as follows: Amherst, 1 site; Angostura, 34 sites; Baldhill, 2 sites; Big Sandy, 1 site; Bixby, 3 sites; Bonny, 1 site; Boysen, 12 sites; Canyon Ferry, 4 sites; Clark Canyon, 1 site; Des Lacs, 1 site; Devil's Lake, 1 site; Dickinson, 2 sites; Edgemont, 6 sites; Enders, 1 site; Ericson, 1 site; Fort Randall, 85 sites; Garrison, 60 sites; Gavins Point, 1 site; Glendo, 14 sites; Glen Elder, 4 sites; Harlan County, 8 sites; Heart Butte, 5 sites; Jamestown, 7 sites; Kanopolis, 5 sites; Keyhole, 9 sites; Kirwin, 4 sites; Kortes, 1 site; Medicine Creek, 13 sites; Medicine Lake, 2 sites; Moorhead, 5 sites; Mullen, 3 sites; Niobrara Basin, 10 sites; Norton, 1 site; Oahe, 93 sites; Oregon Basin, 9 sites; Red Willow, 1 site; Tiber, 22 sites; Tuttle Creek, 1 site; Wilson, 4 sites; Yellowtail, 3 sites; not in reservoirs, 12 sites.

A special exhibit illustrating and explaining the Missouri Basin Salvage Program was prepared and installed at the Nebraska State Fair held at Lincoln during September. Considerable attention was shown the display by visitors, and numerous requests were received for literature pertaining to the operations of the project and the results obtained from the various excavations. Temporary interpretative displays were also installed from time to time in the windows of the Laboratory in the business section of Lincoln. They attracted favorable attention and numerous passers-by dropped into the office to ask questions about different projects. Much local interest has developed since the Salvage Program has been under way.

Paul L. Cooper, archeologist, was in charge of the intensive testing party in the Fort Randall area from July 1 until September 20. During that time he supervised the digging in 13 sites which were soon to go under water. Mr. Cooper returned to Lincoln on September 22 and during October and the early part of November devoted his time to the

study of the materials obtained during the summer and analysis of the information contained in his field notes. He also read proof on his report, "The Archeological and Paleontological Salvage Program in the Missouri Basin, 1950–51," which appeared in April in the Smithsonian Miscellaneous Collections, vol. 12, No. 2. Because of the shortage of funds and the necessity of curtailing the staff of the Missouri Basin Project, Mr. Cooper's employment was terminated November 20 by a reduction-in-force action.

Harold A. Huscher, assistant archeologist, was in charge of the party excavating at the Oldham site in the Fort Randall Reservoir area from July 1 to July 24. He returned to headquarters at Lincoln on July 27. During August, September, and the early part of October he devoted his time to analyzing and studying the materials obtained during the field season and in correlating his results with those of previous seasons' work at the site. He resigned from the Missouri Basin Project on October 15 to return to Columbia University and continue his work on an advanced degree.

George Metcalf, formerly a member of the regular staff of the Missouri Basin Project but now a member of the division of archeology, U. S. National Museum, completed and turned in a manuscript, "Notes on Some Small Sites on and about Fort Berthold Indian Reservation, Garrison Reservoir, North Dakota." The data contained in the manuscript were collected by Mr. Metcalf during several seasons of fieldwork while a member of various River Basin Surveys parties.

At the beginning of the fiscal year G. Hubert Smith, archeologist, was in charge of the Missouri Basin Project party which was cooperating with the North Dakota State Historical Society party in the Garrison Reservoir where excavations at the sites of Fort Berthold I, Fort Berthold II, and Like-a-Fishhook Village were being brought to completion. The work was finished on July 10 and Mr. Smith proceeded to Bismarck, N. Dak., where he devoted a week to the study of documentary records in the archives of the State Historical Society. Materials there contain considerable information about both of the forts as well as the Indian village and Mr. Smith deemed it advisable to be familiar with the records because of the light they might throw on the evidence obtained by the digging. Mr. Smith was on duty at the Lincoln headquarters from July 19, 1954, to May 20, 1955. From August 16 to August 31, during an absence of Robert L. Stephenson, he served as archeologist in charge. He again took over in the latter capacity from September 3, 1954, until May 20, 1955. While at the project headquarters Mr. Smith revised and completed the draft of his report on excavations at the site of Fort Berthold II, made largely in 1952 and completed in 1954, and in collaboration with Alan R. Woolworth of the North Dakota State Historical Society prepared a pre-

liminary report of the investigations at the site of Fort Berthold I. Throughout the fall and winter months Mr. Smith talked about salvage archeology before numerous groups in Lincoln. He reported on the current work of the Missouri Basin Project at the 12th Plains Conference for Archeology which was held at Lincoln in November. He also presented a paper at the May meeting of the Nebraska Academy of Sciences. At the request of the Indian Claims Section, Lands Division, Department of Justice, Mr. Smith was detailed to that organization on May 20 to assist in gathering data for an Indian land-claims case. He completed that assignment on June 30. A paper by Mr. Smith, "Excavations at Fort Stevenson, 1951," was published in North Dakota History for July 1954.

Robert L. Stephenson, chief of the Missouri Basin Project, was at the headquarters in Lincoln on July 1. Shortly thereafter he left on a tour of inspection of the field parties working in the Missouri Basin. He accompanied Dr. John M. Corbett and Paul Beaubien of the National Park Service. The party visited the excavations at the Oldham and Crow Creek sites and the several sites under investigation by Paul L. Cooper. It also went to the Swan Creek site in the Oahe Reservoir area. After his return to Lincoln, Mr. Stephenson, in addition to directing the operations of the project, continued work on several technical reports. Mr. Stephenson left the field headquarters at Lincoln on September 3 and proceeded to Ann Arbor, Mich. He was still in leave status at the end of the year.

Richard P. Wheeler, archeologist, returned to the Lincoln headquarters on July 1 from Jamestown, N. Dak., where he had been conducting excavations and making surveys in the Jamestown Reservoir basin. Wheeler remained in the office throughout the fiscal year. He devoted his time to the preparation of reports on the results of his excavations in previous years in the Angostura Reservoir area, South Dakota, the Boysen and Keyhole Reservoir areas in Wyoming, and on the Hintz site in the Jamestown Reservoir area, North Dakota. He also prepared several short articles on specific artifact problems and wrote several reviews for professional journals. His paper, "A Check List of Middle Missouri Pottery Wares, Types, and Subtypes," was published in the Plains Anthropologist, No. 2, December 1954. In November Wheeler served as chairman of a symposium on the archeology of the western plains at the 12th Plains Conference for Archeology and read a paper summarizing the results of his investigations in the Jamestown Reservoir area in 1954. In April he served as chairman of the anthropology section at the 65th Annual Meeting of the Nebraska Academy of Sciences held at the University of Nebraska. At that time he also read a preliminary statement relating to a study of aboriginal dwellings and settlement types in the Northern Plains.

During the period when Mr. Smith was absent from the office, Mr. Wheeler performed such duties of the archeologist in charge as were required. At the end of the fiscal year he was preparing to take a field party to the Oahe Dam area in South Dakota where excavations were planned for two sites.

Cooperating institutions.—A number of State and local institutions continued to cooperate in the Inter-Agency Salvage Program throughout the year. Some of the State groups worked independently but correlated their activities closely with the over-all program. A majority of the projects, however, were under agreements between the National Park Service and the various organizations. The Historical Society of Indiana continued making surveys of proposed reservoir areas as part of its general program for archeological studies in that State and made reports on the results of its work. The Ohio State Archeological and Historical Society carried on salvage operations in several localities. In a number of cases the sites involved were not in reservoir areas but the need for the recovery of materials was just as great as though they were ultimately to go under water. The Archeological Survey Association of Southern California continued its voluntary recovery of materials at several projects in the San Diego area, and the University of California Archeological Survey included several proposed reservoir areas in its general survey program.

A number of institutions worked under agreements with the National Park Service. The University of California Archeological Survey had a party under Dr. Adan E. Treganza, research associate, excavating in sites in the Berryessa Valley in the Monticello Reservoir basin in Napa County, California. The area is an important one for linking known Indian groups with specific types of prehistoric remains and the California party obtained valuable information. In the Columbia Basin a party from the University of Oregon, under the direction of Dr. L. S. Cressman, excavated several sites on the Oregon side of the river at The Dalles. At that locality there is a record of long occupation extending possibly from the closing days of the last glacial period to historic times. Dr. Cressman and his associates collected valuable data and interesting specimens in the course of their digging. On the Washington side of the Columbia River, above The Dalles, a party from the University of Washington under Warren Caldwell excavated at the Wakemap Mound, an important site in the area because of its depth and stratified deposits. Parties from the University of Missouri, under the direction of Carl H. Chapman, excavated at a number of sites in the Table Rock Reservoir area, on the White River in Missouri. They investigated five open village locations and one cave. At one site evidences were found for three different Indian occupations. Several cultural complexes

were represented in the materials recovered by the excavations. The Table Rock area is important because of the large number of sites occurring there and the variety of cultures represented. It is the only area remaining in which extensive remains of the Ozark Bluff Dwellers are still to be found. Special funds were appropriated for fiscal 1956 for the Table Rock area and the University of Missouri will continue its operations there throughout the year. Mention has already been made of the work of the cooperating institutions in the Missouri Basin. The River Basin Surveys aided the field activities of those groups by the loan of vehicles and other equipment and in one instance by making a survey of the site and preparing a detailed map locating the numerous features involved. One other project in the Missouri Basin consisted of a basin-wide survey of archeological resources by Dr. Jesse D. Jennings of the University of Utah. That also was a cooperative agreement with the National Park Service and while it was not strictly a salvage undertaking, various phases of the survey had a direct bearing on the problems of salvage archeology.

ARCHIVES

The Bureau archives continued during the year under the custody of Mrs. Margaret C. Blaker.

MANUSCRIPT COLLECTIONS

There has been increasing utilization of the manuscript collections of the Bureau during the year by students through personal visit, mail inquiry, and the purchase of photoreproductions. Approximately 225 manuscripts were used by research workers as compared with 150 last year. Visitors frequently express surprise as well as considerable satisfaction at having located little-known, unpublished sources. Publication of at least a skeleton catalog of the collection is being considered.

Additions to the manuscript collection included the personal papers of Alice Cunningham Fletcher and her adopted son, Francis La Flesche, an Omaha Indian, which were deposited with the Bureau by Mrs. G. David Pearlman, Washington, D. C., on indefinite loan. Preliminary examination indicates that the collection contains little unpublished ethnographic data; its principal interest is biographical and historical.

Dr. Frances Densmore made several additions to her personal papers which are in the Bureau, the most substantial being her diaries for 1899 and 1905–50.

The following short manuscripts were received in the past year:

4467. Lyford, Carrie A. "Dolls of the American Indians." N. d. (ca. 1938). 40 pp., 40–50 illus. Deposited by Harry Lyford, brother of the author, Washington, D. C.

4425. Whitaker, C. H. (U. S. Consul, Colón, Panama). "A Report on the Customs of the San Blas Indians." 1954. 36 pp., 62 photographs, 1 map. Forwarded by the U. S. Department of State.

4424. Witthoft, John. "Dakota (?) 'Border and Box' Painted Bison Robe." 2 pp., 1 illus. Forwarded by the author.

A number of manuscripts received in previous years but heretofore uncataloged were arranged, described, and made available for reference, reducing the backlog of such material by about one-third. In this group were the papers accumulated by Dr. John R. Swanton while acting as chairman of the United States De Soto Expedition Commission, 1935–39. These papers contain an extensive series of photocopies of documents in Spanish archives.

Other manuscripts cataloged and now available for general reference are as follows:

4430. Anonymous. Drawings of tipis and robes obtained by George Miller from an Omaha Indian. N. d. 8 pp. Annotated by J. O. Dorsey.

4452. Anonymous. Drawings by Indians of the Southern Plains. Ca. 1880. In two ledger books of 104 numbered pages each. With one-page letter of transmittal from William H. Myer, Washington, D. C., June 3, 1952.

4442. Bonnerjea, Biren. "Folk-lore in Some Languages of Northern India." Address to Anthropological Society of Washington, February, 1933. 18 pp.

4450. Capron, Louis. "The Hunting Dance of the Cow Creek Seminoles, October 1946." 11 pp., 8 illus.

4444. Carter, John G. (recorder). "Picture Writing of the North American Indians Translated by Richard Sanderville, Chief Bull, a member of the Blackfeet tribe of Indians of Montana, at the Bureau of American Ethnology . . . June 13 to June 18, 1934, from material furnished by the Bureau." 27 pp., 5 illus.

4445. Carter, John G. "Statement of Robert Friday of Fort Washakie, Wyoming, member of Arapho tribal council, concerning his grandfather, Friday." Washington, D. C., 1938. 3 pp., typed.

4446. Carter, John G. "Statements by Gilbert Day, a Shoshone Indian of Fort Washakie in regard to the Peyote Church among the Shoshone Indians." Washington, D. C., 1938. 22 pp.

4447. Carter, John G. "Memorandum on the Proper Usage of the Word 'Blackfoot' or 'Blackfeet' as Applied to the Siksika, Kainah and Pikuni, or Blackfoot, Blood, and Piegan Tribes." N. d. 8 pp.

4448. Carter, John G. "Big Snake, Oh-muck-see Sin-a-kwan, or Loud Voice, also Called Black Snake Man, a Piegan Indian Chief." N. d. 15 pp.

4451. Cleveland, A. G. "The San Blas Coast." N. d. 77 pp. Also miscellaneous items relating to the Cuna and Tule Indians, including a notebook of picture writing and 8 pp. of interpretations.

4438. Clifford, Capt. Walter. "The Indian Campaign of 1876." Chapters written for the *Rocky Mountain Husbandman*. N. d. About 50 pp., unarranged.

——. "Notes at Random." Journal, Oct. 6, 1879–Nov. 4, 1879. Copy. 15 pp.

4433. Cuoc, Jean Andre. Mohawk-French Dictionary. N. d. 1 vol., 973 pp. Dialect spoken at Lake of Two Mountains, Caughnawaga, and St. Regis in Quebec, Canada.

4436. Fenton, William Nelson. Papers accumulated while acting as representative of the Smithsonian Institution on the Policy Board of the National Indian Institute, 1948–50. About 80 pp.

4429. Giroux, Louis J. "Sketch of the Mayo and Yaqui Indians, who are helping to fight Carranza." Nogales, Ariz (sic), 1920. 5 pp.

4463. Harrington, John P. "The Indian Place Names of Maine." 1949. 2 boxes, contents itemized in catalog.

4421. Genealogical chart by Hewitt showing his ancestory. 3 oversize sheets.

4459. (Lee, Dale?). Field plans and profiles of Murphy Mound, North Carolina. N. d. (W. P. A. period.) Miscellaneous oversize sheets in 1 roll.

4435. Newcomb, Franc J. "Navaho Ceremonies." Observations made on Navaho Reservation, Newcomb, N. Mex., 1939. About 80 pp., with snapshots, drawings, and botanical samples.

4441. (Schoolcraft, Henry Rowe?). "The Age of Science: A Satire in Ten Numbers." Verses to Washington Irving, George Bancroft, B. Butler, John Torrey, Frederick Hall, Dr. Skinner, Charles F. Hoffman, John A. Dix, Henry Inman, and Lewis Cass. 1840. About 42 pp.

4437. Snider, G. L. "A Maker of Shavings." Manuscript based on information from Edward Forte, known to the Indians of Standing Rock Agency as Chau Cozhepa (A Maker of Shavings), formerly First Sgt., Troop "D," 7th Cavalry, and said to be the last white man who talked with Sitting Bull. With miscellaneous notes, including 4-page statement by Sgt. Forte, 12-page letter from Forte to Frank Fiske, Oct. 21, 1932, and 4 photographs.

4432. Stirling, Matthew W. Field notes on archeological work in the vicinity of Mobridge, S. Dak., 1923, with extracts from various sources. 150–200 pp.

4439. Swanton, John R. "The Psi Capacities." Discussion of extrasensory perception. Ca. 1950. 94 pp.

4443. Tauber, Charles. "Entzifferung der Osterinsel-Hieroglyphen." 36 pp. (In German.)

4434. Taylor, Douglas. "Notes on the Carib of Dominica." Text, notes, anthropometric data, photographs, drawings, and correspondence received 1938–40.

4440. Verrill, John. "Results of Preliminary Survey of the Archeology and Ethnology of the Atrato Valley of Colombia, South America." 27 pp. Cuna glossary, 8 pp. Glossary with ethnographic notes, tribe unidenfied, 11 pp. 5 maps. About 59 snapshots of Cuna and Choco Indians, with 8 pp. of captions and background information. N. d. Received 1933.

4431. Woodbury, George. "Preliminary Report on Excavation of Mortuary Mounds in Brevard County, Florida East Coast." Archeological Report of CWA Project 5-F-70, Dec. 18, 1933–Feb. 15, 1934. 12 pp., 11 maps, about 200 photographs (mainly uncaptioned).

Additional progress was made in the amplification of the catalog by preparing new and detailed descriptions of manuscripts that had been only briefly listed in the original catalog many years ago. The usefulness of the catalog has been increased by cross-referencing the additional subjects.

A number of nonmanuscript items, which had previously been housed in the archives, were transferred to more suitable repositories.

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Among these were wax cylinder recordings of Indian songs, which were transferred to the Bureau's record deposit in the music division of the Library of Congress. Ten cylinders contained Hopi songs recorded about 1900 and bore descriptive labels largely unintelligible except to a specialist in the Hopi language. Dr. Frederick Dockstader, a Hopi specialist, assisted in the interpretation of these labels before the recordings were sent to the Library.

A collection of mounted plant specimens unrelated to ethnological studies collected by Dr. A. E. Jenks early in his professional career were transferred to the University of Minnesota, with which Dr. Jenks was long associated.

PHOTOGRAPHIC COLLECTIONS

Public interest in the photographic collections continues to grow. Additions to the photographic collection included an album of photographs relating principally to Indians made by William S. Soulé in the vicinity of Fort Dodge, Kans., Camp Supply, Okla., and Fort Sill, Okla., in 1867–74. Although numerous examples of the fine work of this frontier photographer have long been in the Bureau, and have appeared in Bureau publications, the new volume is notable in that it belonged to the photographer and contains captions written by him. It also contains a number of prints not previously received, including a likeness of Soulé himself. The photographs were presented by Miss Lucia A. Soulé of Boston, the daughter of the photographer.

A group of 32 negatives made on the Madeira, Tapajoz, and Xingú Rivers, Brazil, in 1911–12, were presented by the photographer, Francisco von Teuber, engineer. They include views of the country and the Indians of the region.

Copy negatives were made for the Bureau files of a number of photographs from the personal collection of the late A. K. Fisher, well-known naturalist. The photographs were lent by Dr. Fisher's daughter-in-law, Mrs. Walter K. Fisher, of Pacific Grove, Calif., before she donated Dr. Fisher's personal papers, including photographs, to the Manuscript Division of the Library of Congress.

Photographs copied include views of Tlingit and Haida villages on the Alaskan coast and of habitations at Plover Bay, Siberia, all made on the Harriman Expedition to Alaska in 1899. A few photographs of Hawaiians made by H. W. Henshaw about 1900 and a series of photos made and collected by E. W. Nelson in Mexico in 1902 were also copied.

A group of commercial portraits of Indians, collected by Gen. E. R. Kellogg while in command at Fort Washakie, Wyo., about 1891, was donated by his daughter, Mrs. Robert Newbegin, of Toledo, Ohio.

Two important sets of photographs were obtained for reference purposes from other institutions (which retain the negatives and the right to grant publication permission). The first is a set of 86 photographs of paintings of Indians by Paul Kane and a microfilm copy of Kane's sketchbook, made on his trip across the continent to the Pacific Northwest in 1845–48. The photographs were purchased from the Royal Ontario Museum of Archaeology, Toronto, which owns the original paintings. The second reference collection consists of approximately 400 copy prints of photographs relating to the Indians of the Plains made by Stanley J. Morrow in the 1870's and 1880's. The prints were received from the W. H. Over Museum of the University of South Dakota, through the River Basin Surveys.

In addition to photographs recently received from sources outside the Bureau, a collection of some 1,000 photographic prints made in the years 1880–1905 and representing about 130 Indian tribes was transferred from the photographic laboratory. A number of researchers have benefited this year from the newly available material, and copy negatives are being made as required.

Another project making available additional photographic resources in the Bureau was begun in the past year. It was found that a number of former staff members and collaborators had deposited rather extensive series of snapshot and other small negatives. Most of these were in labeled jackets, now deteriorating, and were without prints.

Prints were requisitioned for some 260 of James Mooney's negatives of Arapaho, Kiowa, Comanche, Navaho, and Cherokee; by the end of the year about half of these had been sorted and arranged with proper identification, and placed in protective vinylfilm albums. It is hoped that in time similar groups of photographs by M. C. Stevenson, W. J. McGee, W. H. Holmes, F. W. Hodge, A. E. Jenks, J. O. Dorsey, and others may be processed in the same way.

ILLUSTRATIONS

Throughout the year work was continued by E. G. Schumacher, illustrator, on drawings, charts, maps, diagrams, and sundry other illustrative tasks concerning the publications and work of the Bureau of American Ethnology, including the River Basin Surveys. He also made a variety of drawings for other branches of the Institution.

EDITORIAL WORK AND PUBLICATIONS

There were issued 1 Annual Report and 4 Bulletins, as follows:

Seventy-first Annual Report of the Bureau of American Ethnology, 1953–1954. ii+17 pp. 1955.

Bulletin 157. Anthropological Papers, Nos. 43–48. iii+415 pp., 76 pls., 23 figs. 1955.

No. 43. Stone monuments of the Rio Chiquito, Veracruz, Mexico, by Matthew W. Stirling.

No. 44. The Cerro de las Mesas offering of jade and other materials, by Philip Drucker.

No. 45. Archeological materials from the vicinity of Mobridge, South Dakota, by Waldo R. Wedel.

No. 46. The original Strachey vocabulary of the Virginia Indian language, by John P. Harrington.

No. 47. The Sun Dance of the Northern Ute, by J. A. Jones.

No. 48. Some manifestations of water in Mesoamerican art, by Robert L. Rands.

Bulletin 158. River Basin Surveys Paper No. 7. Archeological investigations in the Oahe Dam area, South Dakota, 1950–51, by Donald J. Lehmer. xi+190 pp., 22 pls., 56 figs., 6 maps. 1954.

Bulletin 159. The horse in Blackfoot Indian culture, with comparative material from other western tribes, by John C. Ewers. xv+374 pp., 17 pls., 33 figs., 1955.

Bulletin 160. A ceramic study of Virginia archeology, by Clifford Evans. With an appendix: An analysis of projectile points and large blades, by C. G. Holland. viii+196 pp., 30 pls., 23 figs., 1 chart. 1955.

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 163. The Diné: Origin myths of the Navaho Indians, by Aileen O'Bryan.

Publications distributed totaled 24,533 as compared with 21,222 for the fiscal year 1954.

COLLECTIONS

Acc. No.

202531. Archeological materials consisting of potsherds collected by Dr. Matthew W. Stirling on Taboguilla Island in 1953.

203786. Insects, 95 mammals, and 15 marine invertebrates from Southampton and Coats Islands collected by National Geographic Society, National Museum of Canada, and Smithsonian Institution Expedition, 1954, led by Dr. Henry B. Collins.

204571. 385 plants collected by James Mooney at Cherokee Reservation, Qualla, N. C., in 1888.

205978. Models of heraldry, peyote and game equipment, collected by James Mooney among the Kiowa Indians.

206445. 1 badger from New Mexico.

FROM RIVER BASIN SURVEYS

202135. Archeological material from the Allatoona Reservoir area on the Etowah River, Cherokee, Bartow, and Cobb Counties, Ga.

202358. 327 specimens of archeological material consisting of potsherds, copper, stone, bone, and shell objects, from 3 sites in Tuttle Creek Reservoir, Pottawatomie County, Kans., collected by Missouri Basin Project field parties in 1952–53.

202532. 120 archeological specimens from site 35-WS-5, Dalles Reservoir on Columbia River, Wasco County, Oreg.

202537. Archeological materials from the Conomaugh Reservoir, Pennsylvania, scattered sites in Marshall and Wetzel Counties, W. Va., and Cheatham and Old Hickory Reservoirs, Tenn., collected by Ralph S. Solecki, 1950 and 1954.

203964. Archeological material from 2 sites in Cachuma Reservoir areas on Santa Ynez River, Santa Barbara County, Calif.

205436. Archeological material in and about Broncho Reservoir, Mercer County; Dickenson Reservoir Area, Stark County; Kochler site, Heart Butte Reservoir, Grant County, all in North Dakota.

205437. 21,046 archeological specimens from 2 sites in Oahe Reservoir, Stanley County, S. Dak.

205438. Archeological material from sites in and about Garrison Reservoir, in Dunn, Mercer, McLean, Mountrail, and Williams Counties, N. Dak.

205526. 797 archeological specimens from Allatoona Reservoir area, Cherokee County, Ga.

206347. 3,648 archeological specimens from Montana, collected by the Missouri Basin Project.

MISCELLANEOUS

Dr. Frances Densmore, Dr. John R. Swanton, 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. On April 12, 1955, Sister M. Inez Hilger, an ethnologist and a teacher at the School of Nursing, Saint Cloud Hospital, Saint Cloud, Minn., was appointed an honorary research associate of the Smithsonian Institution.

Information was furnished during the past year by members of the Bureau staff in reply to numerous inquiries concerning the American Indians, past and present, of both continents. The increased number of requests from teachers, particularly from primary and secondary grades, from Scout organizations, and from the general public, indicates a continuously growing interest in the American Indian. Various 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, 1955:

The Astrophysical Observatory includes two research divisions: the Division of Astrophysical Research, for the study of solar radiation, 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, for woodwork, and for optical and electronic work, are maintained in Washington to prepare special equipment for both divisions.

On November 20, 1954, I reached the mandatory age for retirement. No successor having been chosen at that time, however, I was asked to continue in office pending the installation of a new director. Dr. Fred L. Whipple, professor of astronomy at Harvard University, will become Director of the Astrophysical Observatory effective July 1, 1955. At Dr. Whipple's request, A. G. Froiland, director of the Table Mountain station, was transferred to Washington to act as liaison officer.

DIVISION OF ASTROPHYSICAL RESEARCH

During the fiscal year 1955 the two high-altitude observing stations, Montezuma in northern Chile and Table Mountain in southern California, remained in continuous operation.

Work in Washington.—The cooperative work with the U. S. Weather Bureau, mentioned in last year's report, was continued. This concerned the calibration of Eppley pyrheliometers and the simplification and automatic recording of silver-disk pyrheliometry. The progress of this work is summarized in two papers by T. H. MacDonald and Norman B. Foster, published in the Monthly Weather Review for August 1954 and February 1955.

The loss of William H. Hoover, whose sudden death in September 1953 was recorded in last year's report, has continued to delay not only the preparation and testing of improved equipment but also the statistical studies of field observations normally carried on in Washington. No one has been appointed to succeed Mr. Hoover since it was felt that the new director should choose his own staff.

Orders were received during the year from interested institutions and laboratories for three silver-disk pyrheliometers and five modified Ångström pyrheliometers. Preparation and calibration of these

instruments are nearly completed. In addition, silver-disk SI#69 was repaired, recalibrated, and returned to the Servicio Meteorológico National, Buenos Aires, Argentina, and modified Ångström SI#12 was built, calibrated, and forwarded in March 1955 to the Meteorologisches Observatorium, Hamburg, Germany. Silver-disk SI#52 was received in March 1955 from the University of Münster in damaged condition. Repairs and recalibrations are in progress. In May 1955, modified Ångström SI#13 was lent to Drs. P. R. Gast and Ralph Stair for temporary use on Sacramento Peak, N. Mex.

Work in the field.—The quality of the skies at our two field observing stations during the current year proved inferior to the average of previous years. At Montezuma, our high-altitude station in northern Chile, the sky pollution due to the smelting operations at nearby copper mines, mentioned in last year's report, continued unabated. A study of the average quality of the sky before and after starting the smelters (in March 1953) shows the magnitude of the pollution. A summary by months, covering the period 1940–55, shows that in each of the 12 months, the direct solar beam (at solar altitude of 30°) has been reduced between 1 and 7 percent since the smelters started. The sky brightness around the sun on the same days increased between 1.3- and 2.6-fold after the smelters started. A summary of long-method observations during the same period indicates that the direct solar beam after the smelters started decreased some 2 to 6 percent and the sky brightness increased 1.6- to 2.5-fold. The atmospheric transmission coefficients show the following change at the wavelengths indicated:

Wavelength 0.39μ, a decrease of 2 to 7.5 percent.
Wavelength 0.61μ, a decrease of 1.5 to 4.5 percent.
Wavelength 0.97μ, a decrease of 1 to 2 percent.

As a result of the variable daily output of gas and smoke from the smelters, Montezuma skies are now definitely less uniform than formerly.

At Table Mountain we have noted for some years a gradual increase in the amount of smog from the Los Angeles area, which rises at intervals above the level of Table Mountain. As civilization expands it becomes increasingly difficult to find high-altitude locations that combine clearness, dryness, and uniformity of skies with accessibility and bearable living conditions.

Publications.—During the current year the following publications concerned with the work of the Division of Astrophysical Research appeared:

Annals of the Astrophysical Observatory, volume 7, [July 7], 1954.
Pyrheliometer calibration program of the U. S. Weather Bureau, by T. H. MacDonald and Norman B. Foster. Month. Weather Rev., vol. 82, No. 8, August 1954.

A method for the measurement of atmospheric ozone using the absorption of ozone in the visible spectrum, by Oliver R. Wulf and James E. Zimmerman. Smithsonian Misc. Coll., vol. 123, No. 3, October 27, 1954.

Concerning Smithsonian pyrheliometry, by C. G. Abbot, L. B. Aldrich, and A. G. Froiland. Smithsonian Misc. Coll., vol. 123, No. 5, November 2, 1954.

Silver-disk pyrheliometry simplified, by Norman B. Foster and T. H. MacDonald. Month. Weather Rev., vol. 83, No. 2, February 1955.

Washington, D. C., precipitation of 1954 and 1955, by C. G. Abbot. Smithsonian Misc. Coll., vol. 128, No. 2, March 1, 1955.

Sixty-year weather forecasts, by C. G. Abbot. Smithsonian Misc. Coll., vol. 128, No. 3, April 28, 1955.

Periodic solar variation, by C. G. Abbot. Smithsonian Misc. Coll., vol. 128, No. 4. June 14, 1955.

DIVISION OF RADIATION AND ORGANISMS

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

The work of the Division of Radiation and Organisms was concerned with three general areas of biological research during the year: (1) the photocontrol of the formative and developmental processes in plant growth; (2) the inhibition and potentiation of X-ray damage by red and far-red visible and near infrared energy; and (3) the mechanism of action of the plant hormone, auxin, in the control of growth.

1.—Sunlight exercises its effect on plants chiefly through two groups of photochemical or light reactions. The first is a high-energy process and provides the plant's food supply, converting the energy of sunlight into chemical energy through the synthesis of simple carbon compounds. The second group, which is one of the areas of the Division's research, involves the photocontrol of the formative growth processes, which require relatively little energy but are just as essential to the normal functioning of plant life as is carbohydrate synthesis. These latter photochemical reactions control the development of stems, leaves, and reproductive structures, and are most actively promoted by light from the red end of the visible spectrum. This formative action of the red can be blocked by irradiation with energy from the far-red immediately adjacent to the red.

Previously the laboratory had established that the region of maximum effectiveness in promoting the normal formative processes in seedling development is at 660±5 mμ, in the red, the results substantiating those of other laboratories investigating seed germination and flower-bud initiation. This year the photoreversal reaction involving the blocking of the formative processes has been found to have two maxima in the far-red at 710 and 730 mμ, with a minimum of 480 mμ. Several rather poorly defined secondary maxima occur at 520 to 550 mμ and 650 mμ. Since the maximum efficiency of the far-red energy occurs about 1.5 hours after the end of the red irradiation period rather than immediately following, the results are indicative that the

far-red energy interferes with the developmental process by acting on a product of the photochemical reaction initiated by the red energy. These studies have all been done on seedlings of the bean plant, using the changes in growth of the bean hypocotyl hook as an assay of the growth regulating effects of the radiant energy.

2.—One of the first evidences of damage to living organisms by any form of ionizing radiation, including X-rays, is the breaking of the threadlike hereditary structures of the cell known as chromosomes. It has been found that if X-rays are preceded by exposure to red visible light, the incidence of X-ray-induced chromosome damage is markedly reduced on the order of 30 to 50 percent. If, on the other hand, the X-rays are preceded by exposure to radiant energy from the far-red or near infrared, the damage is potentiated by these wavelengths by as much as 30 to 40 percent at the energy levels used. The plant material employed for these studies was the root-tip cells of broad bean (*Vicia faba*), the chromosomes of which are extremely sensitive to X-ray damage.

Work is now in progress to study the mechanism of these reactions of inhibition and potentiation of X-ray damage and how the results may be applied to the mediation of the damaging effects of ionizing radiations. The medical implications of these findings are extremely important in the control of damage by ionizing radiation and in cancer therapy.

3.—Auxin, the only plant hormone isolated to date, controls certain phases of the growth process such as cell elongation. The effects of auxin may be produced or modified by a number of growth-regulating chemicals, including the common weed killers and other materials used for controlling rooting of plants, fruit set, and sprouting.

Although auxin has been identified for many years as indole acetic acid, it has not been possible to quantitatively measure its activity on any metabolic function and biological assay methods have been used in the past to determine auxin activity. During the past year, however, using differential centrifugation methods to fractionate plant tissues, it has been found that the fraction remaining after sedimenting cell walls, nuclear material, mitochondria, plastids, and other particles within this size range, contains an enzyme system which, on the addition of auxin, brings about a marked oxygen consumption. The rate of auxin activity can be measured quantitatively on this cell-free fraction. Avocado fruit tissue is being used as the experimental plant material. Studies are now in progress to determine the initial biochemical steps of the process.

Respectfully submitted.

L. B. Aldrich, *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, 1955:

SMITHSONIAN ART COMMISSION

The 32d annual meeting of the Smithsonian Art Commission was held in the Regents Room of the Smithsonian Building on Tuesday, December 7, 1954. Members present were: Paul Manship, chairman; Robert Woods Bliss, vice chairman; Leonard Carmichael, secretary (member, ex officio); John Nicholas Brown, Gilmore D. Clarke, David E. Finley, Lloyd Goodrich, Walker Hancock, George Hewitt Myers, Charles H. Sawyer, 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.

Resolutions on the deaths of George H. Edgell (June 27, 1954), and Reginald Marsh (July 3, 1954), members of the Commission, and of Ruel P. Tolman (August 24, 1954), former director of the National Collection of Fine Arts, were submitted and adopted.

The Commission recommended to the Smithsonian Board of Regents the names of Bartlett Hayes to succeed Mr. Edgell, whose term expires in 1955, and Stow Wengenroth to succeed Mr. Marsh, whose term expired in 1954. The Commission also recommended the reelection of Gilmore D. Clarke and Andrew Wyeth for the next 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.

Dr. Carmichael explained briefly the main points of the Smithsonian building program, especially in relation to proposed improvements in Southwest Washington, and displayed models of Smithsonian

structures, existing and contemplated. Salient features of the proposed National Air Museum were pointed out.

Mr. Goodrich recalled that recommendations for early erection of a Smithsonian Gallery of Art had been made in the report on Government and Art by the Fine Arts Commission, in the report by the Committee on Government and Art, of which Mr. Goodrich is chairman, and in the minority report of the hearings on the Howell and 12 other bills offered in the 83d Congress. Mr. Goodrich's motion that the Smithsonian Art Commission recommend to the Board of Regents that it go on record as favoring the early construction of a Smithsonian Gallery of Art was unanimously approved.

Dr. Carmichael and Mr. Beggs reviewed accomplishments during the year, making particular mention of the exchange of traveling exhibitions with foreign countries and the urgent need for the proposed Smithsonian Gallery of Art building to provide necessary office, assembling, and exhibition space for its distinguished temporary shows as well as to house the permanent collections.

The Commission accepted the following objects:

Oil, The Bathers, by Robert Reid, N. A. (1862–1929). Gift of Mrs. Francis Marion Wigmore, in memory of her husband. Accepted for the National Collection of Fine Arts.

Oil, The Rapids, by W. Elmer Schofield, N. A. (1867–1944). Henry Ward Ranger Bequest. Accepted for the National Collection of Fine Arts.

Oil, Gen. Dwight D. Eisenhower, Supreme Commander of Allied Powers in Europe, 1949, by Capt. Sir Oswald Birley (1880–1952). Gift of British friends of the artist to the people of the United States. Accepted for the National Portrait Gallery.

Pastel, Huichol Indian, by Anton Sario. Presented through the Department of State. Accepted for the Smithsonian Institution with recommendation that it be assigned to the Bureau of American Ethnology.

TRANSFERS ACCEPTED

One gold necklace set with 30 garnets; a round-headed fibula with garnet inlay; a brooch; an amethyst ball pendant framed in gold with garnets; a gold ring studded with 3 garnets; a Y-shaped fibula, and a coin of Constantine II (317–340), were transferred from the Department of State on September 21, 1954.

Three heroic-size oil portraits by Chester Harding (1792–1866), George Washington, Henry Clay, and Andrew Jackson, were transferred from the Supreme Court of the District of Columbia on November 24, 1954.

One unframed watercolor, Münich Model, by William H. Holmes (1846–1933), was transferred from the United States National Museum (Division of Graphic Arts) on December 8, 1954.

WITHDRAWALS BY OWNERS

Two oil portraits, Gen. John J. Pershing and Adm. William S. Sims, by E. Hodgson Smart, lent in 1932 by the artist, were released on August 17, 1954, to James Shenos, in accordance with a court decision.

Two pastel portraits of George and Martha Washington, by James Sharples, lent in 1934 by Mrs. Robert E. Lee, Dr. George Bolling Lee, Mrs. Hanson E. Ely, Jr., and Mrs. William Hunter de Butts, were withdrawn and delivered to the Mount Vernon Ladies' Association of the Union on September 14, 1954.

Two miniatures, Unknown Gentleman, by Robert Field, and Mr. W., by an undetermined artist, lent in 1952 by Mr. and Mrs. Ruel P. Tolman, were withdrawn by Mrs. Tolman on April 4, 1955.

An oil portrait of George Washington, by Charles Willson Peale, lent in 1914 by John S. Beck, was withdrawn by Mrs. Beck through her attorney, Robert S. Bains, on May 26, 1955.

A miniature of Martha "Patty" Custis, painted at Mount Vernon in 1772 by Charles Willson Peale, lent anonymously in 1934, was withdrawn on June 15, 1955.

ART WORKS LENT

The following art works were lent for varying periods:

To the City Art Museum of St. Louis for its Westward America Exhibition, October 23 to December 6, 1954; then forwarded to the Walker Art Center, Minneapolis, Minn., for a special exhibition, January 14 to February 28, 1955 (shipped September 21, 1954):

Cliffs of the Upper Colorado River, Wyoming Territory, by Thomas Moran. (Returned March 8, 1955.)

To the Pennsylvania Academy of the Fine Arts, Philadelphia, Pa., for its 150th Anniversary Exhibition, January 15 through March 13, 1955:

Cardinal Mercier, by Cecilia Beaux. (Returned April 8, 1955.)

Man in White (Dr. Henry S. Drinker), by Cecilia Beaux. (Later included in a selection of paintings from the 150th Anniversary Exhibition for an 8-month European tour sponsored by the U. S. Information Agency.)

To the White House, Washington, D. C.:

September 17, 1954---------- Summer, by Charles H. Davis.

Sundown, by George Inness.

Niagara, by George Inness. (Returned November 30, 1954.)

Temple Mountain, by Chauncey F. Ryder. (Returned November 30, 1954.)

October 22, 1954------------ Wild Parsley, by Sarah Paxton Ball Dodson.

Evening on the Seine, by Homer Martin.

Fired On, by Frederic Remington. (Returned November 30, 1954.)

April 20, 1955	Groton Long Point Dunes, by Henry Ward Ranger.
	Shinnecock Hills, by William M. Chase.
	Mountain Scene, by Frederick Edwin Church. (Returned May 2, 1955.)
	Tohickon, by Daniel Garber. (Returned May 2, 1955.)
	November, by Dwight W. Tryon. (Returned May 2, 1955.)
May 13, 1955	George Washington, by William Winstanley, after Stuart.
	Mountain Scene, by Frederick Edwin Church.
To the Supreme Court, Washington, D. C.:	
October 29, 1954	Mountain Scene, by I. Diday.
	Scene from the "Gentlemen of France," by Antoine Etex.
	The Wreck, by Harrington Fitzgerald.
	Landscape, by Herman Saftleven.
	One Day in June, by William Thomas Smedley.
	Mountain Scene, by Frederick Edwin Church. (Returned November 26, 1954.)
	The Mysterious Woods, by Roswell M. Shurtleff. (Returned November 26, 1954.)
	Rockwell Studio, by Macowin Tuttle. (Returned November 26, 1954.)
To the U. S. Court of Military Appeals, Washington, D. C.:	
November 24, 1954	Andrew Jackson, by Chester Harding.
	George Washington, by Chester Harding.
To the Department of Justice, Washington, D. C.:	
March 15, 1955	Temple Mountain, by Chauncey F. Ryder.
	The Mysterious Woods, by Roswell M. Shurtleff.
	Abraham Lincoln, by George H. Story.
	Fog, by James Craig Nicoll.
	The Figurine, by William M. Paxton.
	Late Afternoon near Providence, by Joseph F. Cole.
	A Group of Elk, Wind River Mountains, Wyoming, by Edwin W. Deming.
	The Cornfield, by Henry Ward Ranger. (Returned May 23, 1955.)
	The Grand Canal, Venice, by Gabrini. (Returned May 23, 1955.)
	Marshlands at Sundown, by Alice Pike Barney. (From the Smithsonian Lending Collection.)
To the Barney Neighborhood House, Washington, D. C.:	
March 29, 1955	Lady in White, by an undetermined artist.
	Three fans from the DeArcos Collection.
	Eight items from the Eddy Collection.
	Three items from the Pell Collection.
To the Octagon House, Washington, D. C., for the National Trust Tour:	
April 16, 1955	The Signing of the Treaty of Ghent, Christmas Eve, 1814, by Sir Amedee Forestier. (Returned to the U. S. District Court on April 18, 1955.)

To the Bureau of the Budget, Washington, D. C.:

April 22, 1955	Shallow wall case. (Returned May 27, 1955.)
June 29, 1955	Gen. Dwight D. Eisenhower, by Capt. Sir Oswald Birley.
	Mists of the Morning, by George Glenn Newell.

LOANS RETURNED

Oil, Prince Kimmochi Saionji, by Charles Hopkinson, lent May 5, 1954, to the Institute of Contemporary Arts, Boston, Mass., was returned July 6, 1954.

Oil, portrait of Dr. George F. Becker, by Fedor Encke, lent April 17, 1953, to the National Academy of Sciences, Washington, D. C., was returned July 23, 1954.

Two oils, Fired On, by Frederic Remington, and Westward the Course of Empire Takes Its Way, by Emanuel Leutze, lent April 16, 1954, to the Joslyn Art Museum, Omaha, Nebr., were returned July 26, 1954.

Model of prize-winning design for the Smithsonian Gallery of Art, by Eliel Saarinen, lent October 1, 1953, to the American Institute of Architects, Washington, D. C., was returned September 16, 1954.

Wash drawing, The Devil's Tower from Johnston's, Crook County, Wyoming, by Thomas Moran, lent December 18, 1953, to the Smithsonian Traveling Exhibition Service, was returned October 11, 1954.

Two oils, A Group of Elk, Wind River Mountains, Wyoming, by Edwin W. Deming, lent December 8, 1953, and Tohikon, by Daniel Garber, lent February 2, 1954, to the Supreme Court, Washington, D. C., were returned November 26, 1954.

SMITHSONIAN LENDING COLLECTION

Two paintings, The Dimple and Waterlily, by Alice Pike Barney, were returned by the Joslyn Art Museum, Omaha, Nebr., on July 26, 1954.

Oil, Where Desert and Mountain Meet, by Evylena Nunn Miller (1888–), a gift of Joseph S. Wade, was accepted December 7, 1954, for the Smithsonian Lending Collection to be exhibited in the Geology Hall, Natural History Building.

Ten paintings by Edwin Scott—La Concorde; Marine; Place de la Concorde No. 2; Porte Saint Martin No. 1; Rue de Village; Rue des Pyramides; Rue San Jacques, Paris; St. Germain des Pres No. 1; The Seine at Paris, Pont de la Concorde; and Self Portrait—lent to the Department of Health, Education, and Welfare, on January 18, 1954—were returned on January 18, 1955.

ALICE PIKE BARNEY MEMORIAL FUND

Additions to principal during the year totaling \$2,608.44 have increased the total invested sums in this fund to \$34,603.85.

THE HENRY WARD RANGER FUND

According to a provision in the Ranger bequest that paintings purchased by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest and assigned to American art institutions may be claimed during the 5-year period beginning 10 years after the death of the artist represented, one painting, The Rapids, by W. Elmer Schofield, N. A. (1867–1944), was recalled and accepted by the Smithsonian Art Commission at its meeting on December 7, 1954.

The following paintings, purchased by the Council of the National Academy of Design since the last report, have been assigned as follows:

Title and Artist	*Assignment*
163. Still Life in Winter (watercolor), by Charles E. Burchfield N. A. (1893–).	Carnegie Institute, Pittsburgh, Pa.
164. Head of Red Moore, by Eugene Speicher, N. A. (1883–).	Buffalo Fine Arts Academy, Buffalo, N. Y.
165. Tuscany, by Ogden M. Pleissner, N. A. (1905–).	Cincinnati Art Museum, Cincinnati, Ohio.
166. Tree Forms, by Sidney Laufman, N. A. (1891–).	Georgia Museum of Art, University of Georgia, Athens, Ga.
167. The Falls of Schuylkill, by Walter Stuempfig, A. N. A. 1914–).	Whitney Museum of American Art, New York, N. Y.
168. Ryder's House, by Edward Hopper (1882–).	Museum of Fine Arts, Boston, Mass.
169. Sunset Cornwall (watercolor), by Gordon Grant, N. A. (1875–).	Cooper Union for the Advancement of Science and Art, New York, N. Y.
170. Alviso Slough (watercolor), by Maurice Logan (1886–).	Staten Island Institute of Arts and Sciences, Staten Island, N. Y.
171. Grape Hill, Manayunk, by Giovanni Martino, N. A. (1908–).	Butler Art Institute, Youngstown, Ohio.
172. Still Life with Ground Pink, by Eugene R. Witten (1920–).	Springfield Art Museum, Springfield, Mo.
173. Study of a Young Man, by Nancy Ellen Craig (1927–).	Art Museum of the New Britain Institute, New Britain, Conn.
174. Circus Performers, by Ben Kamihira (1925–).	(Not yet assigned.)
175. West 4th Street (watercolor), by Jerri Ricci, A. N. A. (1916–).	Farnsworth Museum, Wellesley College, Wellesley, Mass.
176. On Strike, by Robert A. Hitch (1920–).	(Not yet assigned).
177. Still Life #98, by Robert Brackman, N. A. (1898–).	The Parrish Art Museum, Southampton, Long Island, N. Y.
178. San Barnaba, by Louis Bosa, N. A. (1905–).	Art Association of Indianapolis, John Herron Art Institute, Indianapolis, Ind.
179. The Eviction, by Everett Shinn, N. A. (1876–1953).	Wilmington Society of Fine Arts, Wilmington, Del.

No. 7, Shrine of the Rain Gods, by E. Irving Couse, N. A. (1866–1936), permanently assigned to the Toledo Museum of Art, Toledo, Ohio, in 1946, was returned to the National Academy of Design and reassigned to the Museum of the American Indian, Heye Foundation, New York, N. Y., as its absolute property, on May 31, 1955.

No. 107, The Blue Jar, by Cullen Yates, N. A. (1886–1945), assigned to the Portland Art Association, Portland, Oreg., in 1933, was reassigned to the Norfolk Museum of Art and Sciences, Norfolk, Va., on November 16, 1954.

No. 150, End of Winter, by A. Lassell Ripley (1896–), was assigned to the High Museum, Atlanta, Ga., on June 18, 1954.

SMITHSONIAN TRAVELING EXHIBITION SERVICE

Sixty-three exhibitions were circulated during the past season, 52 in the United States and 11 abroad, as follows:

UNITED STATES

Paintings and Drawings

Title	*Source*
American Indian Painting	Philbrook Art Center, Tulsa.
American Natural Painters	Galerie St. Etienne and private collectors.
Austrian Drawings and Prints	Albertina, Vienna; Austrian Embassy.
Paintings by Austrian Children	Superintendent of Schools in Vienna; Austrian Embassy.
Paintings by George Catlin	Smithsonian Institution, Department of Anthropology.
Children's Paintings from Forty-five Countries.	Embassy of Denmark; Friendship Among Children, and Youth Organization.
Children's Paintings from Japan	United Nations Educational, Scientific, and Cultural Organization.
Chinese Paintings, by Tseng Yu-ho	Art Institute of Chicago; artist.
Contemporary American Drawings	American Academy of Arts and Letters; artists.
Ethiopian Paintings	George Washington University; Dr. Bruce Howe; Embassy of Ethiopia.
Fusell Drawings	Pro Helvetia Foundation, Zurich; Legation of Switzerland.
Watercolors and Drawings by Gavarni.	Walters Art Gallery, Baltimore; Rosenwald Collection, National Gallery of Art.
German Drawings and Watercolors	Dr. Charlotte Weidler; artist.
Gloriana	British Embassy; artist, John Piper.
Goya Drawings and Prints	Prado and Galdiano Museums, Madrid; Spanish Embassy; Rosenwald Collection, National Gallery of Art.
Winslow Homer Drawings	Cooper Union Museum; American Academy of Arts and Letters.
Watercolors and Prints by Redouté	Luxembourg State Museum; private collectors; Legation of Luxembourg.

Title	*Source*
19th Century American Paintings from the Karolik Collection.	Maxim Karolik; Museum of Fine Arts, Boston.
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.
Birds of Argentina by Salvador Magno.	Artist; Williams Foundation; American Museum of Natural History.

Graphic Arts

Title	*Source*
American Color Prints	Library of Congress.
Recent British Lithographs	British Council; British Embassy.
Children's Picture Books	Washington Post Children's Book Fair.
Contemporary Japanese Prints	Art Institute of Chicago; Japanese Association of Creative Printmakers.
Japanese Woodcuts	United Nations Educational, Scientific, and Cultural Organization.
Prints 1942–1952	Brooks Memorial Art Gallery; artists.
Southern California Serigraphs	Los Angeles County Museum; artists.
Woodcuts by Antonio Frasconi	The Print Club of Cleveland; The Cleveland Museum of Art; Weyhe Gallery; artist.

Architecture

Title	*Source*
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.
The Crystal Palace	Smith College Museum of Art; Massachusetts Institute of Technology.

Design

Title	*Source*
American Craftsmen, I	University of Illinois, Urbana.
American Jewelry and Related Objects.	Huntington Galleries, Huntington, W. Va.
Brazilian Landscape Architecture New Designs by Roberto Burle Marx.	Brazilian Embassy; artist.
Dutch Arts and Crafts	Department of Education, Art and Science in The Hague; Netherlands Embassy.
Fifty Years of Danish Silver	Georg Jensen, Inc.; Danish Embassy.
Italian Arts and Crafts	Compagnia Nazionale Artigiana, Rome; Italian Embassy.

Photography

Title	*Source*
Ansel Adams Photographs 1933–1953	Artist; George Eastman House, Rochester.
Birds in Color by Eliot Porter	Artist; American Museum of Natural History.
Venetian Villas	Soprintendenza ai Monumenti Medievali e Moderni, Venice; Italian Embassy.

Folk Art

Title	*Source*
Americana	Index of American Design, National Gallery of Art.
Eskimo Art, I Eskimo Art, II	Eskimo Art, Inc.; Canadian Handicrafts Guild; Canadian Embassy.
Norwegian Decorative Painting	Norwegian Artists Guild; Embassy of Norway.
Popular Art in the United States	Index of American Design, National Gallery of Art.
The Art of the Spanish Southwest	Index of American Design, National Gallery of Art.

Oriental Art

Title	*Source*
Chinese Gold and Silver from the Kempe Collection.	Dr. Carl Kempe; Embassy of Sweden.

Ethnology

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

ABROAD

Title	*Source*
American Primitive Paintings	Museums; private collectors.
Children's Picture Books	Washington Post Children's Book Fair.
American Indian Painting	Philbrook Art Center, Tulsa, Okla.
American Church (2)	Design and Production; Mrs. Stephen Dorsey.
The American Theatre (2)	Tom Lee Limited; ANTA.
Community Art Centers (3)	The Toledo Museum of Art, Toledo, Ohio.
Contemporary American Glass	Corning Museum of Glass, Corning Glass Center, Corning, N. Y.

These displays were scheduled as an integral part of the programs of 145 museums and galleries, located in 39 States and the District of Columbia.

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 2,342. Examination was made of 774 works of art submitted for identification.

An article, "Harriet Lane Johnston and the National Collection of Fine Arts," by Thomas M. Beggs, was prepared for the General Appendix to the Smithsonian Institution Annual Report for 1954.

Special catalogs were published for the following seven exhibitions: American Primitive Paintings and Fifty Years of Danish Silver (published abroad); Austrian Drawings and Prints; Brazilian Landscape Architecture by Roberto Burle Marx; Goya Drawings and Prints; Nineteenth Century American Paintings from the Maxim Karolik Collection; and Watercolors and Prints by Redouté. The last five contained acknowledgments written by Mrs. Annemarie H. Pope, chief of the Smithsonian Traveling Exhibition Service.

At the invitation of its Foreign Office, Mr. Beggs was guest of the Federal Republic of Germany from October 18 to November 17, 1954, visiting leading museums and art centers.

Mr. Beggs served as sole juror of the Sixth Annual Exhibition of the Florida Artists Group at the Norton Gallery, West Palm Beach, Fla., and spoke at its symposium April 29 and 30, 1955. On March 21, he was one of two judges for the 22d Annual Exhibition of the Miniature Painters, Sculptors, and Gravers Society of Washington, D. C.

Paul Gardner, curator of ceramics, gave talks (illustrated) to the Garden Club, Largo, Md., on October 19, 1954, and the Arlington Branch of the American Association of University Women (gallery) on January 20, 1955. He served as one of the judges for the 24th Annual Photographic Salon at the Washington County Museum, Hagerstown, Md., on January 26, 1955.

Mrs. Pope visited 11 European countries, including England, France, Italy, Austria, Germany, Switzerland, Netherlands, Sweden, Finland, Norway, and Denmark, between June 4 and August 17, 1954. She discussed exhibitions from these countries for circulation in the United States and American exhibitions which might be sent abroad.

Mrs. Pope represented the Smithsonian Traveling Exhibition Service at the Southeastern Museums Conference held at Miami, Fla., October 19–23, 1954, and also spoke at the opening of the Goya Drawings and Prints Exhibition at the City Art Museum, St. Louis, Mo., June 8–10, 1955. She attended the opening of the new wing at the J. B. Speed Art Museum, Louisville, Ky., and the opening of the Goya Drawings and Prints exhibition at the Metropolitan Museum of Art, New York, N. Y.

An exhibition of 25 block prints, by Rowland Lyon, exhibits preparator, opened at the Casa Americana Biblioteca in Madrid, Spain, on November 25, 1954, and later toured other Spanish cities. Mr. Lyon served on the juries of four local exhibitions. He gave a demonstration on the Restoration of Oil Paintings at a meeting of the Society of Washinton Artists on October 6, 1954, was chairman of the May Arts Fair at the Arts Club on May 20, and acted as moderator at a panel discussion, "The Status of Washington Art," held at the Workshop Center on May 22, 1955.

The canvases of 9 paintings in the permanent collection, and 10 borrowed from the U. S. National Museum for use in the Smithsonian Traveling Exhibition Service, were cleaned and varnished. Twenty-one frames were renovated for use for permanent or loan exhibitions.

Fluorescent lights were installed in 7 cases in the Gellatly Collection. Eleven cases were rearranged.

Miss Doanda Wheeler finished repairing the Turfan frescoes in the Gellatly Collection in September 1954.

The renovation of the tapestry "Julius Caesar Crossing the Rubicon" was completed by Neshan G. Hintlian in April 1955.

Glenn J. Martin cleaned and restored 2 paintings in the permanent collection and 6 in the Smithsonian Lending Collection.

Newly decorated offices were occupied by the curator of ceramics August 27, 1954, and the preparator of exhibits February 1, 1955.

SPECIAL EXHIBITIONS

Fourteen special exhibitions were held during the year:

July 21 through September 24, 1954.—Portrait of General Dwight D. Eisenhower, Supreme Commander of Allied Powers in Europe, 1949, by Capt. Sir Oswald Birley (1880–1952), gift of British Friends of the Artist to the People of the United States.

September 1 through 23, 1954.—An Exhibition of Creative Crafts under the joint sponsorship of the Kiln Club and the Potomac Craftsmen consisting of 133 pieces. Demonstrations of the basic steps involved in the production of work in the various crafts were given twice daily. A catalog was privately printed.

October 13 through 28, 1954.—The Fourth Biennial Exhibition of Sculpture by the Washington Sculptors Group, consisting of 75 pieces of sculpture. A catalog was privately printed.

October 18 through November 19, 1954.—A Smithsonian Institution Traveling Exhibition entitled "Building in the Netherlands," sponsored by the American Institute of Architects, and held under the patronage of His Excellency, the Netherlands Ambassador, Dr. J. H. van Roijen. Included were 92 photographs and 3 models of Dutch architecture. A catalog was privately printed. A film in connection with the exhibition was shown on November 2, 1954.

November 7 through 26, 1954.—The Seventeenth Metropolitan State Art Contest held under the auspices of the D. C. Chapter, American Artists Professional League, assisted by the Entre Nous Club, consisting of 229 paintings, sculpture, prints, ceramics, and metalcraft. A catalog was privately published.

December 10 through 29, 1954.—The Eleventh Annual Exhibition of the Artists' Guild of Washington, consisting of 77 paintings and sculptures. A catalog was privately printed.

January 6 through 26, 1955.—"Carl Bodmer Paints the Indian Frontier," held under the patronage of His Excellency, the German Ambassador, Heinz L. Krekeler, consisting of 118 watercolors and drawings. A catalog was privately printed. This exhibition was circulated to 11 other Institutions by the Smithsonian Traveling Exhibition Service.

January 25, 1955.—A bronze statue, Laboring Youth, by Hermann Blumenthal, presented to the American Nation by His Excellency, the German Ambassador, Heinz L. Krekeler, on behalf of the German people, was received by President Dwight D. Eisenhower for the people of the United States in the auditorium of the United States Natural History Building. It was on special exhibition in the lobby until April 25, 1955.

February 4 through 27, 1955.—The Fifth Interservice Photography Contest, consisting of over 250 photographs.

March 6 through 25, 1955.—The Fifty-eighth Annual Exhibition of the Washington Water Color Club, consisting of 171 watercolors, etchings and drawings. A catalog was privately printed.

April 3 through 24, 1955.—Exhibit of 60 photographs and 37 watercolors under auspices of the Audubon Society, D. C. Chapter.

April 3 through 24, 1955.—The Twenty-second Annual Exhibition of the Miniature Painters, Sculptors, and Gravers Society of Washington, D. C., consisting of 235 examples. A catalog was privately printed.

May 8 through 31, 1955.—"Under Freedom," an exhibition depicting 300 years of Jewish Life in the United States, presented by the Greater Washington Committee for the American Jewish Tercentenary, consisting of ritual objects, portraits, sculpture, engravings, photographs, books, letters, documents, charts, maps, and innumerable other items. A catalog was privately printed.

June 15 through July 7, 1955.—The Sixty-third Annual Exhibition of the Society of Washington Artists, consisting of 65 paintings and 15 pieces of sculpture. 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-fifth annual report on the Freer Gallery of Art, for the year ended June 30, 1955.

THE COLLECTIONS

One hundred and twenty objects were added to the collections by purchase, as follows:

BRONZE

54.22. Chinese, T'ang dynasty (A. D. 618–906). Eight-lobed mirror; backed with a sheet of silver decorated with floral and animal designs in repoussé on a punchwork ground; some green patina, earthy adhesions, and traces of silk wrapping. Diameter: 0.245.

54.121. Chinese, Late Chou dynasty (5th–3d century B. C.). Garment hook inlaid with silver, gold, glass, and jade. Length: 0.220.

54.122. Chinese, Early Chou dynasty (11th–10th century B. C.). Ceremonial vessel of the type *tsun;* decorated with cast designs in intaglio and low relief; grayish-green patina. 0.275 x 0.247. (Illustrated.)

55.1. Chinese, Shang dynasty (12th–11th century B. C.). Ceremonial vessel of the type *tsun;* decorated with casting in intaglio and low relief; gray patina, fossae filled with chalcolite; single character inscription cast inside foot. 0.254 x 0.204.

JADE

54.120. Chinese, Late Chou dynasty (5th–3d century B. C.). Garment hook, carved, white jade in a gold mounting. Length: 0.123.

55.7. Persian, Safavid period (16th century). Dark-green jug with canine head on handle; intaglio carving of arabesque rinceaux inlaid with gold. 0.087 x 0.100.

LACQUER

54.19. Chinese, Late Chou dynasty (5th–3d century B. C.). Circular wood tray lacquered with designs in red and yellow on brown ground. Diameter: 0.312.

54.18. Japanese, Tokugawa period (18th century). Small chest of drawers lacquered in several techniques with landscape scene and flora. 0.206 x 0.168 x 0.245.

54.118. Japanese, Tokugawa period (18th century). Incense box in four pieces lacquered in several techniques with landscape, birds, and flowers; inlaid with mother-of-pearl, gold, and silver; tray signed Shogyoku. 0.113 x 0.113 x 0.106. (Illustrated.)

METALWORK

54.115. Persian, Safavid period (16th–17th century). Silver bowl decorated with arabesques and a poem in *nasta'liq* script inlaid in gold; niello in background. 0.032 x 0.112.

54.128. Persian, Seljuq period (12th–13th century). Nine-sided bronze candlestick inlaid with nine bands of silver decoration showing enthroned rulers, musicians, and conventional designs. 0.163 x 0.180.

PAINTING

54.20. Chinese, Yüan dynasty, attributed to Ch'eng Ch'i (13th century). Handscroll illustrating sericulture; full color on paper; 40 seals and 8 inscriptions on mount; 92 seals and 49 inscriptions on painting; 1 seal on label on outside. 12.493 x 0.319.

54.21. Chinese, Yüan dynasty, attributed to Ch'eng Ch'i (13th century). Handscroll illustrating rice culture; full color on paper; 96 seals and 10 inscriptions on mount; 306 seals and 45 inscriptions on painting; 1 seal on label on outside. 10.340 x 0.326.

54.126. Chinese, Sung dynasty, by Li Chih (11th century). Parakeet on an apricot branch; full color on silk. 0.270 x 0.225.

54.27. Indian, late 16th century, Mughal, school of Akbar. Emperor Babur with attendants in a garden pavilion; line drawing, partly colored and gilded, on paper. 0.191 x 0.122.

54.29. Indian, early 17th century, Mughal, attributed to Kānhā and Manṣūr. Leaf from a *Bābur-nāmeh*; recto: 2 water buffaloes in a landscape, text; verso: 2 miniatures, each with two antelopes in a landscape, text; full colors on paper, text in black *nasta'līq*. 0.253 x 0.151.

54.30. Indian, early 17th century, Mughal, attributed to Manohar. Leaf from a historical manuscript; recto: text; verso: scene of an army on the march, text; full colors and gold on paper, text in black *nasta'līq*. 0.432 x 0.279.

54.31. Indian, late 16th century, Mughal, school of Akbar. Leaf from a *Chingiz-nāmeh*; a Mongol emperor (Khubilai Khan) enthroned with empress and attendants; full colors on paper. 0.388 x 0.253.

54.116. Indian, early 17th century, Mughal, school of Akbar. Leaf from imperial album; recto: prince on horseback handing a drink to a youth in a tree; verso: text, and margin with figures; full colors and gold on paper, text in black *nasta'līq*. 0.425 x 0.266.

54.33–54.114. Iraqi, late 14th century (Baghdad?). 82 leaves from a manuscript of Qazwini's "Wonders of Creation"; each has 23 lines of text and one or more illustrations; full colors and some gold on paper, text in black *naskhī*, captions in red or blue. Average leaf, 0.327 x 0.224. (54.95 illustrated.)

54.119. Japanese, Tokugawa period. Ukiyoe school, by Hokusai (1760–1849). Portrait of a courtesan walking; ink, colors, and gold on silk; 1 signature and 1 seal on painting. 1.105 x 0.415.

55.2. Japanese, Tokugawa period. Nanga school, by Tani Bunchō (1764–1840). Peacock and peonies; ink and colors on paper. 1.230 x 0.517.

55.3–55.6. Japanese, Tokugawa period, Ukiyoe school, by Hokusai (1760–1849). Four paintings for the block-print series *Hyakunin Isshū Ubaga Etoki*, Nos. 72, 57, 70, 83; ink on paper; inscription, signature, and seal on each. Average sheet, 0.259 x 0.376.

54.23. Persian, Timurid period (mid-15th century). Leaf from a Kalila Wa-Dimna manuscript; recto: "The battle between the crows and the owls," 2 lines of text; verso: gold caption, 13 lines of black text, 1 red subheading; colors on paper, *nasta'līq* script. 0.229 x 0.146.

54.24. Persian, Safavid period, time of Shāh 'Abbās (early 17th century), Isfahan school, signed Rizā. Reclining nude asleep at a watercourse; picture and illumination in colors and gold on paper; black *nasta'līq* text. 0.321 x 0.208. (Illustrated.)

54.25. Persian, Safavid period (late 16th century), signed Jān Qulī. Mounted prince with attendants approaching a pavilion; colors and gold on paper; mounted on a leaf speckled with gold. 0.245 x 0.162.

54.26. Persian (about A. D. 1500), Shiraz school. Leaf; recto: groom with horse in a wooded grove; colors and gold on paper; verso: black *nasta'līq* text, blue headings. 0.168 x 0.097.

54.28. Persian, Safavid period (early 17th century), Isfahan school. Leaf; recto: two youths embracing in a landscape; ink and slight color on paper; verso: quatrain in black *nasta'līq* on floriated ground; signed Muḥammad Ḥusain al-Tabrīzī. 0.334 x 0.229.

54.32. Persian, Safavid period (mid-16th century). Leaf; recto: a hunting scene, line drawing, with light colors and gold, mounted on an album page; verso: illuminated text; dark blue and gold, and black *nasta'līq* script. 0.335 x 0.232.

POTTERY

54.117. Chinese, Ming dynasty (early 15th century). Vase of *albarello* shape; fine white porcelain; glossy, transparent glaze; decorated in underglaze blue with floral scrolls, hatching, and stylized waves. 0.212 x 0.132.

54.124. Chinese, T'ang dynasty (A. D. 618–906). Circular dish on three low feet; buff-white clay; soft lead glazes, transparent, green, brown, and blue; impressed decoration of floral motifs surrounding a flying goose. 0.064 x 0.285.

54.125. Chinese, Han dynasty (207 B. C.-A. D. 220). Cylindrical covered jar of the type *lien* on three low feet; soft brick-red clay; soft, dark-green lead glaze, yellowish brown inside; decoration molded in relief. 0.197 x 0.201.

54.127. Chinese, Ch'ing dynasty, Ch'ien-lung period (1736–1796). Bottle-shaped vase with "onion mouth"; fine, white porcelain; glossy, transparent glaze; decorated in delicate enamel colors, a woman and two boys in a landscape, poem in black, three simulated seals in red; 4-character Ch'ien-lung mark in gray enamel on the base. 0.172 x 0.095.

54.123. Japanese, Tokugawa period (17th century). Chrysanthemum-shaped bowl of Kakiemon ware; fine, white porcelain; lustrous milk-white glaze, brown rim. 0.095 x 0.225.

55.8. Turkish, Ottoman (16th century), probably Isnik. Dish with flattened rim; buff clay, transparent glaze; decoration of floral motifs in cobalt and some turquoise blue; base glazed. 0.068 x 0.376.

55.9. Persian (late 12th century), signed Hasan al-Qāshānī. Bowl with octagonal rim and high foot; soft earthenware; soft, cream-white glaze with splashes of blue; decoration molded in clay, large *naskhī* inscription, small *kufic* signature, arabesque ground and band of leaves. 0.117 x 0.152.

Total number of accessions to date (including above) ------ 10,952

REPAIRS TO THE COLLECTIONS

Thirty-six Chinese and Japanese objects were restored, repaired, or remounted by T. Sugiura. W. N. Rawley strengthened the joints of a Chinese gilt bronze by soldering and mended a Japanese lacquer box with silver nails.

CHANGES IN EXHIBITIONS

Changes in exhibitions totaled 955 as follows:

American art:	
Etchings	32
Lithographs	15
Oil paintings	34
Pastels and drawings	23
Watercolors	18
Chinese art:	
Bronze	201
Gold	8
Jade	42
Paintings	97
Silver and silver gilt	28
Stone sculpture	2
Christian art:	
Crystal	4
Glass	12
Manuscripts	65
Metalwork	36
Paintings	26
Stone sculpture	1
Japanese art:	
Lacquer	8
Paintings	26
Pottery	13
Korean art:	
Paintings	60
Pottery	10
Near Eastern art:	
Bookbindings	10
Crystal	2
Glass	8
Manuscripts	16
Metalwork	31
Paintings	83
Pottery	42
Stone sculpture	1
Woodcarving	1

LIBRARY

Accessions of books, pamphlets, periodicals, and study materials totaled 802 pieces, of which over half were received by gift or exchange from generous friends and institutions.

Cataloging included 471 analytics, 219 books and pamphlets, and 35 titles recataloged and reclassified. A total of 3,188 cards was added to the catalog and shelf lists. The specialized nature of the library and its unique importance for the study of Oriental art are underscored by the fact that less than 10 percent of the necessary cards are available at the Library of Congress.

Six bibliographies were prepared in response to outside requests, and two were made for Freer Gallery publications which were also indexed by the librarian. In all, 426 items were bound, labeled, repaired, or mounted.

Since December 2, 1954, the library has been closed to the public for extensive reconstruction, including the installation of steel stacks and special folio shelves. Rearrangement under way and to be completed at the time of reshelving involves discontinuing the old geographical divisions and shelving of all Western material by classification, and moving all periodicals from an obscure closet into the library. Orientalia will be cataloged and shelved separately as before, but all have been marked with special insignia for ready identification. These changes will greatly increase the librarian's control over her material and facilitate its use by the staff and the public.

PUBLICATIONS

Four publications were issued by the Gallery as follows:

Ars Orientalis, The arts of Islam and the East, vol. I, 267 pp. + 93 collotype pls. and text illus. (Smithsonian Publ. 4187. Published jointly with the Department of Fine Arts, University of Michigan. Two members of the staff contributed to this issue.)

Gettens, Rutherford J., and Usilton, Bertha M.: Abstracts of technical studies in art and archaeology, 1943–1952. 408 pp. Occasional Papers, vol. 2, No. 2. (Smithsonian Publ. 4176.)

The Freer Gallery of Art of the Smithsonian Institution. Revised edition, 16 pp. + 9 halftone illustrations and 3 plans. (Smithsonian Publ. 4185.)

Annotated outline of the history of Japanese art. Revised edition. (Multigraphed.)

Papers by staff members appeared in outside publications as follows:

Wenley, A. G.: A spray of bamboo, by Wu Chên, in *Archives of the Chinese Art Society of America*, vol. VIII, 1954.

Pope, J. A.: Blue-and-white in London, in *Far Eastern Ceramic Bulletin*, vol. VI, No. 2, serial No. 26, 1954.

———. Communication on Bahrami's paper on Chinese porcelains, in *Far Eastern Ceramic Bulletin*, vol. VI, No. 4, serial No. 28, 1954.

———. The art of Gandhāra, in Baltimore Museum of Art *News*, No. 18, 1955.

Ettinghausen, R.: The "snake-eating stag" in the East, in *Late Classical and Medieval Studies in honor of Albert Mathias Friend, Jr.* Princeton, 1955.

———. D. S. Rice, The baptistère de St. Louis, Paris, 1954, reviewed in *The Muslim World*, vol. 44, No. 1.

Ettinghausen, R.: Harry W. Hazard, The numismatic history of late medieval North Africa (Numismatic Studies No. 8, American Numismatic Society, New York 1952), reviewed in *The Muslim World*, vol. 44, No. 1.

Gettens, R. J.: Calcium sulphate minerals in the grounds of Italian paintings, in *Studies in Conservation*, No. 4 (co-author with Miss Mary Mrose).

———. A visit to an ancient gypsum quarry in Tuscany, in *Studies in Conservation*, No. 4.

Stern, H. P.: James A. Michener, The floating world, New York 1954, reviewed in *The Saturday Review*, Jan. 1, 1955.

REPRODUCTIONS

The photographic laboratory made 4,881 items during the year as follows: 2,752 prints, 563 negatives, 1,527 color transparencies, 39 black-and-white slides. Total negatives on hand, 10,850; lantern slides, 9,216.

Two reproductions of objects in the collection were completed by the Alva Studios of New York and placed on sale.

BUILDING

The general condition of the building is good, and maintenance and operation have been satisfactory. The exterior needs cleaning and pointing and water valves need repair or replacement throughout. Air-conditioning is badly needed and there is hope that it may be installed in the near future. Fixtures for fluorescent lighting are on hand and will be installed shortly. A new 500-gallon hot-water tank was put in operation. Complete redecoration of the exhibition galleries was begun under contract in April but came to a standstill after one week because of a local painters' strike. Work had not been resumed as the year ended. All offices, laboratories, storage rooms, and shops are in sore need of general upkeep such as painting and floor covering.

The major work of the cabinet shop was devoted to the reconstruction of the library including rearrangement of the space, installation of steel stacks, new ceiling, and new lighting facilities in stack area. Miscellaneous odd jobs related to storage, exhibition, restoration, crating, and maintenance of office and Gallery equipment continue as usual.

Court planting maintains steady growth, and, as the year ended, plans were under consideration for major alterations in the planting and for a revised maintenance program.

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 88,306. The highest monthly attendance was in April, 11,818, and the lowest was in December, 2,942.

There were 1,866 visitors to the office for the following purposes:

For general information	692
To submit objects for examination	374
To see staff members	133
To take photographs in court or exhibition galleries	121
To study in library	*67
To see building and installations	30
To examine, purchase, or borrow slides	29
To sketch in galleries	11
To use Herzfeld Archive	1
To see objects in storage:	
Far Eastern paintings and textiles	103
Far Eastern metalwork	20
Far Eastern pottery	39
Far Eastern jade, lacquer, wood, ivory, etc	33
Near Eastern painting, miniatures, MSS	39
Near Eastern metalwork	8
Near Eastern pottery	11
Near Eastern glass, bookbindings, etc	8
Christian Art (Washington MSS.)	59
American Art	183

*Library closed after Dec. 2, 1954.

AUDITORIUM

The series of illustrated lectures was continued as follows:

1954

October 20. Soame Jenyns, British Museum. "Kakiemon Porcelains of Japan." Attendance, 123.

November 16. Dr. Schuyler Cammann, University Museum, Philadelphia. "Symbolism in Chinese Bronze Mirrors." Attendance, 128.

1955

January 18. George N. Kates. "Chinese Household Furniture." Attendance, 201.

February 15. Prof. Sirarpie der Nersessian, Dumbarton Oaks. "Armenian Illuminated Manuscripts in the Freer Gallery of Art." Attendance, 128.

March 15. Dr. George C. Miles, American Numismatic Society. "Arabic Inscriptions in Art and History." Attendance, 96.

April 19. Eliot O'Hara, "Oriental Brushwork." (Motion pictures.) Attendance, 320.

In addition, one staff member gave a lecture in the auditorium:

1955

March 16. Dr. Ettinghausen addressed members of the American Association of University Women, Arlington Branch, and others on *Near Eastern art in the Freer Gallery.* Attendance, 45.

Five outside organizations used the auditorium as follows:

1954	
November 17.	Lecture sponsored by the Smithsonian Institution. Dr. Konrad Z. Lorenz, Director, Research Institute for Comparative Ethnology, Max Planck Institute, Bulden, Westphalia, Germany. "Evolution of Behavior Patterns in Animals." Attendance, 350.
1955	
February 3.	Lecture sponsored by the Archaeological Institute of America and the Smithsonian Institution. Prof. Sumner McKnight Crosby, "Excavations in the Abbey Church of St.-Denis." (Motion pictures.) Attendance, 414.
March 30.	Far Eastern Association (Art Section). A. G. Wenley, Chairman. H. P. Stern read one of the papers. Attendance, 28.
May 7.	National Capital Parks. Camp Counsellors training course. Attendance, 137.
May 14.	[Same.] Attendance, 76.
May 21.	[Same.] Attendance, 76.
June 2.	American Association of Museums (Art Technical Section). R. J. Gettens read one of the papers. Attendance, 350.

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 4,111 objects as follows: for private individuals, 2,233; for dealers, 1,427; for other museums, 451. In all, 482 photographs were examined, and 680 Oriental language inscriptions were translated for outside individuals and institutions. By request 24 groups totaling 611 persons met in the exhibition galleries for docent service by staff members.

In the technical laboratory 42 objects from the Freer collection and 37 from outside sources were examined. Investigation of the copper corrosion product on ancient Egyptian bronze was concluded and prepared for publication as the identification of a new mineral. X-ray diffraction studies of copper corrosion products were continued, and similar studies of jade objects in the Freer collection were begun. Analysis of inlays on ancient Chinese bronzes was begun. New equipment included platinum gage electrodes and stand for electrolytic analysis and two new lamps for comparison microscope.

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

1954	
July 26.	Dr. Ettinghausen lectured at the Art Historical Institute, Istanbul University, Istanbul, Turkey. "Turkish and Islamic Art in the Freer Gallery of Art" (in German). Attendance, 50.
September 23.	Dr. Ettinghausen at the Victoria and Albert Museum, London, addressed staff members of that museum and the British Museum who are interested in Islamic art. "Islamic Art in the Freer Gallery of Art." Attendance, 5.
1955	
January 13.	Mr. Wenley addressed the Regents of the Smithsonian Institution. "The Freer Gallery of Art—A Retrospective Glance."
March 20.	Dr. Ettinghausen, at Arlington Unitarian Church, Arlington, Va. "Shiite Islam" (not illustrated). Attendance, 95.
March 23.	Dr. Ettinghausen, at Vienna Episcopal Church, Vienna, Va. "Iran—Land and People." Attendance, 85.
March 29.	Dr. Ettinghausen, at the Cosmos Club, Washington. "In pursuit of Art Treasures in Iran." Attendance, 250.

Members of the staff traveled outside Washington on official business as follows:

1954	
July 1–November 1.	Dr. Ettinghausen continued his studies in the Near East and Europe. In Iran he worked in Tehran and also visited Mashhad and the sites of Nishapur and Tus. He then proceeded to Istanbul, Vienna, Munich, Berlin, Paris, Mariemont (Belgium), London, Oxford, and Cambridge where he attended the 23d International Congress of Orientalists. En route home he stopped in Dublin to study the famous collection of manuscripts in the library of Sir Chester Beatty. In all cities he visited collections and conferred with scholars; much of the time was devoted to the study of materials relating to the Shâh Jâhân album which he is preparing for publication by the Freer Gallery of Art, and to arranging for contributions to the new journal, *Ars Orientalis*.
September 13–18.	Mr. Gettens in New York attended meetings of the American Chemical Society; inspected the restoration laboratories of Joseph Ternbach, the Brooklyn Museum, and the Metropolitan Museum of Art; in Philadelphia attended the Micro-chemical Symposium and the International Congress and Exposition of Instruments.
October 11–13.	Mr. Gettens in Oberlin, Ohio, visited the Intermuseum Laboratory to discuss restoration methods and techniques; examined objects in the laboratory.
November 6.	Mr. Pope in Alfred, N. Y., attended the meeting of the Far Eastern Ceramic Group held at the New York State College of Ceramics, Alfred University.
November 8.	Mr. Wenley in Ann Arbor for meeting of the Freer Fund Committee at the University of Michigan.

1954	
November 19.	Dr. Ettinghausen in Baltimore examined objects in the Baltimore Museum of Art and the Walters Art Gallery.
December 1–5.	Mr. Pope in New York examined objects belonging to dealers.
December 13–16.	Mr. Wenley in New York examined objects belonging to dealers.
December 21–22.	Mr. Wenley in Cleveland to visit loan exhibition of Chinese landscape painting at the Cleveland Museum of Art; examined objects in museum and belonging to a dealer.
1955	
January 24–27.	Mr. Wenley in New York examined a private collection of Chinese furniture offered for sale, and also objects belonging to dealers.
January 26–31.	Dr. Ettinghausen in New York examined objects belonging to dealers, and in museums and private collections.
January 27.	Mr. Gettens in Baltimore at the chemical laboratory of the Johns Hopkins University to observe progress of the work on the Dead Sea Scrolls; at the Walters Art Gallery visited the technical laboratory to examine equipment.
February 16–22.	Mr. Stern in New York examined objects belonging to dealers, museums, and the New York Public Library.
March 16–17.	Mr. Wenley in New York examined objects belonging to an estate, and others belonging to a dealer.
March 30.	Dr. Ettinghausen and Mr. Gettens in Baltimore examined objects at the Walters Art Gallery.
April 25–27.	Mr. Wenley in Ann Arbor for meeting of the Freer Fund Committee at the University of Michigan; examined objects in a private collection; discussed problems of printing *Ars Orientalis* with the University Press.
May 20.	Dr. Ettinghausen in Baltimore examined objects at the Walters Art Gallery.
May 30–31.	Mr. Wenley in Baltimore for meeting of the Association of Art Museum Directors at the Baltimore Museum of Art.

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.

Board 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, Board of Trustees, Hermitage Foundation, Norfolk, Va.

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, House Committee, Cosmos Club, Washington, D. C.

Mr. Wenley: On July 21, 1954, made a tape recording of a short talk on Chinese bronzes, for use on Collector's Items program (NBC).

On April 4, 1955, at the National Gallery of Art, attended a meeting of the Washington Committee on Arrangements for the annual meeting of the American Association of Museums.

Mr. Pope: President, Far Eastern Ceramic Group.

Art Editor, *Far Eastern Quarterly*.

Member, Editorial Board, *Archives of the Chinese Art Society of America*.

Member, Board of Governors, Washington Society, Archaeological Institute of America.

American Member, Consultative Committee, International Exhibition of Chinese Art, Venice.

Member, Art Committee, Cosmos Club.

President, Association of the Southern Alumni of the Phillips Exeter Academy.

On August 20, 1954, at the studios of WCFM, made a tape recording, "The Freer Gallery of Art," for the series of programs called "The Washington Art Scene," a series conducted by Mrs. Portner, art critic of the Washington Post-Times Herald.

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.

On Saturday, March 12, 1955, appeared on TV program "What in the World," in Philadelphia, Pa. (University Museum program.)

On March 25, 1955, was one of three jurors at the Annual Art Fair held in Alexandria, Va., under the auspices of the Alexandria Junior Women's Club.

Mr. Gettens: Associate Editor, *Studies in Conservation* published for the International Institute for the Conservation of Museum Objects.

Abstractor for *Chemical Abstracts*, American Chemical Society.

Sponsor of the Artists Technical Research Institute, 240 East 20th Street, New York 3, New York.

Socio Corrispondente, Centro de Storia della Metallurgia (Associazione Italiana di Metallurgia). Via Moscova 16, Milano, Italy.

Consultant, Advisory Board of the Intermuseum Conservation Association, Oberlin College, Oberlin, Ohio.

Member of the Committee of Scientific Laboratories, International Council of Museums, 10 Parc du Cinquantenaire, Bruxelles, Belgique.

Vice President, Washington Society, Archaeological Institute of America.

54.122

54.118

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

54.24

54.95

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

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

On October 12, 1954, attended a meeting of the Council of Art Museums, at the Smithsonian Building; was appointed chairman of a committee on Guidebook for Museums in Washington, D. C.

On October 21, 1954, made a tape recording for the Voice of America on "The Freer Gallery of Art and its Collections."

On February 1, 1955, took Mr. Sugiura to Vice President Nixon's office where they assembled a suit of Japanese armor.

Mr. Sugiura: On October 28, 1954, made a tape recording in Japanese for the Voice of America on "The Freer Gallery of Art and its Collections."

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, 1955:

STATUS OF PROPOSED NATIONAL AIR MUSEUM BUILDING

The advancement of plans for the construction of the National Air Museum building involves procurement of a site and planning of the structure. The requirements for a site are that it shall be of adequate size, in a location accessible to the maximum number of visitors, and close to other Smithsonian buildings. The most desirable site would be on Independence Avenue between 9th and 12th Streets, south to C Street. On November 5, 1954, formal application was made by the Secretary of the Smithsonian Institution to the National Capital Planning Commission for assignment of this site to the National Air Museum. Action by the Commission was delayed by their consideration of a plan for developing southwest Washington submitted by the New York firm of Webb & Knapp, headed by William Zeckendorf. On June 14, 1955, the Secretary of the Smithsonian Institution, using a large map especially prepared for the purpose, showed the Commission that the location of the National Air Museum building on the proposed site would not conflict with the Zeckendorf plan but instead would enhance the South Mall, which is one of the features of that plan. With the close of the fiscal year, action on this application was still pending.

In the previous annual report grateful acknowledgment was made to the Aircraft Industries Association and the Air Transport Association for providing the Smithsonian Institution with funds for a study of building plans for a National Air Museum building. The architectural firm of McKim, Mead & White of New York City was chosen. The study began early in July when the Navy made available to the National Air Museum a helicopter, pilot, and photographer, and views of the Mall area were made from various angles and altitudes. Shortly thereafter the architects made a detailed examination on the ground of the recommended site and studied the requirements of the building.

It is important to realize that an aeronautical museum has never yet been constructed. Existing collections of aircraft make use of existing buildings. For example: a group of notable aircraft in Germany, prior to World War II was displayed in a railroad station; in France, their famous air mementos are in a former balloon assembly

shed; and those in England are in the South Kensington Museum, which was built for general scientific displays and not specifically for aircraft. The United States National Air Museum exhibits are housed for the most part in a World War I hangar, while the Wright brothers' original "Kitty Hawk Flyer," the *Spirit of St. Louis*, the *Winnie Mae*, and 14 other famous aircraft are inadequately displayed in the Arts and Industries Building constructed in 1880.

The architects were, therefore, undertaking this work without previous examples to guide them. More than 80 separate plans and renderings were prepared and from each concept the best features were selected. One of the most impressive details was the plan to enshrine the "Kitty Hawk Flyer" in a scene reproducing the historic moment when man first flew in a powered heavier-than-air craft, December 17, 1903. In a full-scale diorama the airplane would be seen just rising from the ground, Orville at the controls, and Wilbur running beside it, the amazed Coastguardsmen in the background, and with the sheds built by the Wright brothers and Kill Devil Hill in the distance. Next would be the Hall of Famous Flying Firsts exhibiting eight outstanding American pioneer aircraft; and beyond that the main exhibition hall where about 75 aircraft including commercial types, fighters, bombers, racers, seaplanes, flying boats, autogyros, helicopters, and lighter-than-air craft would be arranged, some shown on the floor to permit close technical study and others suspended as though poised in flight. Other unit displays of this first true aeronautical museum would feature the old wood-and-wire craft of the "Early Birds," heroic warrior planes of World War I, interesting and unique experimental types, ex-enemy planes of World War II contrasted with our own victorious fighters, technical exhibits showing details of aeronautical developments from the flight of a kite to the sonic boom, dioramas illustrating the varied and valuable uses of aircraft, an aeronautical Hall of Fame, provision for special displays, and manufacturers' shows, together with the necessary facilities for museum operations.

Two scale models of this Air Museum building were constructed, one showing the early layout and the other a more recent refinement. As the fiscal year came to a close the architects were preparing estimates of cost and computations of the cubic footage assigned to specific purposes.

ADVISORY BOARD

Although no formal meetings of the Board were held during the year, contacts were maintained with all members. Their assistance was very helpful. The Air Force member, Maj. Gen. George W. Mundy, made several visits to the Museum, studying the collections pertaining to the Air Force and discussing their improvement with

the Secretary and the head curator. General Mundy's aide, Maj. John P. Clowry, and the curator of Air Force Historical Properties, Henry Caldwell, cooperated with the head curator in planning a group of five displays featuring the role of the air arm in warfare. These exhibits are under construction. By direction of General Mundy, repairs and improvements to Air Force planes in the Museum were made by personnel of Bolling Air Force Base, who installed engines in America's first jet airplane, refinished all struts of the Douglas World Cruiser, re-covered the tail surfaces of the World War I Voisin bomber, and painted the cowling of the Spad–XIII.

The Navy member of the Board, Rear Adm. Apollo Soucek, aided the Museum by approving the transfer of significant naval aircraft items. Toward the end of the fiscal year Admiral Soucek was forced by illness to relinquish his duties, and it was with a keen sense of loss that the news of his death was received shortly after the close of the fiscal year.

Grover Loening continued to give stimulating advice; it was at his suggestion that the cooperation of the Aircraft Industries Association and the Air Transport Association in financing the architectural study for the proposed new National Air Museum building was sought and obtained. The other civilian member of the board, William Stout, during his visit to Washington in April, took time from a busy program to discuss the progress and needs of the Museum. He has aided throughout the year in procuring exhibits and enlisting the cooperation of air lines and aeronautical manufacturers.

STEPHENSON BEQUEST

The statue of the famous pioneer of air power Gen. William Mitchell, provided for in the bequest of George H. Stephenson, of Philadelphia, is progressing satisfactorily. By the fall of 1954, the sculptor, Bruce Moore, had completed his initial study in plastiline, one-third size. It represents the General in World War I uniform standing beside his open-cockpit airplane, braced against the airstream and ready for flight. After approval by the Secretary of the Smithsonian Institution, on October 28, 1954, the model was cast in plaster and submitted to the Commission of Fine Arts, by whom it was approved at their meeting of February 10, 1955. The formal contract between the Smithsonian Institution and Mr. Moore was signed April 7, and a duplicate cast of the one-third size study was deposited with the Museum to insure the preservation of the original concept during the making of the full-size enlargement.

SPECIAL EVENTS AND DISPLAYS

On October 26, 1954, the National Air Museum was host at an evening meeting of the Institute of Aeronautical Sciences, Washington

chapter. The subject under discussion was the development of human flight, and each of the three speakers eminently represented the period assigned to him. Gen. Frank P. Lahm, USAF retired, described his first flight in 1908 when he rode as a passenger with Orville Wright, told of his early training as one of the first two officers assigned by the Army to receive flight instruction, and of his experiences during the period of the first World War, when he performed outstanding service. Col. Bernt Balchen, renowned transatlantic, arctic, and antarctic flier, spoke of the "Golden Age" of aviation when many famous first flights were made. He recalled his experiences with Admiral Byrd, Roald Amundsen, Sir Hubert Wilkins, and other fliers of the 1920's and 1930's. The present era was represented by Maj. Arthur Murray, who had but recently piloted the supersonic Bell XI-A airplane to a new world's altitude record of 82,325 feet. His description of the physical stresses exerted on both plane and pilot at such great heights, in rarefied air, and at speeds twice that of sound brought a vivid realization of the great extent to which aeronautics has advanced in half a century. The meeting was enhanced by a tour of the aircraft collection and comparisons between such aircraft as the Wright brothers' "Kitty Hawk Flyer," Lindbergh's *Spirit of St. Louis*, and the Bell supersonic X-1.

Considerable interest was aroused by the delivery on its own wings of the famous racing airplane *Buster*, constructed in 1931 by Steve Wittman of Oshkosh, Wis., and flown by him and other pilots in more than 50 races, winning many events until it was finally retired in 1954. It is a small type of "homemade" airplane embodying excellent construction and aerodynamics, and has earned the title "King of the Midget Racers," holding several world records for speed and performance in its class. The 750-mile flight from Oshkosh to Washington piloted by Robert Porter was made in less than 5 hours and required only 11 gallons of gasoline. The Goodyear Aircraft Corporation, sponsor of national contests which stimulate the designing and flying of these little planes, kindly arranged for the formal presentation of this airplane.

December 17, 1954, marked the 51st anniversary of the Wright brothers' first flight. On that date, the Early Birds, an organization of pioneer fliers, unveiled a monument on Governors Island, New York, to the early airmen who had flown there when that military post included an aviation field. The monument is a granite boulder on which is mounted a copy of a Wright brothers' propeller in bronze. The pattern for that casting was one of the propellers from the first military airplane in the world, built by the Wright brothers in 1909, and preserved in the National Air Museum. The monument was unveiled by a helicopter, which lifted a parachute canopy from the

boulder. The head curator represented the National Air Museum at the ceremony and spoke of progress and plans for better exhibition of the national areonautical collections.

For the meeting of the Smithsonian Institution Board of Regents, on January 13, 1955, there was prepared a special exhibit of an ejection seat used in modern military aircraft. Photographs showing the ejection, release of the seat, and descent by parachute, illustrated the utility of this apparatus.

This year the National Advisory Committee for Aeronautics celebrated its fortieth anniversary and because the NACA had its genesis in the Smithsonian Institution it was appropriately decided to commemorate the anniversary in the Great Hall of the Smithsonian Building. The principal feature of that occasion was the awarding of the Langley gold medal for aerodromics to Dr. Jerome Hunsaker, professor emeritus of aeronautical engineering at the Massachusetts Institute of Technology and a Regent of the Smithsonian Institution, who has been prominent in the development of aircraft and aeronautical knowledge for a period even longer than the existence of the NACA. For this occasion the National Air Museum prepared a series of 40 model airplanes, all of the same scale and illustrating successive developments in design from the Wright brothers' airplane to a current naval supersonic delta-winged fighter. These were suspended above the banquet table.

William B. Stout has been responsible for numerous developments in transportation during the past 40 years. One of his many advanced aircraft designs was the Stout Air Pullman of 1924, a high-wing monoplane of all-metal construction. It was the forerunner of the renowned Ford-Stout trimotored transport popularly called the "Tin Goose." Air Pullmans were used for inaugurating Contract Airmail Route #1 between Detroit, Cleveland, and Chicago in 1926. The Museum has wanted to add a scale model of this type of plane to the series illustrating the development of postal aviation. Thanks to the generosity of the Women's National Aeronautical Association, which encouraged the use of airmail in those critical pioneer days, a model was formally presented on April 16, 1955, at a luncheon at which Mr. Stout was the guest of honor. His description of the difficulties encountered and surmounted in the manufacture and operation of these airplanes was supplemented by stories of flight experiences recalled by Edward G. Hamilton and Lawrence G. Fritz, who piloted the plane on many of its flights with cargo and airmail. The model, 1:16 size, was made by Herbert Hartwick. The presentation was made by Mrs. Chester S. Bleyer of the Association.

The head curator served again this year on the Brewer Trophy Committee, which honors leaders in air-youth education and which

is administered by the National Aeronautic Association. He represented the National Air Museum at the meeting of the American Helicopter Society on April 27, and at the inauguration of flight of members of the Ninety-Nines, association of women pilots, in Washington, June 7, prior to their take-off for Havana, Cuba. On January 20, he received the trophy of the Washington Air Derby Association for his promotion of air education and recording of aeronautical history.

IMPROVEMENTS IN EXHIBITS

Assistance was extended by the United States Air Force in improving the condition of Air Force planes in the collection.

The painting of the four main halls of the Arts and Industries Building required the partial dismantling, draping, and erection of scaffolding around the eight aircraft suspended in those halls. Upon completion of the project, all these planes required cleaning and repairing. In the East Hall of that building it was necessary temporarily to remove the three Langley aerodrome models, the Lilienthal glider, the Stringfellow triplane model, and the Gallaudet hydro-kite. Renovation of exhibits in the Power Hall of the Arts and Industries Building required the removal of two aircraft: the Voisin bomber and the Pitcairn-Cierva autogyro; while the installation of the racing plane *Buster* in the Aeronautical Hall necessitated the removal of the Pitcairn Roadable Autogyro. A number of other planes in the Aircraft Building required repair. These projects continued throughout the year and limited the time available for preparing new exhibits.

The Goodyear Aircraft Corporation assigned expert personnel to remove, reconstruct, and replace the gas-bag canopy of the *Pilgrim*, first airship designed to use helium gas, 1925. It has been shown in the Aircraft Building since 1933. Goodyear cooperated with Rohm and Haas in supplying a new Plexiglas canopy for the cockpit of the Republic F–84 Fighter airplane. The Pratt & Whitney Aircraft Division of the United Aircraft Corporation designed and constructed a new base for the Type 4360 engine of 3,500 h. p., which was one of four that powered the first nonstop flight around the world, accomplished by the *Lucky Lady II* bomber in 1949. The continued assistance of these companies is sincerely appreciated.

Three exhibits were added to accredit renowned fliers. From Gen. Frank P. Lahm, USAF retired, there was received a group of gold medals and other awards given to him and his father, F. S. Lahm, recalling the winning by General Lahm of the first International Gordon-Bennett balloon race in 1906 and the beginning of military aviation in the United States, 1908 and 1909. The story of a World

War I ace and executive officer, Lt. Col. H. H. Hartney, whose service extended from the beginning of the war in 1914 to victory in 1918, is told in a new display assembled with the cooperation of his widow. This exhibit shows the types of aircraft flown and encountered during that period, and enables the Museum visitor to appreciate more fully the limited training received by those early fighting pilots, their heroism, and the difficulties they had to overcome. Another famous World War I aviator was Capt. Vernon Castle who was a member of the Royal Flying Corps in 1916. He served with distinction as a combat pilot but after the entry of America into the war was assigned to the instruction of cadet fliers at Benbrook Field in Texas. He lost his life, February 15, 1918, but avoided injuring his student and two fliers in another airplane. The story of his heroism is revealed in an exhibit prepared with the assistance of Mrs. O. D. Cook, of Portland, Oreg., and his widow, Irene Castle Enzinger. The biographical exhibit of Wiley Post, which supplements the display of his famous airplane *Winnie Mae*, has been improved with a map showing the routes of his two world flights, the radio from that airplane, and the supercharger from his engine. The exhibit memorializing Amelia Earhart has been improved by the substitution of a bronze portrait for the former plaster cast. The portrait was sculptured by Grace Wells Parkinson and provided by the Amelia Earhart Post #678 of the American Legion. Underwood & Underwood, photographers, have provided a selection of historic pictures for this exhibit.

The accessions received this year, listed in the final section of this report, have each required care in their preparation for exhibition or storage. Improved labels have been composed and printed for many exhibits but a great deal remains to be done to improve the presentation and labeling of existing displays.

STORAGE

Two projects continued into this fiscal year, namely, transfer to the Suitland, Md., storage facility of aircraft material stored at Park Ridge, Ill., and reduction of the amount of space devoted to storage in Smithsonian buildings in Washington, D. C.

At the close of the previous fiscal year, there remained at the Park Ridge storage facility 58 full-sized aircraft, 147 engines, some propellers and instruments, and all the equipment and supplies in the office and shop. These occupied over 25,000 square feet of outdoor space and nearly 65,000 square feet indoors. The outdoor area was reduced to half its size by eliminating access aisles and fire lanes, and superimposing boxes wherever possible. The indoor space was reduced to an absolute minimum of about 60,000 square feet.

It was suggested to the Air Force Advisory Board member that the Air Force would save money in the long run by financing the shipment of these Museum specimens, all of which were of Air Force origin, to Suitland, Md. Examination by Air Force storage and traffic officials confirmed the fact that the cost of storage and servicing space would in less than a year balance the cost of this shipment, and so the Air Force agreed to finance this move. By the first of October all arrangements had been completed for starting shipments, which were organized in three phases: aircraft, engines, and equipment and supplies. A schedule of four rail cars per week was planned, and a target date of January 1, 1956, was set.

By the end of March 1955 the indoor area was reduced to 30,000 square feet, and all the boxes remaining in the outdoor area had been brought under cover.

The strenuous work during the winter involving transportation of very heavy loads in bitter weather and over rough and icy surfaces had exacted a toll upon the Museum's vehicles and handling equipment, requiring continuous attention to the repair of the crane, fork-lifts, truck, and dollies, but with the coming of spring the shipping program was resumed. As the final aircraft were being moved out, engines were loaded on the flatcars and in boxcars, and items of office and shop equipment were inserted wherever an opening permitted. By the close of the fiscal year, with only one aircraft remaining and more than half of the engines shipped, the Park Ridge unit was reasonably certain of meeting the deadline for complete evacuation of the storage area.

Owing largely to the efforts and abilities of the Museum's senior aide, supplementing those of the superintendent of buildings, the storage facility at Suitland—about 6 miles from the Smithsonian exhibition premises—was able to keep pace with the shipping program of the Park Ridge unit. The loads of aircraft that began arriving the second week of November were stored in Building 7, which had just been completed at the close of the previous fiscal year. Owing to the rapid shipping rate maintained at Park Ridge, the entire 20,000 square feet of floor space in that building was occupied by the end of January. Construction of storage buildings 8, 9, 11, and 12, each of 4,000 square feet area, built of prefabricated steel with concrete floors, was started early in August and completed by mid-October. Building 12 was erected on 3-foot concrete walls to make it high enough to receive the taller boxes. Material was purchased for Building 10, which is to be constructed during the fiscal year 1956.

By the end of the fiscal year all completed buildings were filled to capacity except Building 11, in which there is a small space for the storage of the engines yet to be received.

RESEARCH

The continuing efforts to improve the national aeronautical collection, collect related data, label specimens, plan improved displays and premises, and perform educational service, require constant research in aeronautical history and development, and museum techniques. In addition, whenever time permits, individual research projects are advanced.

During this fiscal year the text for the 9th edition of the Handbook of the National Aeronautical Collection was completed and all illustrations assembled. This edition, much larger than previous ones which were limited to describing the exhibited portion of the collection, will include many of the aircraft necessarily kept in storage until an adequate building can be provided, as it was felt that their interesting histories and important technical characteristics should be made known.

Material is being assembled to provide an interesting and authoritative description of kite specimens in the Museum collection, together with a brief history of kites and their practical utility, and instructions for building and flying several of the principal types.

THE LINK FOUNDATION

Through the sponsorship of the foundation established by Edwin A. Link, of Binghamton, N. Y., two projects were promoted this year. The first was the publication by the Smithsonian Institution of a popular booklet entitled "Masters of the Air," describing 12 of the famous aircraft in the collection. Technical assistance in the preparation of this booklet was given by the staff of the National Air Museum. The second project—a catalog of the man-carrying aircraft in the national collection—has been approved by the Foundation and was assigned to the associate curator, who, by the end of the fiscal year, had assembled photographs of most of the aircraft and was engaged in writing the texts for each one.

INFORMATIONAL SERVICES

The national aeronautical collection has long since outgrown any characterization as a group of aeronautical oddities. Instead it is recognized as a record of progress, and the proof of its value is evidenced by the constantly increasing number of visitors and correspondents who utilize these aircraft, the associated documentary files, and the expert knowledge of the staff. These requests for information have increased nearly two and a half times in the past three years, but during the same period the curatorial staff has been reduced from four persons to two, who are each, therefore, endeavoring to accomplish about five times the amount of informational service formerly

undertaken. This service requires more than three times the man-hours applied to other functions. Every effort is made, however, to maintain this valued service to the many inventors, engineers, designers, historians, authors, teachers, students, and others who consult the Museum and request assistance in their many projects, all bearing a relationship to the aeronautical progress of the Nation. The following examples are representative of the more than 4,600 inquiries attended to this year:

The Department of the Navy was assisted in the preparation of articles, including one describing the development of parachutes and another recalling the first time that the United States flag, attached to an airplane, was under fire; that was during the operations against Veracruz, Mexico, in 1914, when Lt. P. L. Bellinger was the pilot. Engineers of the Bureau of Aeronautics were provided with facts about early power plants, first instances of cannon fired from aircraft, and technical data on a jet-engined installation involving recessed exhaust areas, the latter being required in defense of a patent suit against the Government. A number of inquiries regarding historical facts received by the Air Force Office of Public Relations were referred to the National Air Museum. The United States Air Force Office of Historical Records was furnished with biographies of noted Air Force pilots and with squadron histories. Several graduating classes of Air Cadets were assisted in preparation of their yearbooks where information was needed to describe noted events in Air Force progress. Discussions were held with officers planning the curriculum for the new Air Force Academy. Arrangements were made to trade periodicals and books in order to supply missing issues. Contractors to whom research projects had been assigned by the Air Force consulted the Museum for developments in airplane structures and operation. The Department of Justice, engaged in assembling information with which to consider the claims of inventors against the Government, consulted Museum specimens and files pertaining to helicopters, autogyros, wing radiators used for the cooling of engines, and the origin of safety belts and shoulder harnesses dating back to World War I and also during the earlier period around 1911. An early example of a high-aspect ratio stabilizer, embodied in one of the Museum's pioneer airplanes, provided a helpful source for contesting another suit against the Government. An official of the Bureau of the Budget, engaged in preparing a treatise on air photography, was shown valuable references in the Museum library and useful illustrations in the photographic file. The National Bureau of Standards was assisted in the preparation of scale models of aircraft to be used in determining the best locations for electrical installations.

Fifteen schools and colleges are listed among the educational organizations that applied to the Museum for assistance, ranging from details of performance and design of aircraft to the planning of instruction courses. The Buffalo Society of Natural Sciences was helped in preparation of a special exhibit honoring the Wright brothers, the Air Education Council was supplied with descriptions of Museum aircraft, and the National Geographic Society consulted the Museum to check details of manuscripts pertaining to aeronautics and noted aviators. The Museum of Science and Industry in Chicago was helped in planning a hall to include exhibits of Naval aircraft, and the French Musée de l'Air received assistance in the preparation of exhibition models of American airplanes. Among the organizations that came to the Museum for assistance was the Air Transport Association, which required information about the Junkers-Larsen airplane of 1919. The Army and Navy Club in Washington, searching for illustrations of air squadrons for its walls, found in Museum files an excellent group picture of the First Aero Squadron. The American Helicopter Society was assisted in planning exhibits for its annual meeting, and the Junior Chamber of Commerce of the District of Columbia received help in planning a contest for youthful model-makers.

Ten authors and four illustrators of aeronautical books consulted Museum specimens and records for facts. Many newspaper reporters checked details of their stories with the Museum staff. Magazines that turned to the Museum for help included Life, Aero Digest, Popular Mechanics, True, and Aviation Daily; and the World Scope Encyclopedia and Aircraft Yearbook depended upon the Museum for assistance in the preparation of several articles. Commercial photographers received identification of photographs in their files by referring to the Museum staff. Model-airplane manufacturers, who cater to tens of thousands of enthusiasts of that sport, requested Museum aid to insure the accuracy of their products. United, Capital, and Pan American Airlines received assistance in preparing advertisements and publicity; the Boeing Aircraft Co. obtained facts about refueling history; North American Aircraft consulted Museum airplanes to check details of engine cooling; the General Electric Co. came to the Museum for photographs of early jet engines; and Fokker Aircraft of Holland received assistance in restoring its files from which valuable records had been lost during World War II. Toward the close of the fiscal year three motion-picture companies were engaged in producing pictures about famous events in aeronautical history. Warner Brothers' film on the *Spirit of St. Louis* depended upon the original airplane in the Museum for the accuracy of the re-

productions being constructed; and their technical experts assembling facts about the trial of Gen. William Mitchell used Museum photographs in preparing some of the scenes. Paramount Pictures found in the Museum's three Wright brothers' aircraft, and in the series of scale models showing types developed by the Wright brothers and the Wright Company, the technical data required for the copies of those aircraft now being made for the film about Wilbur and Orville Wright.

Radio and television have found in the National Air Museum subjects and data for numerous programs. The General Electric Co. based one of its commercial announcements advertising their important accomplishment during World War II, when they made copies of the English Whittle jet engine to power America's first jet airplane, on a visit to the National Air Museum exhibits. Fulton Lewis, Jr., stood beneath the *Spirit of St. Louis* while he described its importance in stimulating confidence in the reliability of aircraft and thus giving great impetus to the progress of commercial airlines. Arlene Francis, in her Home Show, told her audience about one of the Museum's helicopter exhibits; and some interesting facts about the development of helicopters were related by the head curator in the "Collectors' Item" radio broadcast. In a series of television programs broadcast over Station WMAL–TV, under the auspices of the Greater Washington Educational Television Association, one prepared by the National Air Museum on the history of aeronautics received wide acclaim; and Station WTOP–TV carried two programs which originated at this Museum, one describing the national aeronautical collection and the other telling about the design, construction, and uses of kites. Six television stations located in other cities broadcast programs based on Museum material and information.

Numerous requests were received during the year from organizations and groups for conducted tours of the collection, and for lectures on various aspects of aeronautics. Whenever possible these were provided. Sixteen lectures on aeronautics were given by the head curator during the year, most of them in the evening and illustrated by motion pictures and slides. With the exception of the talk on the history of aeronautics to the American Airlines' Gas Model Club at Cleveland January 29, all were in the Washington area. Among these lectures was a description of the purpose and progress of the National Air Museum given to the Sphinx Club of the Masonic Fraternity, the story of the Wright brothers told to the local chapter of the League of American Penwomen, the history of air mail described to the National Airport Club, and talks on various phases of aeronautical history and development presented to several Reserve Officers associations.

REFERENCE MATERIAL AND ACKNOWLEDGMENTS

The Museum maintains a library and file of books, periodicals, documents, and contemporary records of aeronautical data to supplement the exhibits and serve as sources of reference both for the staff and others who consult the Museum in connection with their research projects. The improvement of these sources and the arrangement of this material in readily available form are necessary factors in maintaining the service described in the previous section of this report. Many persons who appreciate the importance of the National Air Museum reference collection have donated to it their own files, thus preserving them and extending their usefulness.

The following lots of reference material were received:

Aero Digest, Washington, D. C: 19,998 photographs pertinent to aeronautics—a collection accumulated in connection with the publication of "Aero Digest," "The Sportsman Pilot," and "Aircraft Yearbook." Mostly 8 x 10 inches in size and dating from the early 1920's.

Air Trail Hobbies, New York, N. Y.: Approximately 1,500 photographs dealing with aeronautics in general, from 1920 to 1940.

Beilstein, Chris W., Arlington, Va.: A collection of clippings contained in 67 envelopes and file folders, covering aviation in general. Selected from magazines, books, and newspapers from 1920 to the present.

Chance Vought Aircraft, Dallas, Tex.: 45 enlarged photographs, framed, covering the history of Vought aircraft from 1917 to date.

Curtiss-Wright Corporation, Wood-Ridge, N. J.: 11 books relating to aeronautics in general.

Gleditsch, Ernest W.: 770 aeronautical magazines, including "Aviation," "Aero Digest," and "Flight," published between 1917 and 1935.

Grumman Aircraft Engineering Corporation, Bethpage, L. I., N. Y.: A collection of aviation magazines covering 12 titles, some dating back to 1919.

Hargraves, Mrs. W. R., New York, N. Y.: A piece of the fabric from the NC-3 which was one of the flying boats of the U. S. Navy's first transatlantic squadron, 1919.

Ijams, Mrs. J. Horton, Lawrence, L. I., N. Y.: A collection of "Air Facts" in three binders, complete from February 1, 1938, through 1941.

Navy, Department of, Washington, D. C.: Drawings, assembly, for Douglas D-558-1 "Skystreak."

Pratt & Whitney Aircraft, East Hartford, Conn.: A collection of manuals, drawings, and brochures covering data and specifications on the Pratt & Whitney #2180 Twin Wasp E-1 powerplant.

Weeks, E. D., Des Moines, Iowa: 289 photographs of European aircraft, 1909-1914, which were purchased in Germany from Heinz J. Nowarra.

Wolffsohn, Hans J., Suffern, N. Y.: A series of the magazine *The Aeroplane Spotter*, 1941 through 1946. Five issues of *Flughafen und Luftverkehr*, 1942, 1943, and 1954; 16 issues of *Der Flieger*, 1953 and 1954.

Other acquisitions included several motion-picture films: "We Saw It Happen," and the story of the Sikorsky helicopter, received from United Aircraft Corporation of East Hartford, Conn.; the picturization of 50 years' progress in aeronautics, assembled by the Shell Oil

Corporation, and a group of films pertaining to Charles Lindbergh's famous transatlantic flight given to the Museum by the Aircraft Industries Association. Grateful acknowledgment is also due the following for their valuable contributions to the reference collection: D. J. Harrill of Arlington, Va.; J. W. Gwinn, Jr., of Wayne, Mich.; Jesse Davidson, of Underwood & Underwood, New York City; Bert Williams of Melbourne, Victoria, Australia; the Institute of Aeronautical Sciences of New York City; Col. Floyd J. Sweet of the Soaring Society of America; Maj. Richard R. Sheak; Mrs. M. S. Gilpatric of New York City; Charles J. MacCartee of Orlando, Fla.; Maj. Kimbrough Brown, USAF, of Brookfield Air Force Station, Brookfield, Ohio; Col. J. E. Jarrett, curator of the Army Ordnance Museum at Aberdeen, Md.; Ray Fife of Coronado, Calif.; Harvey Lippincott of Hebron, Conn.; Wright-Patterson Air Force Base; Hiller Helicopters of Palo Alto, Calif.; North American Aviation, Incorporated; and Mr. and Mrs. Keith C. Whitehouse, who permitted copies to be made of their pictures illustrating Curtiss aircraft.

The Book Exchange maintained at the Library of Congress continued to be an excellent source for issues of magazines required to fill gaps in the Museum series.

ACCESSIONS

Additions to the national aeronautical collections received and recorded this year total 117 specimens in 31 separate accessions. Those from Government departments are entered as transfers; others were received as gifts except as noted.

Alexander, Mary, Los Angeles, Calif., through Amelia Earhart Post #678, American Legion: Flying suit designed by Amelia Earhart for the Ninety-Nines, an international organization of licensed women pilots, and typical of the apparel worn by Miss Earhart during her many flights (N. A. M. 858).

Allen, Sloan, Omaha, Nebr.: Kite, 3-stick frame, hexagon outline, incorporating improvements made by the donor through extensive practice, and flyable through a wide range of wind velocity (N. A. M. 861).

Army, Department of, Washington, D. C.: Clothing and equipment of the type used by U. S. paratroopers during World War II (N. A. M. 857).

Atchison, Joseph Anthony, Washington, D. C.: Plaster bust of Wiley Post, sculptured by the donor in 1940 (N. A. M. 853, loan).

Bendix Aviation Corporation, Scintilla Magneto Division, Sidney, N. Y.: Two magnetos from the Wright Whirlwind J-5 engine which powered the Bellanca "Columbia," flown by Clarence Chamberlain and Charles A. Levine, nonstop, New York to Eisleben, Germany, June 4-6, 1927. Ignition systems for Pratt & Whitney R-2800, Pratt & Whitney R-2000, Allison V-1710, and Wright R-3350 aircraft engines (N. A. M. 856).

Bleil, Mrs. Alida W., Alhambra, Calif.: Cup given to Harriet Quimby, first American woman licensed to pilot an airplane, as she landed after flying across the English Channel from Deal, England, to Epihen, France, April 26, 1912.

COMMERCE, DEPARTMENT OF, NATIONAL BUREAU OF STANDARDS, Washington, D. C.: Five impellers of the types used for rotating aircraft generators, 1915–25 (N. A. M. 842).

COOK, MRS. O. D., Portland, Oreg.: Hub of propeller from an airplane flown by Capt. Vernon Castle, renowned dancer and aviator, who achieved an impressive combat record in the Royal Flying Corps during World War I and, following America's entry into the War, was assigned to the aviation section of the Signal Corps, U. S. Army, to train student fliers (N. A. M. 863).

ELLIS, FRANK H., West Vancouver, B. C.: Two scale models of airplanes associated with the early development of aviation by Canadians; model of the multiplane designed and built in 1910–11 by W. W. Gibson, Victoria, B. C., and flown in 1911; and a model of the Aerial Experiment Association's "Red Wing," designed by members of that Association organized by Alexander Graham Bell, and first flown by Frederick W. Baldwin, the first British subject to pilot an airplane at Hammondsport, N. Y., on March 12, 1908 (N. A. M. 851).

HARTIGAN, COL. JOHN D., Washington, D. C.: Tunic, cap, and Sam Brown belt worn by the donor as part of his uniform as an officer in the Signal Corps Aviation Section during service in France, World War I, 1917–18 (N. A. M. 854).

HUTCHINSON, CAPT. J. D., Denver, Colo.: Five drop bags used for air to ground deliveries of messages by the U. S. Air Service and U. S. Army Air Corps during the 1920's and 1930's; and a pair of mittens worn during winter flying operations, representing regular issue equipment of the same period (N. A. M. 867).

KAMAN AIRCRAFT CORPORATION, Bloomfield, Conn.: Scale model, 1:20, of the HOK-1, a four-place helicopter which uses a servo-flap control for its two intermeshing rotors; developed by the donors for the U. S. Navy, 1953 (N. A. M. 848).

KOLLSMAN INSTRUMENT CO., Elmhurst, N. Y.: Air speed indicator and clock developed by the donors for use in aircraft of the World War II period (N. A. M. 845).

LAHM, BRIG. GEN. FRANK P., Huron, Ohio: Medals and awards received and collected by the donor and his father, Frank S. Lahm, including the Aero Club of France gold medal awarded to Frank S. Lahm in recognition of his services to aeronautics, 1906, the Gordon Bennett gold medal, the Aero Club of America gold medal, and the Aero Club of France bronze medal awarded to Frank P. Lahm for winning the first international balloon race, 1906 (N. A. M. 855).

LOCKHEED AIRCRAFT CORPORATION, Burbank, Calif.: Two scale models of aircraft developed by the donors: a 1:72 model of the YC–30 and a 1:64 model of the type 1049 Superconstellation (N. A. M. 860).

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, Washington, D. C.: Display item representing the award, in 1929, of the Robert J. Collier Trophy, awarded annually since 1911 for the "greatest achievement in aviation in America, the value of which has been truly demonstrated by actual use during the preceding year." It was awarded to the NACA for development of a cowling for radial air-cooled engines which improved flight performance. The display consists of a scale model of the Lockheed "Air Express" airplane which, equipped with the cowling, established a transcontinental record of 18 hours 21 minutes 59 seconds, February 4–5, 1929, piloted by Frank Hawks. The cowling made possible a 29 m. p. h. increase in speed (N. A. M. 868).

NAVY, DEPARTMENT OF, Washington, D. C.: Collection of spark plugs used with aircraft engines produced in various nations and dating from pre-World War I era to recent years; and a Heinkel Hirth RR2 gas turbine engine of experimental type produced in Germany during World War II in 1944 (N. A. M. 840). A waist hatch door from a Martin PBM-5 "Mariner" flying boat of the World War II period. The door is equipped with racks for mounting jato tanks used for increasing takeoff power and reducing the distance required to be airborne (N. A. M. 843). A collection of flight instruments, engine instruments, and miscellaneous aircraft accessories of Japanese origin, produced and used during World War II (N. A. M. 846).

RICHMOND, LT. JACK J., Hollywood, Calif.: Crash helmet worn by the donor, 1918 (N. A. M. 866).

RUFFE, INC., Miami, Fla.: Cutaway example of an ejection seat catapult used in many current types of jet-engined fighter airplanes (N. A. M. 864).

SMITH, MILTON M., Shreveport, La.: Insigne of the Lafayette Escadrille, famous squadron of American pilots who fought with the French prior to America's entry into World War I, removed by the donor from an airplane used by Raoul Lufbery, one of America's most famous pilots of that war (N. A. M. 850).

UNITED AIRCRAFT CORPORATION, HAMILTON STANDARD DIVISION, East Hartford, Conn.: Air-conditioning unit, heat-exchanger type, developed for use in the North American F-86H "Sabre" (N. A. M. 847). R-2180 Twin Wasp aircraft engine, developed by the donors in 1947 for powering medium transport aircraft, with complete installation equipment including the nacelle and the associated electrical fuel and lubrication accessories (N. A. M. 849).

UNITED AIR LINES, Chicago, Ill.: Scale model, 1:16, of the Laird "Swallow" which was flown by Varney Air Lines, predecessor of United Air Lines, on the original Contract Air Mail Route 5, April 1926 (N. A. M. 862).

U. S. NATIONAL MUSEUM, DEPARTMENT OF HISTORY, Washington, D. C.: German bomb of World War I (N. A. M. 839). Radio receiver, transmitter, and accessories of the type used in Naval aircraft during World War I and the early 1920's (N. A. M. 844).

UNIVERSITY OF DETROIT, Detroit, Mich.: Collection of aircraft engine instruments, flight instruments, and engine accessories used during World War I (N. A. M. 838).

VERVILLE, ALFRED V., Washington, D. C.: Group of personal items presented to the donor by Gen. William Mitchell, including the General's swagger stick and the pennant flown from his airplane (N. A. M. 865).

WITTMAN, S. J., Oshkosh, Wis.: *Buster*, a midget racing airplane formerly named "Chief Oshkosh" designed and built by the donor in 1931, and entered in numerous races throughout the period 1931-54, winning many notable competitions and placing among the leaders in most of the more than 50 competitions entered (N. A. M. 859).

WOERNER, C. E., Geneva, Ohio: Warner "Scarab" aircraft engine of the type produced in 1928 (N. A. M. 852).

Respectfully submitted.

PAUL E. GARBER, *Head Curator.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

370930—56——8

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, 1955.

In all, 934 accessions, comprising 2,347 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, thus fostering the Smithsonian's established purpose of "the increase and diffusion of knowledge." 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 $46,212 a year. This money is deposited in the United States Treasury to the credit of the General Fund, District of Columbia. The concessionaire serves meals and light refreshments and sells souvenirs.

FUNDS

The regular appropriation for the fiscal year was $645,000, which is carried in the District of Columbia Appropriation Act. This amount was supplemented by $3,000, which was transferred to the appropriation in accordance with Public Law 123, for payment of retroactive pay made necessary by the Federal Employees' Salary Increase Act of 1955, approved June 28, 1955, effective the first payday of the first pay period beginning after February 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.

ACCESSIONS

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

FIRSTS

"Firsts" that are desirable are welcomed in almost every organization, and the fiscal year covered by this report had a gratifying number of "firsts" for the Zoo. These are listed below.

The greatest rarities obtained during the year were two Goeldi's marmosets (*Callimico goeldii*) which until recently had been known from only half a dozen specimens from habitats in widely scattered localities far up the tributaries of the Amazon River. The Zoo's examples are black throughout, with brown tips to the hairs on the back of the head and portions of the back which are conspicuous when back-lighted. They also have what looks like a crew cut of two different lengths, that on the front of the head being fairly short and that on the back of the head somewhat longer.

Also acquired were two of the little-known dinomys paca (*Dinomys branickii*), a rather large rodent that is apparently rare in the wild as well as in captivity.

Another outstanding accession was a rare and little-known foussa (*Cryptoprocta ferox*) of Madagascar, obtained by purchase. This is a relative of the civets that looks somewhat like a large, slender-bodied, short-haired brown cat.

Two young southern sea lions (*Otaria flavescens*) were purchased. When received they were about 3 and 4 feet long.

An interesting accession was a pair of rat kangaroos (*Hypsiprymnodon moschatus*), which produced a baby that was observed in the pouch of the mother on June 30, 1955. These are not conspicuous as exhibition animals but help to round out the collection, giving the visitors a glimpse of the remarkable variation of the marsupials.

An African dormouse (*Graphiurus murinus*), an attractive little mouselike creature, was sent to the Zoo by Dr. Lawrence Kilham of the National Institutes of Health from his Entebbe, Africa, headquarters. Dr. Kilham also sent two specimens of the black-and-white casqued hornbill (*Bycanistes subcylindricus*), a rare species of showy birds.

Two eider ducks (*Somateria mollissima*) were obtained by exchange.

The bird collection was also enriched by specimens of the Mahali weaver (*Plocepasser mahali*) and cliff chat (*Thamnolaea cinnamomeiventris*).

Six African chameleons (*Chamaeleon dilepis*) were hatched on June 23, 1955, from eggs laid April 2, 1955. Perhaps other establishments have had African chameleons lay eggs that hatched, but this Zoo is unaware of such an event.

OUTSTANDING GIFTS

The outstanding gift of the year was a pair of baby gorillas (*Gorilla gorilla*) presented to the National Zoological Park by Russell Arundel, of Warrenton, Va., a longtime friend of the Zoo. They were captured by the Arundel Expedition in French Equatorial Africa, near the Belgian Congo. In the Belgian Congo they were cared for in the home of John L. Biname, then director of the Zoo at Leopoldville, and at Antwerp in the home of Walter Van den Bergh, head of the Zoo there, so they received especially good attention on their trip to the States. The male, "Nikumba," weighed 17 pounds and the female, "Moka," weighed 20 pounds on arrival. These are the first gorillas the Zoo has had since 1932 and are highly desirable additions to the collection. They are thriving and are popular entertainers, as they are very active.

The Hon. Charles S. Thomas, Secretary of the Navy, presented to the National Zoological Park 7 emperor penguins (*Aptenodytes forsteri*) and 4 Adelie penguins (*Pygoscelis adeliae*). These birds had been obtained by Navy explorers while on an Antarctic expedition on the U. S. S. *Atka* with Commander Glen Jacobsen in charge. Emperors are the largest living penguins, and this group, together with the king penguins received a few days before, made an outstanding exhibit. At the request of Secretary Thomas two of the emperors were turned over to the Bronx Zoo in recognition of the assistance given by the New York Zoological Society in transporting the birds from Miami to Washington.

The Ambassador of Pakistan, Syed Amjad Ali, presented a beautiful young jungle-caught Bengal tiger through the Foreign Operations Administration.

The Japanese Ambassador Sadao Iguchi presented to Secretary of Defense Charles E. Wilson a pair of long-tailed fowl (*Gallus gallus*) which are being kept on display in the National Zoological Park.

This is a domesticated bird that has developed, through painstaking breeding by the Japanese, exceptionally long upper tail coverts. The feathers of these birds are sometimes as much as 20 feet in length.

Dr. Lawrence Kilham, of the National Institutes of Health, who was spending a year in the vicinity of Entebbe, Uganda, East Africa, kindly sent several shipments of African animals, all of which were well selected and desirable additions to the Zoo. These animals are enumerated in the donors' list.

Dr. Robert Rausch, of the National Institutes of Health at the Arctic Health Research Center, Anchorage, Alaska, continued to show his interest in the National Zoological Park. Through his organization there have been received 1 Canada lynx (*Lynx canadensis*), 1 emperor goose (*Philacte canagica*), and 1 black brant (*Branta bernicla nigricans*). These were all desirable additions as there were none of these species in the collection at the time, nor had there been for some years.

The Walter Reed Army Medical Center, the National Institutes of Health, and Johns Hopkins University continued to deposit with the Zoo young chimpanzees (*Pan troglodytes*) used in their medical experiments. These animals are all suitable for exhibition and are available to the medical research workers when needed. This is proving to be a thoroughly satisfactory arrangement, and when the chimpanzees are no longer suitable for the work of the scientists they are turned over to the Zoo permanently. A young female chimpanzee (*Pan troglodytes*) was presented by Mr. and Mrs. John T. Smith, Jr., of Monrovia, Liberia.

The United Cerebral Palsy of Washington, D. C., presented a baby howler monkey (*Alouatta*), three cottontop marmosets (*Callithrix oedipus*), six blue tanagers (*Thraupis cana*), and four saffron finches (*Sicalis luteola*) after they had been used for publicity purposes by the organization.

A domestic burro or donkey (*Equus asinus*), the first one exhibited in the Zoo in many years, was presented by Del Rensel, president of Slick Airways. Donkeys, of course, are not rare, but by reason of their religious, agricultural, and other associations, and of their odd appearance, they are of considerable interest to the visiting public.

Through the kind interest of Dr. Juan Rivero, College of Agriculture, Mayagüez, Puerto Rico, the Zoo received two of the rare Mona Island iguanas (*Cyclura stejnegeri*). These are large, heavy-bodied lizards that look like miniature dinosaurs of past ages. One of these was dead on arrival, and the other refused to eat at first but was finally hand-fed and soon became a pet. Shortly after her arrival she laid 16 eggs.

Eleven Humboldt's penguins (*Spheniscus humboldti*) were received as gifts from the Perfection Stove Co. of Cleveland, Ohio.

A green conure (*Aratinga leucophthalmus*) was a gift from N. H. Caudell, of College Park, Md.

A horn-nosed iguana (*Iguana iguana rhinolopha*) obtained by Jack Reed, of Tampa, Fla., while on a cruise along the Mexican coast, was given to the Zoo. It is a beautiful example and, although closely related to the common iguana, is sufficiently different to make a very desirable addition to the collection.

GIFTS AND 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.

DEPOSITORS AND DONORS AND THEIR GIFTS

(Deposits are marked*; unless otherwise indicated, addresses of donors are Washington, D. C.)

Ackerman, Mrs. Anita, Pittsburgh, Pa., black-widow spider.
Adams, W. A., Hyattsville, Md., 2 Pekin ducks.
Akins, Ken, Indian Head, Md., hog-nosed snake.
Allen, Louis S., Silver Spring, Md., caiman.
Amber, Dianne, Arlington, Va., 2 Pekin ducks.
Anderson, Louis E., Alexandria, Va., rhinoceros beetle.
Andreano, Joseph, Takoma Park, Md., 2 Pekin ducks.
Andrews, David, Silver Spring, Md., snapping turtle.
Andrews, Richard, Silver Spring, Md., 2 Pekin ducks.
Angleton, Cicily, Arlington, Va., skunk.
Anonymous, salt-water gray crab.
Archer, Mrs. S. R., pigeon.
Arctic Health Research Center, Anchorage, Alaska, Canada lynx, emperor goose, black brant.
Armstrong, Mrs. Amelia, Arlington, Va., guinea pig.
Armstrong, W. T., Silver Spring, Md., domestic rabbit.
Arnold, Mrs. Joseph, Falls Church, Va., blue-fronted parrot.
Aronson, Michael, Belgian hare.
Arundel, Russell, Warrenton, Va., 2 gorillas.
Ashworth, James T., Arlington, Va., Pekin duck.
Atzinger, Dorothea, 2 strawberry finches, society finch, white zebra finch.
Ayers, Lorraine, domestic rabbit.
Babbitt, Lewis H., Petersham, Mass., 5 toads, 2 Cuban boas.
Badinelli, Joseph, Takoma Park, Md., common newt.
Balderson, R. H., gray fox.
Balderson, Warren, purple gallinule.
Baldwin, Mrs. Fred, Cumberland turtle.
Ball, Mrs. S. M., Arlington, Va., 2 Cumberland turtles.
Ballman, Barbara, Silver Spring, Md., 2 Pekin ducks.
Bannockburn Cooperative School, Bethesda, Md., 2 guinea pigs.
Barnes, John P., Arlington, Va., opossum.
Barnes, Mrs. Sara M., 3 Pekin ducks.
Barney, Mrs. C. N., Takoma Park, Md., Pekin duck.
Barr, Mrs. J. A., Jr., Takoma Park, Md., Pekin duck.
Baskett, T. S., flying squirrel, hamster.

Baxter, Bruce, 2 Florida "chameleons."
Beck, Mrs. Rivi, Silver Spring, Md., 2 Pekin ducks.
Belintende, Sam J., salamander.
Benton, Bobby, Silver Spring, Md., snapping turtle.
Bernstein, Edward, *white-throated capuchin.
Betesh, Stanley, 4 domestic chickens.
Bierly, Edward, Arlington, Va., Pacific pond turtle, desert tortoise.
Billington, R. C., Silver Spring, Md., 2 red-lined turtles.
Bird, Arthur, barred owl.
Bishop, Robert T., domestic rabbit.
Bissonette, H. A., domestic rabbit.
Black, Cordell, Arlington, Va., snapping turtle.
Blish, Linda, Pekin duck.
Blush, Mrs. Ernest, Kensington, Md., 3 domestic rabbits.
Booher, Joe, McLean, Va., great horned owl.
Botkin, Marshall, Mount Rainier, Md., box turtle.
Bowman, Gary, and Korab, Harry, University Park, Md., snapping turtle.
Boyd, Charles H., 2 grass parakeets.
Boyd, Nancy, Alexandria, Va., Pekin duck.
Bradley, Daniel E., 4 gray squirrels.
Bridge, David, Greenbelt, Md., red-bellied turtle.
Brittain, Charles, Lanham, Md., water snake.
Brown, Mrs. Jane, Arlington, Va., gray squirrel.
Brown, Thaddeus III, 2 caimans.
Brown, Tom, Bethesda, Md., snapping turtle.
Brunhouse, Mrs. Helen, raccoon.
Brunhouse, Mrs. W. A., skunk.
Buffett, Cheryl, guinea pig.
Burgess, G. S., 3 alligators.
Burgess, Jack, Riverhead, Long Island, N. Y., black racer.
Burkhart, Paul, sparrow hawk.
Burris, Robert, Cabin John, Md., *squirrel monkey.
Burton, Chip, Florida king snake.
Burton, Mrs. Esther, 2 hamsters.
Burton, Mrs. Louise H., Arlington, Va., alligator.
Bush, William R., white-faced capuchin.
Cahnmann, Hans J., Bethesda, Md., opossum.
Cain, R. M., Landon Hills, Md., 2 Muscovy ducks.
Calandera, Fred A., Pekin duck.
Caleb, I. B., Chevy Chase, Md., 2 Pekin ducks.
Calvert, Gordon L., Silver Spring, Md., 2 domestic rabbits.
Campanella, S. Joseph, opossum.
Campbell, Mrs. Josephine, Mount Rainier, Md., *mallard duck.
Cantona, Pascal J., Jr., *kinkajou.
Carlson, Carl, University Park, Md., Pekin duck.
Carmack, Angela, Arlington, Va., Pekin duck.
Carnicero, George, domestic rabbit.
Carrena, Carlota, sparrow hawk.
Carroll, P. G., domestic rabbit.
Cartner, Helen, 2 raccoons.
Cassett, Charles and Michael, Silver Spring, Md., 2 Pekin ducks.
Catholic University (through Dr. Roland Nardone), 2 Arctic ground squirrels.
Caudell, N. H., College Park, Md., green conure.
Chambers, R. A., domestic rabbit.
Chase, Joseph C., Franklin, Va., brown water snake, red-bellied water snake.
Chauvenet, Allen R., Silver Spring, Md., domestic rabbit.
Cheargam, Chuck, Arlington, Va., Muscovy duck.
Cheatham, B. B., Arlington, Va., 3 Muscovy ducks.
Cheatum, Chuck, Arlington, Va., Muscovy duck.
Cheney, Sheldon, musk turtle.
Chevy Chase Pet Shop, *indigo snake.
Chick, Drew, copperhead snake.
Cholden, Mrs. Lea, Kensington, Md., robin.
Chueng, Mrs. Mary, guinea pig.
Churchill, David, Arlington, Va., snapping turtle.
Claar, Lester, Bradbury Heights, Md., woodchuck.

Clagett, R. B., Silver Spring, Md., caiman.
Clark, David L., Bethesda, Md., 2 pine lizards, water snake.
Clarke, George L., Arlington, Va., Petz's parakeet.
Clarke, Mrs. J. H., Arlington, Va., 2 Pekin ducks.
Clepper, Fred, Pekin duck.
Cockrell, Maj. Henry B., Arlington, Va., 3 cottontail rabbits.
Cohan, Hank P., 5 domestic rabbits.
Cohen, Mrs. Wallace, Chevy Chase, Md., domestic goat.
Collins, Billy and Dickey, 5 toads.
Compton, Mrs. Richard, snapping turtle.
Connolly, Capt. D., least bittern.
Cox, H. A., McLean, Va., woodchuck.
Craddock, Roger, Alexandria, Va., *alligator.
Crawford, John D., Jr., Alexandria, Va., Pekin duck.
Crigler, J., snapping turtle.
Crimmins, Col. Martin L., San Antonio, Tex., green rattlesnake.
Crumley, H. W., Hillcrest, Md., turkey vulture.
Crumly, Barbara and Hal, 2 Pekin ducks.
Daniels, J. W., Jr., Silver Spring, Md., Pekin duck.
Dankers, George, Arlington, Va., 3 Pekin ducks.
Davis, Malcolm, troupial.
Davison, Doreen, caiman.
Deahl, Dennis, Bethesda, Md., caiman.
Degutis, John J., College Park, Md., 2 Pekin ducks.
Deininger, Estelle, 2 domestic rabbits.
Delaney, Peter H., Java finch.
DeMent, Walter, box turtle.
DePrato, Jack, Langley Park, Md., garter snake, 2 pine lizards, pilot black snake, 5 fence lizards, 4 blue-tailed skinks, 2 common toads.
DePrato, Joe, Langley Park, Md., mole snake.
DePrato, Mario, Langley Park, Md., Florida water snake, black racer, gopher turtle, gopher frog.
Deskins, Leon D., Arlington, Va., caiman.
Deutsch, Richard, Bethesda, Md., guinea pig.
Dickson, Mrs. R., Alexandria, Va., Pekin duck.
Dieterich, L. F., grass parakeet.
Dillon, Allen, Arlington, Va., Florida water turtle.
Dix, Michael, *black snake.
Doehrer, Allen, Silver Spring, Md., domestic rabbit.
Donohoe, Charla, Falls Church, Va., alligator.
Dornin, Walter W., Phoenix, Ariz., 15 western diamond-backed rattlesnakes, 2 sidewinders, 2 western bull snakes, 2 gila monsters.
Douglass, Beverly, *caiman.
Dustin, Commander F. G., *grass parakeet.
Duvall, George C., Lanham, Md., Nubian goat.
Easter, Louis, Finsch's parrot.
Edwards, A. M., Arlington, Va., domestic rabbit.
Edwards, Sheffield, Alexandria, Va., pilot black snake, garter snake, *yellow chicken snake.
Edwards, Mrs. S. T., Arlington, Va., 2 guinea pigs.
Egan, Denise, 2 Pekin ducks.
Eisenberg, Philip, Takoma Park, Md., Pekin duck.
Elias, Alix, horned lizards.
Ellis, Richard D., Falls Church, Va., caiman.
Eskew, William, alligator.
Estep, Gary, Falls Church, Va., caiman.
Etter, Dr. Harry S., Chevy Chase, Md., Pekin duck.
Evans, Mrs. James M., Bethesda, Md., 2 caimans.
Evans, Nancy, Falls Church, Va., caiman.
Ewing, J. Hunter, Arlington, Va., 2 Pekin ducks.
Faison, Walter E., Falls Church, Va., grass parakeet.
Falck, Bengt H., Alexandria, Va., screech owl.
Farrier, John, Hyattsville, Md., kinkajou.

Fay, Mrs. William M., Chevy Chase, Md., *American crow.

Feeney, Lt. Harold, Arlington, Va., cottontail rabbit.

Ferguson, Gary, Alexandria, Va., indigo snake, boa constrictor, musk turtle, painted turtle, *common iguana, *collared lizard.

Ferretti, Domingo, hog-nosed snake.

Fillman, Ralph A., Lanham, Md., horned lizard.

Finlay, Capt. John S., Jr., Bethesda, Md., gila monster.

Fitzpatrick, John, eastern skunk.

Follin, James W., Centreville, Va., great horned owl.

Ford, Bertelle E., Rockville, Md., 2 common iguanas.

Fowler, J. G., domestic rabbit.

Franklin, R. D., Arlington, Va., 2 alligators.

Frazier, Elmer E., Brookmont, Md., osprey.

Freshman, D., Silver Spring, Md., snapping turtle.

Frishmann, Michael and Steven, Silver Spring, Md., pied-billed grebe.

Fu, Hua Priscilla, domestic rabbit.

Fuller, Robert J., Arlington, Va., domestic rabbit.

Gaines, Mary, Silver Spring, Md., 2 Pekin ducks.

Garths, E. C., Bethesda, Md., 3 domestic rabbits.

Gatti, Stephen A., Jr., *pigeon hawk.

Gaver, Gordon P., Thurmont, Md., *4 alligators, *rhesus monkey, *Java macaque, *2 gopher turtles, *alligator snapping turtle, *4 black tegus.

Geigan, F. Stewart, opossum.

German, Robert, caiman.

Geyser, Robert J., Prince Georges County, Md., green frog.

Gillespie, Mrs. Hilda G., Takoma Park, Md., 3 flying squirrels.

Ginberg, Joseph, parakeet.

Gleason, James, Herndon, Va., pied-billed grebe.

Gleason, Shirley, Vienna, Va., skunk.

Glidden, Richard S., black snake.

Godfrey, Harry, Hyattsville, Md., 5 black-tailed platys, 2 guppies, 10 pearl danios, red-tailed barbus, 12 Siamese fighting fish.

Goldthorpe, Freddy, Bethesda, Md., skunk.

Gordon, Marvin, woodchuck.

Graham, Mrs. John H., 2 grass parakeets.

Grant School, sparrow hawk.

Gray, Albert G., Suitland, Md., 2 black-widow spiders.

Gray, Gary, Hyattsville, Md., Pekin duck.

Grayson, Marilyn, 2 Pekin ducks.

Green, Robert E., Arlington, Va., mallard duck.

Green, William, canary.

Greenbaum, Samuel M., 9 box turtles.

Greenwood, Walter B., Arlington, Va., snapping turtle.

Grosskopf, W. H., eastern skunk.

Guilford, L. W., Silver Spring, Md., hamster.

Gunthrop, James, bantam hen.

Haber, Mrs. L. J., Riverdale, Md., *douroucouli monkey.

Hackenbrock, Charles R., Staten Island Zoo, Staten Island, N. Y., 5 canebrake rattlesnakes.

Hagler, Walter, Arlington, Va., guinea pig.

Hahn, Lt. Walter, Dahlgren, Va., osprey.

Haines, Tracy, Mt. Rainier, Md., *alligator, *wood turtle.

Hambleton, Edson J., copperhead snake.

Hare, Mrs. A. E., Camp Lejeune, N. C., white-tailed deer.

Harnsberger, H. P., pilot snake.

Harrison, W. P., Alexandria, Va., barn owl.

Hartsell, Mrs. Mary, 3 parakeets.

Hay, Michael, domestic rabbit.

Haymaker, Capt. John, Chevy Chase, Md., yellow-naped parrot.

Hecht Co., 2 mute swans, *3 penguins.

Hennessy, R. E., Annandale, Va., Pekin duck.

Herbert, Paul, Bethesda, Md., 2 domestic rabbits.

Heslop, Bill, Mt. Rainier, Md., indigo snake.

Higley, John R., barred owl.
Hileman, George, McLean, Va., 4 raccoons.
Hoffman, Irvin M., Cabin John, Md., silky bantam.
Hopkins, J. R., Takoma Park, Md., squirrel monkey.
Hopkins, Mrs. R. J., Arlington, Va., blue jay.
Hord, Earlene, Alexandria, Va., Cumberland turtle.
Hord, Eugene R., Silver Spring, Md., snapping turtle.
Hough, Dr. L. Frederick and family, New Brunswick, N. J., 2 pottos.
Hudgins, Tommy, Arlington, Va., 2 Pekin ducks.
Huebner, Mrs. Robert, Ijamsville, Md., raccoon.
Hutchinson, Bobby, Arlington, Va., domestic rabbit.
Ikao, Tanit, Jamaica, N. Y., *5 alligators, *boa constrictor, *Indian python.
Ingham, Rex., Ruffin, N. C., *African palm civet.
Izenour, Frank M., Arlington, Va., Pekin duck.
Jacobs, J. C., gray squirrel.
Jacobson, N. M., 2 Pekin ducks.
Japanese Ambassador, Sadao Iguchi (through the Hon. Charles E. Wilson, Secretary of Defense), *2 long-tailed fowls.
Jawarski, Stephen, Bethesda, Md., mallard duck hybrid.
Jennings, Michael, 8 common waxbills.
Johnson, Mrs. H. W., Arlington, Va., horned lizard.
Johnson, Julia V., Arlington, Va., eastern skunk.
Johnson, R. E., East Riverdale, Md., blue jay.
Jones, Brenda, Arlington, Va., 4 Pekin ducks.
Jones, Mrs. H. T., Norfolk, Va., raccoon.
Jones, Melvin, Silver Spring, Md., spotted salamander.
Jones, Tom, Arlington, Va., snapping turtle.
Jones, William E., Jr., Arlington, Va., hog-nosed snake.
Judson, Marcia, black rabbit.
Kahn, Sharon, Silver Spring, Md., 2 Pekin ducks.
Kale, D. R., Arlington, Va., 2 Pekin ducks.
Kerr, Mrs. Victor H., Falls Church, Va., 3 blue jays, sparrow, cardinal.
Kilham, Dr. Lawrence, Entebbe, Uganda, 4 hornbills, African side-neck turtle, African yellow-billed kite, starling, African ground squirrel, 22 chameleons, monitor lizard, African palm civet, boomslang snake, 2 hinge-backed turtles, dormouse, 5 rats, 2 genets.
Kirouac, Kathleen, Accokeek, Md., white skunk.
Kise, W. Kent, Takoma Park, Md., caiman.
Kuntz, Dr. Robert E., Bethesda, Md., 2 pilot black snakes.
Ladiges, Werner, Hamburg, Germany, hedgehog.
Laney, Culbert, Silver Spring, Md., opossum.
Lardner, Mrs. Lyn, Silver Spring, Md., 3 Pekin ducks.
Latta, Mrs. James B., Bethesda, Md., crab.
Laurell, Mrs. S. F., caiman.
Leizear, Reginald, Derwood, Md., red fox.
Leverenz, Joseph, Alexandria, Va., domestic rabbit.
Libby, Mrs. Lionel M., Kensington, Md., cedar waxwing.
Liebenberg, M., American anolis.
Lillie, H. D., sparrow hawk.
Lilly, Eileen, domestic rabbit.
Linden, Charles J., Falls Church, Va., Cumberland turtle.
Lindner, Leonard Charles, Oakton, Va., horned owl.
Lions International, Chicago, Ill., African lion.
Lloyd, Daniel B., black-widow spider.
Locke, Otto Martin, New Braunfels, Tex., 31 horned lizards, 4 Texas diamond-back rattlesnakes.
Long, W. C., caiman.
Lonquar, Mrs. Mary, domestic rabbit.
Lovell, W. D., Hyattsville, Md., osprey.

Lowell, Brenda, Pekin duck.
Ludwig, Charles G., Arlington, Va., *Cuban Amazon parrot.
Lynch, Dana, domestic rabbit.
Lyon, James, Chevy Chase, Md., Pekin duck.
Lyon, Margaret, Arlington, Va., 2 Pekin ducks, domestic rabbit.
Macari, Denise, Indian Head, Md., box turtle.
MacDaniel, Ruth, talking catfish, sucker catfish.
MacKichan, Robert, Takoma Park, Md., painted turtle.
MacMaugh, Mrs. F. J., red-headed woodpecker.
Malley, Mrs. John W., Chevy Chase, Md., 2 Pekin ducks.
Manoogian, David, opossum.
Marett, W. C., Bethesda, Md., Pekin duck.
Marker, Mrs. Catherine, Florida water turtle.
Marshall, Dr. F. P., pigeon.
Martin, Mrs. Elsie S., Arlington, Va., Pekin duck.
Maske, Jerry, turtle.
Mathews, T. O., Arlington, Va., guinea pig.
Mattingly, Bernard, Arlington, Va., 2 domestic rabbits.
McAfee, Mrs. D. D., Seat Pleasant, Md., English sparrow.
McCabe, John, Arlington, Va., *10 duck hawks.
McDonald, Paul, Arlington, Va., raccoon.
McDonald, Sgt. S. D., and Mr. Holt, Fort Myer, Va., gray fox.
McGruder, Mrs. Virginia, Richmond, Va., *squirrel monkey.
McQuown, Tom and Jim, Silver Spring, Md., opossum.
Mechlin, Dianne, 2 Pekin ducks.
Meryman, Harold T., Cabin John, Md., water snake.
Metcalf, Robert and Richard, caiman.
Metzler, John C., Fort Myer, Va., common crow.
Meyer, Lt. Col. C. R., Alexandria, Va., horned lizard.
Mickey, Donald, Bethesda, Md., pilot black snake.
Miller, Catherine, Richmond, Va., gray squirrel.
Miller, Edward, 200 guppies, 200 snails.
Miller, Joseph B., White Plains, Md., turtle eggs.
Mills, Maj. Gen. John S., caiman.
Mills, Vinn and Laura, Silver Spring, Md., 2 Pekin ducks.
Miracle, Hector, Arlington, Va., Virginia rail.
Moltz, Charles, Alexandria, Va., cottontail rabbit.
Moncure, Griff, Arlington, Va., 2 flying squirrels.
Money, Mark Lawson, Jr., Vienna, Va., snapping turtle.
Monks, Dr. T. R., *woolly monkey.
Monohan, Frank, Silver Spring, Md., domestic rabbit.
Moore, Howard E., 10 guinea pigs.
Moran, John C., Alexandria, Va., Pekin duck.
Morris, Charles A., domestic goat.
Moser, Glen L., Hyattsville, Md., Florida water turtle.
Murphy, E. F., Jr., Chevy Chase, Md., Pekin duck.
Myers, Z., College Park, Md., 2 Pekin ducks.
Navy, U. S. Department of the (through the Hon. Charles S. Thomas, Secretary), 7 emperor penguins, 4 Adelie penguins.
Nelson, Mrs. Alverina H., domestic rabbit.
Nelson, Wallace, Silver Spring, Md., corn snake.
Newton, Joanne, Silver Spring, Md., Cumberland turtle.
Nicholson, John W., Beltsville, Md., raccoon.
Nicodemus, G. K., Bethesda, Md., domestic rabbit.
Nicolls, Barrett, Arlington, Va., Pekin duck.
Norman, David, Hyattsville, Md., horned lizard.
Norris, O. E., 2 Pekin ducks.
North Atlantic Fertilizer & Chemical Co., New York, N. Y., *2 Indian pythons.
O'Meara, Patrick J., Arlington, Va., pilot black snake.

Over, Mrs. Frank, Jr., Falls Church, Va., cedar waxwing.

Paden, Janie, Arlington, Va., skunk.

Pakistan Ambassador, Syed Amjad Ali (through FOA), Bengal tiger.

Palm, Harry W., Arlington, Va., flying squirrel.

Pan American World Airways, New York, N. Y. (through Mr. Samuel Pryor, vice president), 2 lion-headed marmosets, 2 Baillon's toucanets.

Parish, William, gray fox.

Parker, James, 2 Pekin ducks.

Parks, F. N., Silver Spring, Md., caiman.

Payne, Fenton, coatimundi.

Payne, Melvin, Jr., Silver Spring, Md., smooth-scaled grass snake, 2 Pekin ducks.

Perfection Stove Co., Cleveland, Ohio, 11 Humboldt's penguins.

Perry, Eugene, Hyattsville, Md., 8 domestic rabbits.

Pertin, Mrs. Margaret Ann, Bethesda, Md., 2 domestic goats.

Peterson, Edwin H., *caiman.

Philadelphia Zoological Gardens, Philadelphia, Pa., 10 southern copperhead snakes.

Pitterling, Eric, Arlington, Va., squirrel monkey.

Poole, Edwin, W., Hyattsville, Md., hybrid duck.

Possinger, Karlin, Takoma Park, Md., red-lined turtle.

Post, Mrs. Herbert A., Chevy Chase, Md., 3 Pekin ducks.

Potter, Mrs. Lloyd A., Bethesda, Md., copperhead snake.

Powers, Jimmy, Silver Spring, Md., domestic rabbit.

Press, Arthur F., Jr., Bethesda, Md., copperhead snake, timber rattler.

Proctor, Carol, Chevy Chase, Md., opossum.

Pumphrey, Don, Bladensburg, Md., common water snake, queen snake, *2 giant toads, *Murray turtle.

Purcell, Ralph M., Chevy Chase, Md., skunk.

Racoosin, Robert E., 3 Cumberland turtles.

Rare Bird Farm, Miami, Fla., *3 king penguins.

Reed, Jack, Tampa, Fla., horn-nosed iguana.

Regan, Joseph H., College Park, Md., domestic rabbit.

Reichel, R. J., Silver Spring, Md., 2 Pekin ducks.

Rein, Gerald, grass parakeet.

Reinke, Mr. and Mrs. William A., Mount Rainier, Md., skunk.

Reiter, C. H., Jr., opossum.

Remington, Edward, Bethesda, Md., raccoon.

Rensel, Del, president, Slick Airways, New York, N. Y., burro.

Rew, Raymond, Frederick, Md., 4 woodchucks.

Rhodes, K. G., Alexandria, Va., canary.

Richelsen, H., 4 domestic geese.

Rickard, Mrs. Nelson, Virginia rail.

Ridgely, Mrs. A. O., blue jay, robin.

Riley, Don, skunk.

Rivero, Dr. Juan, Mayagüez, Puerto Rico, 2 Mona Island iguanas.

Robbins, Larry, Silver Spring, Md., pilot black snake, mud turtle, musk turtle, 2 painted turtles.

Robert, Lawrence Wood, caiman.

Robertson, A., 2 Pekin ducks.

Rogg, David, Falls Church, Va., caiman.

Rollins, Wade, Forestville, Md., pilot black snake.

Rubel, Mary, Bethesda, Md., domestic rabbit, guinea pig.

Rudkin, John T., W. Hyattsville, Md., 2 alligators.

Russell, Mrs. Edward, gray squirrel.

Sanner, Roland B., Pekin duck.

Saunders, Stephen, Falls Church, Va., *13 parakeets.

Savage, Frank, Rockville, Md., *rhesus monkey.

Scherer, Michael, pine lizard, salamander.

Schribner, A. E., Hyattsville, Md., Java finch.

Schwartz, J. M., domestic chicken.

Scofield, John, blue honey creeper, *sulphur-breasted toucan.

Seegers, Scott, McLean, Va., *boa constrictor, *Florida chameleon.

Seielstad, David, Silver Spring, Md., hog-nosed snake.

Sepulveda, Bobby, snapping turtle.

Shaoshan, Mrs. H. M., Bethesda, Md., 84 ring-necked doves.

Shaw, Bink, Pam, Crict, and Al, Fairfax, Va., 4 foxes.

Sherwood, Robert, Silver Spring, Md., eastern weasel.

Sholar, Lynn J., Alexandria, Va., white-throated capuchin.

Shook, George R., Youngstown, Ohio, 2 horned lizards.

Sidwell Friends School, 4 guinea pigs.

Simmons, Carl S., Newmarket, Va., 3 copperhead snakes, pectoral sandpiper, laughing gull.

Simonds, Joseph, Silver Spring, Md., domestic chicken.

Singleterry, Martha, Bethesda, Md., 2 horned lizards.

Skelton, E. H., caiman.

Smith, Arthur, Arlington, Va., *turtle.

Smith, D. W., opossum.

Smith, Mr. and Mrs. John T., Jr., Monrovia, Liberia, chimpanzee.

Smith, Mike, Bethesda, Md., gray squirrel.

Smith, William A., Arlington, Va., 3 Pekin ducks.

Snyder, Capt. Francis C., 3 cottontail rabbits.

Solomon, Daniel L., Hyattsville, Md., 2 Pekin ducks.

Southard, Robert L., Falls Church, Va., domestic rabbit.

Spencer, William, Rockville, Md., domestic rabbit.

Spitzer, Gisele, Silver Spring, Md., caiman.

Staley, Capt. P. C., 4 rice birds.

Steinbarge, Wayne, Chevy Chase, Md., *American crow.

Stepp, Dick, Riverdale, Md., pilot black snake.

Stevens, Judy and Eric, Arlington, Va., weasel.

Stevens, Mrs. Mary E., Silver Spring, Md., flying squirrel.

Stevens, Robert A., Silver Spring, Md., caiman.

Stewart, Caroline, homing pigeon.

Stewart, Mrs. H. C., white-throated capuchin.

Stone, Kenneth M., Arlington, Va., 2 Pekin ducks.

Storo, Harold Helmer, Silver Spring, Md., pilot black snake.

Strong, Robert, Silver Spring, Md., 2 Pekin ducks.

Stroop, M. A., Newmarket, Va., 6 iguanas.

Stuart, Frank, 2 chickens.

Stubbs, Mrs. F., domestic pigeon.

Sturino, Joe, 7 baby opossums.

Style, Thomas W., Takoma Park, Md., Pekin duck.

Swift, Mrs. H. M., Kensington, Md., ring-necked pheasant.

Symonds, Mrs. Edward, McLean, Va., gray fox.

Teagle, Douglas, copperhead snake.

Temple Manor Kindergarten, opossum.

Terrell, W. B., Takoma Park, Md., *pygmy rattlesnake, *5-lined skink.

Thomasson, Mrs. B. E., Arlington, Va., domestic rabbit.

Thornton, Peter, domestic rabbit.

Tice, Mrs., white-throated capuchin.

Tinnis, Leo M., Jr., Silver Spring, Md., caiman.

Tomlinson, R. C., Alexandria, Va., 2 Pekin ducks, Geoffroy's marmoset.

Tourtelotte, Lt. Col. Franklin K., Alexandria, Va., *spider monkey.

Towers, Richard, Hyattsville, Md., 2 domestic rabbits.

Towner, Nancy, Fort Lee, Va., 2 flying squirrels.

Trigger, Mrs. Lona, Gaithersburg, Md., white-throated capuchin.

Trundle, E. H., owl monkey, red fox.

Twigg, Susan, Alexandria, Va., *boa constrictor.

Tyler, F. D., Alexandria, Va., American crow.

Tyrrell, W. B., Takoma Park, Md., red-bellied turtle.

Ullman, Mrs. Virginia, raccoon.

Underwood, John, Silver Spring, Md., domestic rabbit.

United Cerebral Palsy of Washington, D. C., red howler monkey, 3 cotton-top marmosets, 6 blue tanagers, 4 saffron finches.

U. S. Fish and Wildlife Service, Cambridge, Md. (through Daniel Russ), canvasback duck, red-headed duck, lesser scaup duck, coot, bald eagle.

U. S. Fish and Wildlife Service, Saginaw, Mich., 2 whistling swans.

University of Colorado Museum, Boulder, Colo., chipmunk.

Ursin, Mrs. P. M., McLean, Va., skunk.

Van Dusen, W. R., Alexandria, Va., alligator.

VanPoucke, Alfonso, 22 parakeets.

VanPoucke, Mrs. A., 6 parakeets.

Via, Dr. Hugh, Portsmouth, Va., box turtle.

Vinikoor, Robert, domestic rabbit.

Vinson, W. E., Falls Church, Va., California spotted skunk, guinea pig.

Virginia Reptile and Tropical Bird Farm, Newmarket, Va., peach-faced lovebird, 4 Java rice birds, yellow tegu lizard, African knife fish, 13 cottonmouth moccasins, 9 water snakes, 2 Florida water snakes, 3 pilot black snakes, 2 racers, 13 baby copperheads, *South American boa, *emerald tree boa, *yellow bull snake, *pine bull snake, *indigo snake, *chicken snake, *2 red rat or corn snakes, *9 alligators, *timber rattlesnake, *copperhead, *Florida king snake, *2 ringed toucanets, *sulphur-breasted toucan, *3 cockatiels.

Yeager, W. B., Silver Spring, Md., domestic rabbit.

Young, Bob, domestic rabbit.

Young, Ron, Chevy Chase, Md., raccoon.

Wagner, E. C., 2 alligators.

Walkup, Joe, Landover, Md., night snake.

Walsh, Mrs. E. J., Pekin duck.

Walter Reed Army Medical Center, *17 chimpanzees.

Wannell, Raymond, Silver Spring, Md., toad, hog-nosed snake.

Ward, F. E., 8 white mice.

Ward, Steve, Takoma Park, Md., red-lined turtle, Florida water turtle.

Warner, Tony, Bethesda, Md., water snake.

Washington Animal Rescue League, weeping capuchin, ocelot.

Watkins, Howard B., Jr., alligator.

Watts, Charles D., Jr., 2 Java finches, red-lined turtle.

Weaver, Chief Warrant Officer W. H., Fort Myer, Va., domestic rabbit.

Webb, Henry, opossum.

Weber, Billy, Mt. Rainier, Md., 2 alligators.

Weber, Walter A., Oakton, Va., vervet monkey.

Webster, Clark G., glass lizard.

Wegener, John B., Arlington, Va., Pekin duck.

Weir, Mrs. R. H., Silver Spring, Md., 2 flying squirrels.

Wenderott, Mrs. Pat, Bethesda, Md., 2 opossums.

West, David W., Chevy Chase, Md., cottonmouth moccasin.

Whalen, Billy, Silver Spring, Md., caiman.

Wheeler, Kendall, Chevy Chase, Md., Pekin duck.

Whetzel, Mrs. Hilda L., Manassas, Va., 2 raccoons.

White, Capt. Robert C., Arlington, Va., coatimundi.

Whitley, W. F., Jr., caiman.

Williams, P. B., Hyattsville, Md., raccoon.

Williams, Mrs. Robert E., Riverdale, Md., domestic rabbit.

Williams, Robert H., Falls Church, Va., domestic rabbit.

Wilson, Randy, opossum.

Wink, L. J., Silver Spring, Md., Pekin duck.

Winnacker, Paul, Chevy Chase, Md., 4 guinea pigs.

Wise, W. W., Silver Spring, Md., domestic rabbit.

Witt, J. B., 2 copperhead snakes.

Wolff, Steven, 2 hamsters.

Woodson, H. B., Arlington, Va., 2 sparrow hawks.

Work, Fred A., Alexandria, Va., alligator.

Workman, Mrs. Ira, Crestview, Md., opossum.

Worthington, Sandra, Takoma Park, Md., chicken.

Wright, R. T., Chevy Chase, Md., rabbit.

Wyckoff, William, Arlington, Va., ring-necked pheasant.

PURCHASES AND EXCHANGES

Outstanding animals obtained by purchase or exchange were:

A pair of rare flat-tailed otters (*Pteronura brasiliense*) of Brazil. These have thrived and made a remarkable growth. They are still youngsters, but the larger one of the two is now about the size of the big North American river otters. They have peculiarly flattened tails that look like oars. The Zoo has previously had only two small young ones, which did not survive.

Four king penguins (*Aptenodytes patagonica*) were purchased and three others were deposited for a few days by the dealer. These are slightly smaller than emperor penguins but because of the rich golden color on the upper breast they are even more beautiful than the emperors. These are the first king penguins in the collection since 1947.

Through exchange with Sir Edward Hallstrom of Sydney, Australia, a choice collection of Australian animals was obtained. Included were a pair of rat kangaroos (*Hypsiprymnodon moschatus*), which are marsupials about the size of a fox squirrel; four kinds of wallabies, which are small kangaroos; and six kinds of birds, all choice from an exhibition standpoint.

Through exchange with A. M. Greenhall of the Zoological Society of Trinidad, British West Indies, nine kinds of animals from the Island of Trinidad were obtained. These were highly desirable additions to the collections. Outstanding among them was an exceptionally large bushmaster snake (*Lachesis muta*).

Two of the extremely rare Allen's monkeys (*Allenopithecus nigroviridis*) were received. Only two of these had been in captivity, in England, prior to the spring of 1953, when the Zoo obtained two of them in May of that year. A few have since been brought to this country.

Another interesting accession was a young female hippopotamus (*Hippopotamus amphibius*) about 3 years old and weighing 865 pounds when it was received on June 29, 1955. It is hoped that she will grow and produce young. The Zoo has benefited greatly over the years from the exchange of young hippos born here for other animals needed in the collection and not otherwise obtainable.

During the year there have been received from J. D. Handman, of Nyasaland, East Africa, several shipments that have been particularly desirable accessions. By getting the animals directly from the collector, many not ordinarily available through animal dealers have been obtained.

The following were also obtained by purchase:

Twenty-five African mammals, birds, and reptiles from the Kenya region in Africa. Outstanding among these were two giant Aldabra turtles (*Testudo elephantina*) of stock that is now thriving in Africa

where they were introduced from Aldabra Island in the Indian Ocean. There was also a black-backed jackal (*Canis mesomelas*), the first that has come to this collection since 1924.

Two beautiful examples of the red uakari monkeys (*Cacajao rubicundus*). These monkeys are rare in collections. Their long red hair and brilliant red faces make them outstanding exhibit animals.

Twelve pygmy marmosets (*Cebuella pygmaea*). Two have been born in the group and are thriving. Until the last year or two these marmosets were very rare in collections, but apparently the region inhabited by them is now being drawn upon by animal dealers.

Two Philippine Islands monkey-eating eagles (*Pithecophaga jeffreyi*). These large remarkable eagles are rare in the wild and in captivity. The national collection has previously had only one.

Two young Asiatic tapirs (*Acrocodia indica*).

A fine specimen of white-handed gibbon (*Hylobates lar*).

A tame serval cat (*Felis serval*) of Africa, the first of its kind the Zoo has had for many years. It is a cat of remarkable appearance, with very long ears and fairly long legs.

A galago (*Galago crassicaudatus*) from an African contact. This is one of the large galagos, a nocturnal primate that bears but little resemblance to the monkeys.

Through exchange two young ostriches (*Struthio camelus*), a female mouflon (*Ovis musimon*), and a tahr (*Hemitragus jemlahicus*) were received.

Other accessions were: Rare and beautiful birds of the parrot group—Finsch's parrot (*Amazona finschi*) of South America, Rosella parakeet (*Platycercus eximus*) from Australia, and rainbow parakeet (*Trichoglossus moluccanus*) from Australia, the last being the first of the kind in the collection.

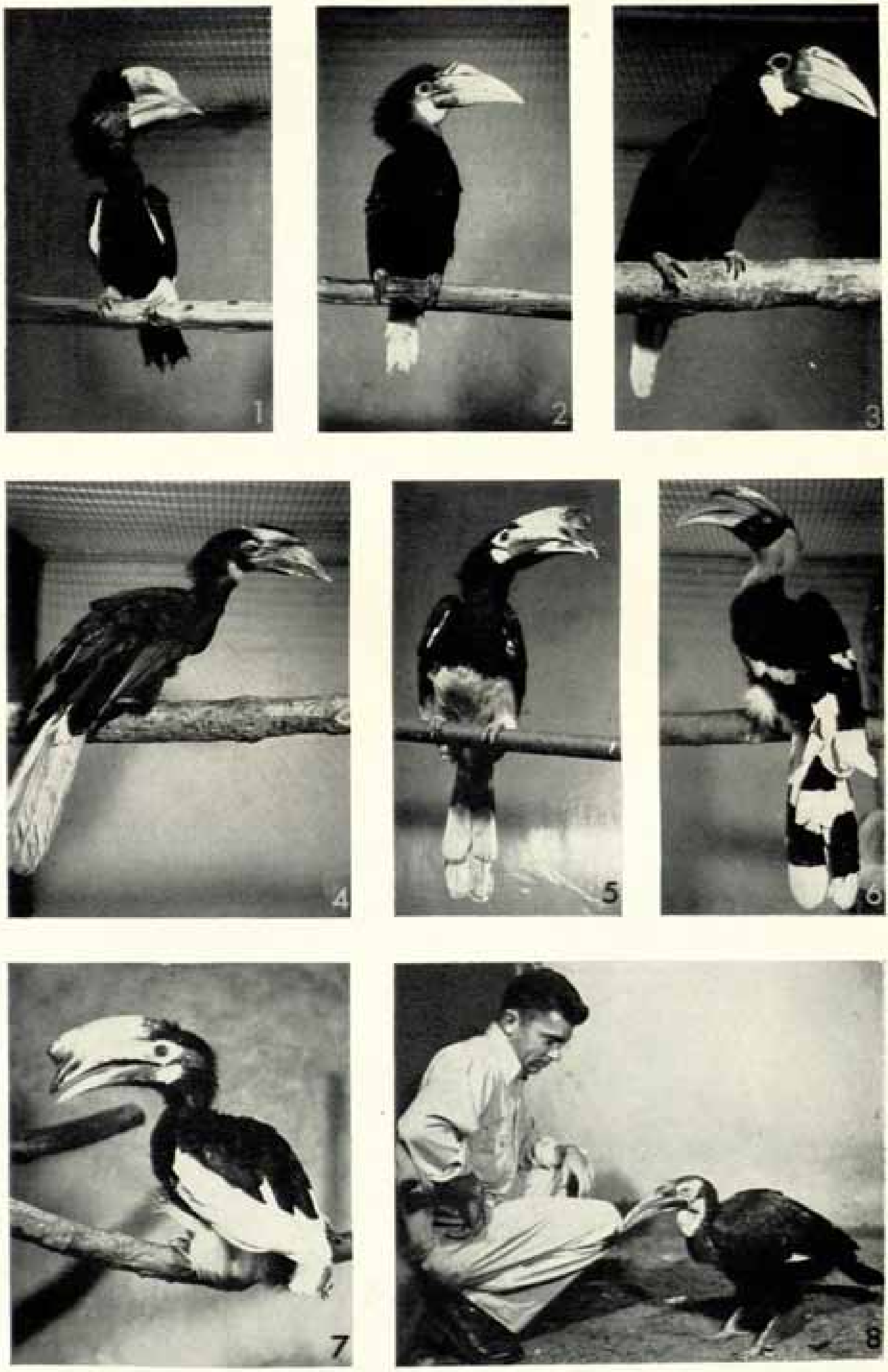
A tawny frogmouth (*Podargus strigoides*), an Australian bird that looks like a gigantic light-colored whip-poor-will. The peculiar form and pose of this bird is a never-ending source of wonder and interest to visitors.

Two concave-casqued hornbills (*Buceros bicornis*). These are large showy Asiatic birds which, with other specimens in the collection, give a good idea of the remarkable forms attained by this group of birds.

A white phase of the peafowl (*Pavo cristatus*). It is many years since the Zoo had one of these showy birds, and although it is not particularly rare, it is an interesting exhibit because it is so beautiful.

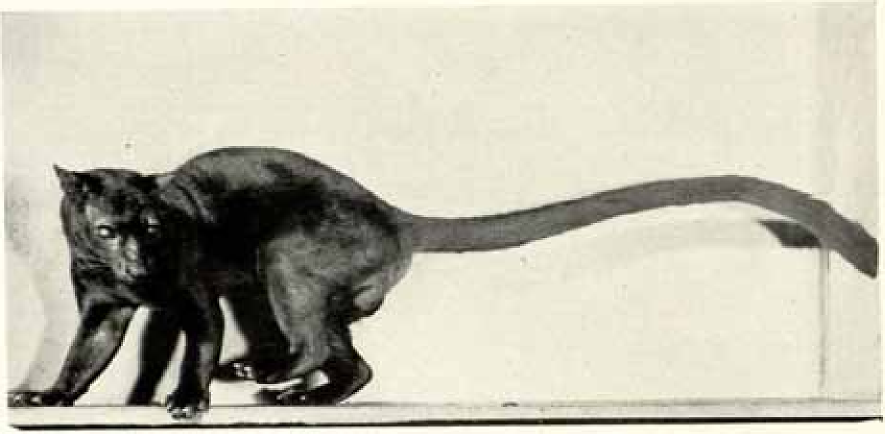
BIRTHS AND HATCHINGS

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 outstanding interest to the



Eight species of hornbills on exhibition in the National Zoological Park simultaneously: 1, Black-and-white hornbill (*Bycanistes subcylindricus*); 2, Malayan hornbill (*Aceros undulatus*); 3, wreathed hornbill (*Aceros plicatus*); 4, Philippine hornbill (*Buceros hydrocorax*); 5, Malabar hornbill (*Anthracoceros malabaricus*); 6, concave-casqued hornbill (*Buceros bicornis*); 7, black-and-white casqued hornbill (*Anthracoceros coronatus*); 8, Abyssinian ground hornbill (*Bucorvus abyssinicus*). (Photographs by Ernest P. Walker.)

Left, Masked Saki monkey (*Pithecia pithecia*) exhibited in National Zoological Park. This monkey is uncommon in collections mainly because it does not thrive in captivity. *Right*, Goeldi's marmoset (*Callimico goeldii*). Only a few specimens, from widely scattered points at the headwaters of the Amazon River, were known to the scientific world prior to 1954, but since then several have been brought into the markets. (Photographs by Ernest P. Walker.)



1. Foussa (*Cryptoprocta ferox*), a Madagascar animal that is related to the civet and is extremely rare in collections. This example is the first that has been exhibited in the National Zoological Park.

2. Branick's paca (*Dinomys branickii*) in National Zoological Park, an extremely rare rodent that has been exhibited in zoos on only a few occasions. Inhabits the mountains of central Peru. (Photographs by Ernest P. Walker.)

public, and are valuable as additions to the group, or for exchange. Outstanding among the births at the Zoo were the following:

A female gaur (*Bibos gaurus*). These magnificent wild cattle are of such rarity in collections that very advantageous terms can be obtained in exchange for those in excess of the Zoo's needs.

A female Grant's zebra (*Equus burchelli bohmi*). It is an attractive youngster and a valuable addition to the wild horse group.

A DeBrazza's guenon (*Cercopithecus neglectus*), a moustache monkey (*Cercopithecus cephus*), and two Barbary apes (*Macaca sylvanus*), all of them thriving.

The pygmy hippopotamus (*Choeropsis liberiensis*) produced one young during the year. The baby (female), born January 30, 1955, to Matilda, weighed 15 pounds and was the mother's ninth child. This is the sixteenth produced in the National Zoological Park.

Three more bear cubs (2 females and 1 male) were born on January 1, 1955, to one of the pairs of hybrids. These are a cross between an Alaskan brown bear mother (*Ursus middendorffi*) and a polar bear father (*Thalarctos maritimus*). They regularly produce young, but so far only one, now 5½ years old, has survived.

The herd of Chinese water deer (*Hydropotes inermis*) continues to multiply in a gratifying manner, sometimes producing as many as four at a time. The mortality of the young is rather high, but in spite of this the herd increases rapidly.

One of the group of pygmy marmosets (*Cebuella pygmaea*) gave birth to two young which have grown rapidly. Until the past year or two, these marmosets have been rare in captivity and have generally not done well, but this group is doing well.

A water civet (*Atilax paludinosus*) was born February 28, 1955, to the pair obtained August 19, 1953. It is thriving and growing rapidly.

Three crested screamers (*Chauna torquata*) were hatched. They are South American birds about the size of a large chicken but are related to the ducks.

Following is a complete list of the births and hatchings:

MAMMALS

Scientific name	*Common name*	*Number*
Ammotragus lervia	Aoudad, or Barbary sheep	5
Atilax paludinosus	Water civet	1
Bibos gaurus	Gaur	2
Bos taurus	British Park cattle	2
	West Highland cattle	2
Bubalus bubalis	Water buffalo	1
Capra hircus	Common goat	7
Cebuella pygmaea	Pygmy marmosets	2
Cercopithecus cephus	Moustache monkey	1
Cercopithecus neglectus	DeBrazza's guenon	1

Scientific name	Common name	Number
Cervus elaphus	Red deer	1
Choeropsis liberiensis	Pygmy hippopotamus	1
Choloepus didactylus	Two-toed sloth	2
Cuniculus paca	Paca	1
Dama dama	Brown fallow deer	3
	White fallow deer	1
Equus burchelli bohmi	Grant's zebra	1
Felis leo	Lion	8
Giraffa camelopardalis	Nubian giraffe	1
Hydropotes inermis	Chinese water deer	8
Hypsiprymnodon moschatus	Rat kangaroo	1
Hystrix galeata	African porcupine	2
Lama glama	Llama	2
Lama pacos	Alpaca	1
Leontocebus rosalia	Lion-headed marmoset	1
Macaca sylvanus	Barbary ape	2
Odocoileus costaricensis	Costa Rican deer	7
Odocoileus virginianus	Virginia deer	2
Ovis musimon	Mouflon	1
Phloeomys cumingi	Slender-tailed cloud rat	2
Poephagus grunniens	Yak	1
Sika nippon	Sika deer	1
Thalarctos maritimus × *Ursus middendorffi*	Hybrid bear (2d generation)	3

BIRDS

Scientific name	Common name	Number
Anas platyrhynchos	Mallard duck	38
Branta canadensis	Canada goose	9
Cairina moschata	Muscovy duck	3
Chauna torquata	Crested screamer	3
Gallus gallus	Fighting fowl	2
	Red jungle fowl	2
Larus novaehollandiae	Silver gull	2
Melopsittacus undulatus	Grass parakeet	14
Padda oryzivora	Java sparrow	24
Pavo cristatus	Peafowl	7
Spheniscus humboldti	Humboldt's penguin	2
Streptopelia decaocto	Ring-necked dove	8
Taeniopygia castanotis	Zebra finch	27

REPTILES

Scientific name	Common name	Number
Ancistrodon mokeson	Copperhead snake	2
Ancistrodon piscivorus	Cottonmouth moccasin snake	4
Chameleon dilepis	African chameleon	6
Epicrates cenchria	Rainbow boa	2
Natrix cyclopion	Green water snake	14
Natrix sipedon	Water snake	11
Natrix septemvittata	Queen snake	10
Scincus officinalis	Egyptian sand skinks	13

PROBLEMS

One of the most challenging of Zoo problems is caring for new animals or those that have not generally thrived in captivity under methods used before. This is particularly difficult with penguins. They are kept in a glass-fronted refrigerated room 22 by 13 feet under conditions suitable for these birds from the far south. Several different kinds have been kept successfully and even emperor penguins have been kept as long as six years. However, they are especially susceptible to aspergillosis, a fungus growth that develops in the respiratory tract and even progresses into other portions of the body. Prior to the receipt of the king and emperor penguins, the cage they were to occupy was given a thorough cleaning, and after their arrival improvements were made to better their environment. For the most part, these consisted of lowering the temperature, reducing the humidity, and providing more perfect filtering of the incoming air. In spite of all efforts, however, only one emperor penguin was living on June 30. The king penguins, which were received shortly before the arrival of the emperor and occupy the same cage, are still thriving.

Since the problem is of far more than academic interest, it might be well to point out that the *Aspergillus* spores are known to exist in soil and are probably of very wide distribution. Under some conditions chickens, turkeys, and ducks are subject to aspergillosis to such an extent that raising them is a difficult problem, and diseases somewhat similar occasionally occur in humans. Therefore, what is learned in efforts to control aspergillosis in penguins may be of use in solving the problem of control of the disease in domestic fowls and human beings.

The flat-tailed otters (*Pteronura brasiliense*) are so rare in captivity that every possible effort was made to insure their survival. Since they are animals of the warm waters of the Amazon, a special installation to fill their tank with water at an accurately controlled temperature of 80° was provided, as were facilities for them to dry themselves quickly when coming out of the water so that they would not become chilled. They are making splendid growth and because of their great activity are first-class entertainers of the public.

MAINTENANCE AND IMPROVEMENTS

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 makes it necessary 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 must cooperate with the keeper force and at all times exercise the utmost care that nothing is done that will injure the animals, the public, or themselves.

Because of inadequate funds, maintenance and repair work for the year was limited to that which was most urgently needed.

A new roof was put on the lion house, and new skylights were constructed and installed. Much of the material used in the skylights had been salvaged, and some had been obtained as surplus from the armed services reduction in stock.

At the end of the fiscal year reroofing of the antelope building was well under way.

Two frame buildings used for emergency housing and as winter quarters for some animals were given an outside sheathing as protection against the weather and to obtain some degree of added insulation.

Throughout the year, and particularly during the warm weather, the entire heating plant is given a thorough overhauling to make certain that it is in first-class condition and to reduce to a minimum the hazard of heating failure. This is an extensive job for the Zoo's limited maintenance force.

Ventilation systems and refrigeration plants for the penguins and for the preservation of food are all watched carefully and maintained in the best possible condition to prevent breakdown.

Working at odd times between other urgent maintenance jobs, the mechanical force has made a remarkable transformation at one end of the monkey house. Eight old, small, poorly lighted cages were removed and the platform on which they stood enclosed with glass and wire fabric. Heavy tree limbs were added so that there is now an excellent large indoor cage for miscellaneous monkeys. At the close of the fiscal year there were 16 individuals in this cage getting along nicely and providing outstanding entertainment, as well as giving people an opportunity to study their movements and ways of life in the wild. Living together in this manner is highly beneficial to the monkeys as it stimulates much-needed exercise.

No other major repair work could be attempted during the year.

As pointed out in previous reports, the funds now available for operating the Zoo are not adequate to keep pace with deterioration of materials in the buildings and other structures that are now reaching such an age that an increasing amount of repair work must be done if they are to be kept in use. Six enclosures in the ravine above the sea lions have had to be abandoned because of inability to keep them in repair.

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 people 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, with the result that the Zoo has been criticized by correspondents and the press for the condition of the grounds.

The lawns, shrubs, and trees cannot be kept in as 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.

During the year Congress provided money for the employment of a veterinarian but the position had not been filled at the end of the year. However, a veterinarian has now been appointed and will be on duty early in the fiscal year 1956.

Temporary policemen were employed this year to assist the regular police during days of heaviest attendance or when the force was short-handed. This is a satisfactory arrangement and much more economical than employing additional full-time policemen when the permanent personnel now authorized is adequate for a large proportion of the time.

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.

NEW BUILDING

The rest-room building, with headquarters for the police and office and storage space for the gardener, should be finished during the fiscal year 1956. The building was designed by the Department of Buildings and Grounds of the Government of the District of Columbia in accordance with provisions of law. Inasmuch as bids under the original specifications exceeded the appropriations by about $30,000, it was necessary to prepare new plans and specifications, omitting about $30,000 worth of desirable but least-needed features, and to readvertise. This delayed final letting of the contract until April 19, 1955.

VISITORS

The estimated number of visitors to the Zoo was 3,476,584, which was 139,636 less than for the year 1954.

Since the daily attendance record of visitors is based entirely upon estimates rather than actual counts, it is entirely possible that there was not really a decline in the total. In spite of possible errors, it is obvious that the attendance is regularly between 3 and 3½ million visitors each year.

By actual count, 10,674 visitors entered the reptile house on Sunday, September 5, 1954, and 9,313 on Monday, September 6. The estimated total attendance for the Park on those dates was 45,000 and 40,000, respectively. These figures are typical of holiday and weekend attendance.

Estimated number of visitors for fiscal year 1955

July (1954)	484,000	February	101,750
August	550,000	March	197,500
September	328,000	April	468,384
October	277,200	May	403,500
November	143,400	June	336,500
December	58,800		
January (1955)	127,550	Total	3,476,584

Groups came to the Zoo from schools in Canada, Colombia, South America, and 31 States, some as far away as Maine, Florida, Mississippi, and Minnesota.

Number of groups from schools

Locality	Number of groups	Number in groups	Locality	Number of groups	Number in groups
Alabama	22	894	Michigan	9	523
Arkansas	2	43	Minnesota	4	155
Canada	1	22	Mississippi	8	357
Colombia, S. A.	1	37	New Hampshire	2	112
Connecticut	16	798	New Jersey	10	574
Delaware	8	284	New York	103	6,759
District of Columbia	138	7,097	North Carolina	256	10,433
Florida	11	1,378	Ohio	48	2,244
Georgia	66	5,595	Pennsylvania	241	12,573
Illinois	4	122	South Carolina	84	3,503
Indiana	8	528	Tennessee	73	3,412
Iowa	1	27	Virginia	566	33,010
Kansas	1	30	West Virginia	48	3,766
Kentucky	7	321	Wisconsin	3	257
Maine	20	900			
Maryland	549	34,294	Total	2,319	130,458
Massachusetts	10	470			

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	27.3	Ohio	1.6
Virginia	22.7	West Virginia	1.2
District of Columbia	21.5	Massachusetts	1.1
Pennsylvania	4.6	Florida	0.9
New York	2.7	Illinois	0.7
North Carolina	2.1	California	0.7
New Jersey	1.7	South Carolina	0.6

The cars that made up the remaining 10.6 percent came from every one of the remaining States, as well as from Alaska, Austria, British Columbia, Canada, Canal Zone, Cuba, England, Germany, Hawaii, Japan, Newfoundland, Nova Scotia, Okinawa, and Puerto Rico.

On the days of even small attendance there are cars parked in the Zoo from at least 15 States, Territories, the 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.

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.

Particular thanks are due C. W. Phillips, Paul R. Achenbach, and R. S. Dill, of the National Bureau of Standards, for their advice and assistance in bringing about the best possible conditions in the refrigerated penguin room.

Dr. Willard H. Eyestone, veterinary pathologist of the Cancer Division of the National Institutes of Health, Bethesda, Md., gave much valuable advice on matters pertaining to the welfare of the animals, and made every effort to help save the emperor penguins. He and other members of the National Institutes of Health isolated the organism *Aspergillus* and established pure cultures of it, and are now trying to find a chemical or bacterial agent to combat the fungus.

Dr. Eyestone also continued his own project of making autopsies on animals that died in the Zoo, in order to obtain information regarding cancer and other diseases affecting human beings.

Special acknowledgment is due to the United States Dispatch Agent in New York City, Howard Fyfe, an officer of the State De-

partment, 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.

For several years past the Zoo has been given, or has been able to buy at greatly reduced prices, considerable quantities of food materials such as rice, flour, beans, and canned and packaged foods that had been condemned by the courts as unsuitable for human consumption. But this year almost no material of this type was made available and the lack has been reflected in the additional expenditures necessary for the purchase of food for the animals.

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 food 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 their experiments. These are a highly desirable addition to the diet of many animals.

Samuel M. Poiley, associate chief of the Animal Production Section, National Institutes of Health, continued to supply surplus laboratory animals and some that were raised for laboratory purposes, which were desirable additions to the exhibition collection.

NEEDS OF THE ZOO

Replacement of antiquated structures that have long since ceased to be suitable for the purposes for which they are used is still the principal need of the Zoo. Urgently required are:

A building to house antelopes and other medium-sized hoofed animals that require a heated building.

A new administration building to replace the 150-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 fireproof service building for receiving shipments of animals, quarantining them, and caring for those in ill health or those that cannot be placed on exhibition.

A new ventilating system for the bird house.

Lesser items of equipment that are needed are a vacuum pump for more efficient and economical operation of the heating system in the reptile house; a band saw to replace one that is more than 40 years old; and an air compressor for general use about the Park.

The enclosures and pools for beavers, otters, seals, and nutrias, in the ravine, need to be reconstructed. Owing to lack of funds for up-

keep, and consequent deterioration, this area has become unsightly and inadequate for the proper care and exhibition of these animals.

In addition to new buildings, new paddocks are needed. Over the years, space for the exhibition of such animals as deer, sheep, goats, and other hoofed animals has been so curtailed that the collection no longer contains the proper assortment of these attractive and valuable animals. This has been brought about by the natural deterioration of materials, making some of the paddocks no longer usable; elimination of some paddocks for the construction of buildings on the sites; and abandonment of some paddocks that were in undesirable locations. Further abandonment of some paddocks is imminent to make way for parking space for cars and buses to offset losses in such space that will occur if the Rock Creek–Potomac Parkway is extended through the Zoo property on the east side of the creek. Construction of ten new paddocks and rehabilitation of six old ones are urgently needed.

Provision of new parking space necessitates grading and surfacing about 14,000 square yards of land in several different locations.

The establishment of parking space near the mechanical shops will make unavailable an area that has been used for the storage of a reserve pile of coal. As this location has never been an entirely satisfactory one, it would be highly desirable at this time to build an addition to the regular coal bunker to increase the capacity and eliminate the need for maintaining a separate reserve pile.

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.

One additional general mechanic is needed to assist the maintenance personnel in what has hitherto been a losing race in trying to keep pace with natural deterioration in the structures. The newest of the exhibition buildings are 18 years old, the reptile house is 24 years old, and the bird house is 27 years old. The minimum of maintenance has fully occupied the mechanical force, mainly on the larger structures, so that there has been almost no opportunity to take care of the lesser structures such as paddocks and outside cages, with the result that an increasing number of these are unusable.

Two additional permanent laborers are needed for proper maintenance, removal of dead or fallen tree limbs and other safety hazards, and repair of walks, guard rails, and other structures, for the protection of the public.

To comply with the requirements of keeping property and inventory records, in accordance with the program laid down by the General

Services Administration, by authority of the Federal Property and Administrative Services Act of 1949 (Public Law 152, 81st Congress, approved June 30, 1949), General Regulation 100 of the General Accounting Office, and Budget-Treasury Regulation No. 1, there is need for three additional clerks.

STATUS OF THE COLLECTION

Class	Species or subspecies	Individuals
Mammals	242	836
Birds	302	1,383
Reptiles	146	701
Amphibians	26	95
Fish	25	292
Arachnids	1	3
Insects	1	100
Total	743	3,410

Animals on hand July 1, 1954	2,980
Accessions during the year	2,347
Total number of animals in collection during the year	5,327
Removals for various reasons such as death, exchanges, return of animals on deposit, etc.[1]	1,917
In collection on June 30, 1955	3,410

Respectfully submitted.

W. M. Mann, *Director.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

[1] Many small creatures are given to the Zoo 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 925 individuals of 27 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.

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, 1955.

SCIENTISTS AND THEIR STUDIES

During the fiscal year 43 scientists came to Barro Colorado Island to do research in their respective fields. This is 21 more than last year. The following list does not include the large number who came to get acquainted with the island but who could spend only a day or two there.

Investigator	*Principal interest or special study*
Abegg, Dr. Roland, University of Louisiana.	Observational studies of birds and plants.
Ansley, Dr. Hudson, Johns Hopkins University.	Collection and preservation of certain pentatomids, scutigerids, and related forms for spermatogenesis studies.
Barnard, Dr. J. Laurens, Allan Hancock Foundation.	Fresh-water amphipods.
Chickering, Dr. A. M., Albion College, Michigan.	Continuation of intensive study of the spider fauna.
Clark, Dr. Walter, Eastman Kodak Research Laboratory, Rochester, N. Y.	Evaluation of extensive corrosion and deterioration tests.
Dawson, Dr. J. Wm., New Zealand to California.	To know the richness of the island's flora and plant ecology.
Eisenmann, Dr. Eugene, New York City.	Continuation of studies of birds of the island.
Enders, Dr. Robert K., Swarthmore College.	Survey of mammalian fauna and preservation of material for histological and embryological studies of agouti, *Procchimys*, and sloth.
Freund, Rudolf, Life Magazine.	Photography of army ant life for extensive paper on these, and collection of much new data and specimens for future articles.
Grégoire, Dr. Ch., L'Université de Liège.	Mechanism of coalgulation of insect haemolymph.
Grégoire, Dr. Jenny Legasse, Brussels, Belgium.	Collection of insects for Dr. Grégoire's studies.
Haig, Miss Janet, Allan Hancock Foundation.	To study the biota for future trips.
Harrell, Dr. Byron E., University of Minnesota.	Natural areas in middle America, distributional studies of birds in cloud forests, ecology of birds of neotropical rain forest; behavior of *Peripatus*.

Investigator	*Principal interest or special study*
Henry, Mr. and Mrs. Thomas R., Smithsonian Institution.	To collect more material on plants and animals for press releases.
Huber, Hugh, Tubingen, Germany.	Naturalistic studies in association with Dr. Ansley.
Humphrey, Richard, Albion College, Michigan.	Assisting Dr. Chickering with his spider studies.
Linford, Mr. and Mrs. James B., Oakland, Calif.	Studies of bird behavior and nesting.
Lichtwardt, Dr. Robert W., University of Illinois.	Study of fungi of the *Eccrinales* living within the hind guts or on the exoskeleton of various arthropods.
Lichtwardt, Mrs. Robert W., University of Illinois.	Collection of host material of the *Eccrinales* order of fungi and related forms.
Littau, Dr. Alan S., Barnard College.	The ecology of fungus-growing ants, and photography.
Littau, Dr. Virginea, Barnard College.	Ecology of fungus-growing ants and related species.
Lloyd, Ivan, Eastman Kodak Tropical Research Laboratory, Panama City.	Deterioration and corrosion studies.
Lundy, Wm. E., Assistant Treasurer, Panama Canal.	Further biological and ecological studies of mammals, birds, and insects.
McEvoy, J. P., Pleasantville, N. Y.	Material for The Readers' Digest.
Mitchener, Dr. C. D., University of Kansas.	Biology of soil-nesting halictine bees.
Morris, Robert C., U. S. Department of Agriculture.	Annual inspection of the termite tests begun in 1923 and his extensive new test areas.
Olivares, Tito, Eastman Tropical Research Laboratory, Panama City.	Biological aspects of corrosion and deterioration.
Patrick, Dr. Ruth, Academy of Natural Sciences of Philadelphia.	Appraisal of the islands limnological possibilities.
Pippin, Miss Mary Ellen, Allan Hancock Foundation.	Plants and animals for future studies.
Rettenmeyer, Carl, University of Kansas.	Associate of Dr. Schneirla and aid to Mr. Freund; observations and collections of bees and social wasps.
Roberts, Dr. H. Radclyffe, Academy of Natural Sciences of Philadelphia.	A revisit to study the surrounding forest improvements.
Schneirla, Dr. T. C., American Museum of Natural History.	Continuation of his studies of the army ants and preparation of manuscripts and his forthcoming book on army ants.
Schrader, Dr. Franz, Columbia University.	Continuation of extensive cytological studies.
Schrader, Dr. Sally Hughes, Columbia University.	Further cytological studies; research on chromozones and preparation of preserved material for further study.

Investigator	*Principal interest or special study*
Schubert, Dr. Bernice, U. S. Department of Agriculture.	Survey of plants of pharmaceutical importance for more intensive future studies.
Soper, Dr. Cleveland C., Eastman Kodak Tropical Research Laboratory, Panama City.	Direction of deterioration and corrosion studies with particular emphasis on photographic equipment.
Swift, Paul, Eastman Kodak Tropical Research Laboratory, Panama City.	Physical and chemical studies related to corrosion and deterioration.
Weber, Neal A., Swarthmore College.	Cultivation of the fungi cultivated by fungus-growing ants.
Wetmore, Dr. and Mrs. Alexander, Smithsonian Institution.	Inspection of the physical plant and continuation of his bird studies.
Wislocki, Louis, Swarthmore College.	Survey of mammal fauna and collection of tissues for histological and embryological studies.

VISITORS

In all, 636 local visitors spent at least a day on the island, and some stayed several days. All were most enthusiastic. Visitors and scientists alike were most interested in taking pictures, especially in color. Scientists are finding photographs increasingly valuable aids in their research and teaching. It is unfortunate that the high cost of transportation still keeps many away or considerably curtails their stay. It is hoped that means can be found to hold seminars of 20 or so undergraduate students for about 3 months each year. Such a program has tremendous possibilities and is receiving careful consideration.

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 Manager of the Canal Zone Biological Area, Drawer C, Balboa, Canal Zone.

RAINFALL

In 1954, during the dry season (January through April) rains of 0.01 inch or more fell on 40 of the 120 days (94 hours), and amounted to only 5.84 inches, as compared to 12.83 inches during 1953.

During the wet season of 1954 (May through December) rains of 0.01 inch or more fell on 191 of the 245 days (724 hours) and amounted to 99.84 inches, as compared to 92.14 inches during 1953.

During 1954 rain fell on 21 days (818 hours), and averaged only 0.45 inch per day, almost 0.13 inch per hour.

March was the driest month (0.21 inch) and November the wettest (17.14 inches.) The wettest year of record (30 years) was 1935 with 143.42 inches, and the driest year of record was 1930 with only 76.57 inches.

The maximums 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; 24 hours, 10.48 inches.

TABLE 1.—*Annual rainfall, Barro Colorado Island*

Year	*Total inches*	*Station average*	*Year*	*Total inches*	*Station average*
1925	104. 37	-------	1940	86. 51	109. 43
1926	118. 22	113. 56	1941	91. 82	108. 41
1927	116. 36	114. 68	1942	111. 10	108. 55
1928	101. 52	111. 35	1943	120. 29	109. 20
1929	87. 84	106. 56	1944	111. 96	109. 30
1930	76. 57	101. 51	1945	120. 42	109. 84
1931	123. 30	104. 69	1946	87. 38	108. 81
1932	113. 52	105. 76	1947	77. 92	107. 49
1933	101. 73	105. 32	1948	83. 16	106. 43
1934	122. 42	107. 04	1949	114. 86	106. 76
1935	143. 42	110. 35	1950	114. 51	107. 07
1936	93. 88	108. 98	1951	112. 72	107. 28
1937	124. 13	110. 12	1952	97. 68	106. 94
1938	117. 09	110. 62	1953	104. 97	106. 87
1939	115. 47	110. 94	1954	105. 68	106. 82

TABLE 2.—*Comparison of 1953 and 1954 rainfall, Barro Colorado Island (inches)*

Month	Total		Station average	Years of record	Excess or deficiency	Accumulated excess or deficiency
	1953	1954				
January	4. 30	1. 24	1. 84	29	−0. 60	−0. 60
February	. 69	1. 29	1. 25	29	+0. 04	−0. 56
March	1. 20	0. 21	1. 16	29	−0. 95	−1. 51
April	6. 64	3. 10	3. 16	30	−0. 06	−1. 57
May	9. 21	11. 09	10. 84	30	+0. 25	−1. 32
June	3. 81	12. 06	11. 17	30	+0. 89	−0. 43
July	15. 93	15. 05	11. 56	30	+3. 49	+3. 06
August	15. 60	12. 92	12. 30	30	+0. 62	+3. 68
September	5. 70	11. 19	9. 95	30	+1. 24	+4. 92
October	18. 27	13. 14	13. 66	30	−0. 52	+4. 40
November	19. 28	17. 14	19. 04	30	−1. 90	+2. 50
December	4. 34	7. 25	10. 89	30	−3. 64	−1. 14
Year	104. 97	105. 68	106. 82	-------	-------	−1. 14
Dry season	12. 83	5. 84	7. 41	-------	-------	−1. 57
Wet season	92. 14	99. 84	99. 41	-------	-------	−0. 43

BUILDINGS, EQUIPMENT, AND IMPROVEMENTS

The 110–220-volt, 60-cycle overhead electrical installation was completed.

The electrical installation in the new building is about half completed. The necessary pipes, sinks, and valves have been obtained and six electric dehumidifiers purchased. New metal shelving was purchased for two of the rooms on the upper floor, which will house the library and in which humidity control is readily possible, and a supply of Dexion slotted angles was purchased for additional shelving, laboratory tables, and benches. Metal is being used wherever possible instead of wood, which is so susceptible to termite infestation.

All the old metal beds were repainted, and four comfortable new beds were purchased for the two large laboratory-dormitory rooms

on the lower floor of the new building. This ground floor has a large dark room, four toilets, and shower baths with hot water. Much of the material for the dark room is on hand for early installation.

The large laboratory building, built in 1923, is in good condition, though a few changes are contemplated which will add to the facilities it offers.

The kitchen was repainted inside, and a new 66-inch white enameled cabinet sink was ordered to replace the stained and corroded iron sink. An electric water heater was purchased and will be installed shortly.

Two of the cottages were repainted and the screening repaired and are now in very good condition. Corrugated iron sheets were purchased to replace the roof on the Haskins building. The repairs made to the Chapman house, plus liberal use of coal-tar creosote, should make this important building serviceable for several years to come. The three other cottages are serving their purpose well, and the few relatively inexpensive changes to be made will enhance their usefulness.

Of the trail-end houses, only the Drayton and Fuertes are in good shape. The one at the end of Zetek trail could be used if repaired. Neither the Bangs house nor the one at the end of Barbour trail is usable.

A 14-foot metal boat and a 10-horsepower Johnson outboard motor were purchased to permit more effective patrolling of the island and in which it will be possible to reach Frijoles faster in emergencies. A new 102-horsepower Gray-Marine Express engine was purchased and installed in the U. S. *Snook* to replace the worn-out Red-Wing engine, and glass windows were made and installed, replacing the inadequate and unserviceable canvas curtains. The U. S. *Moon* is still serviceable.

A railing made of galvanized iron pipe was installed along the north side of the long line of steps from the dock to the laboratory levels. This safety measure has long been needed.

MOST URGENT NEEDS

A new water tank is very badly needed, for the one fed from the roof of the old laboratory building is of coal-tar, creosote-treated timber and may collapse at any time. The use of concrete is not feasible because of the stratigraphy of the area in which it is located. A new tank of California redwood should be purchased without delay. It would cost less than concrete and would last long enough to be economical.

Two of the metal septic tanks, which were installed at least 15 years ago, have rusted through and are a menace. They should be replaced with concrete tanks as soon as possible.

The laboratory storerooms in the new building, which will also house the library, herbarium, and species index, should be stocked with chemicals, preservatives, laboratory glassware, and other necessary equipment.

A separate dry room should be built on the ground floor of the new building to provide a storage area free from mold for visiting scientists to store their cameras, clothing, and luggage. A similar dry room is needed in the old large building for the storage of such items as linens, towels, and bedding to keep them free from the musty odors of the humid tropics; and dry closets should be installed on the upper floor of this building and in the old Z-M-A cottage, the old Chichi cottage, the Barbour guest house, and the Chapman house.

Tables are needed for the additional laboratory rooms, the library, herbarium, and kitchen to replace the miscellaneous collection of odds and ends that have been serving as tables. These can be economically built of Dexion slotted angles and heavy plywood.

Repainting of the exteriors of all buildings is needed. Consideration is being given to making this a paint-test program to determine which paint gives the longest and most satisfactory service at the least cost.

Since electricity is now available 24 hours a day, 4 attic fans, 6 oscillating fans, and 2 window air-conditioning units should be installed in carefully chosen areas. These will help to reduce the interior temperatures and humidity of the laboratory buildings, and thus contribute to the comfort and efficiency of the scientists.

The 29-year-old building occupied by the three laborers is in a bad state of disrepair and must be rebuilt. Originally the U. S. Department of Agriculture used this building for long-term termite tests, and termite damage has contributed largely to its present unsatisfactory condition.

The dock at the island, though it has been extended each year because of silting from the Allee and Lutz streams, is already at an unsafe distance from the shore. Consideration is being given to the relocation of the dock on the south shore of laboratory bay where soil deposition is less likely to occur. A trail will have to be made from the dock to the landing and this will require the purchase of more Decauville track.

The engine of the U. S. *Moon*, which carried the heavy burden when the U. S. *Snook* was laid up for repairs, is still serviceable, but needs to be overhauled soon to prevent more extensive and costly repairs at a later date.

FINANCES

The rate for scientists and visitors for one-day visits is $3 per person. This provides for the launch trip from Frijoles to the island, a guide on the trail, noon meal, and launch trip back to Frijoles in

time for the evening train. Scientists from institutions that contribute to the support of the island through table subscriptions pay $4 per person for each full day; others pay $5 per person for each full day. The full-day rate provides for three consecutive meals and lodging, in addition to the two launch trips required to reach and leave the island.

The grant made by the National Science Foundation to the Smithsonian Institution for the Canal Zone Biological Area was received with sincere appreciation. These funds enabled the Institution to continue the operation of the island without interruption.

The following institutions continued their table subscriptions:

Eastman Kodak Company	$1,000
New York Zoological Society	300
American Museum of Natural History	300
Smithsonian Institution	300

[The Smithsonian Institution provides other funds as needed.]

Donations from the following are also gratefully acknowledged: E. G. Cherbonier, Dr. Eugene Eisenmann, Dr. Margaret Fulford, Dr. C. M. Goethe, Father J. L. Hartman, Robert M. Laughlin, Dr. Harold L. Pierson, James Reid, Dr. Herbert Schwartz, and Dr. G. C. Shattuck.

ACKNOWLEDGMENTS

Thanks are due to the Canal Zone Government, its Executive Secretary, the Customs and Immigration Divisions, the officials and employees of the Panama Railroad, and especially the Police Division; the Panama Canal Company, particularly its Dredging and Commissary Divisions and the Storehouses; and also Dr. Soper, Dr. Swift, and other staff members of the Eastman Kodak Tropical Research Laboratory, especially Dr. Soper. Without such generous and unfailing assistance, the Area could not function so successfully.

Respectfully submitted.

James Zetek, *Resident Manager.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

370930—56——10

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, 1955:

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 126,463 to the yearly total of 1,146,972, and the weight of the packages increased by 15,640 to 812,960 pounds. The average weight of the individual package decreased to 11.34 ounces, as compared to the 12.49-ounce average for the fiscal year 1954.

The total weight of the foreign packages is higher than that received in any year since 1939. The 63 cases received from the National Central Library, Taipei, Taiwan, China, partially accounts for the increase. This is the first shipment from China since the one received from the National Central Library (then at Nanking) in 1949.

The publications received from foreign sources for addresses 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	620,999		272,433	
Publications received in return for parliamentary documents		8,582		16,432
United States departmental documents sent abroad	243,628		175,893	
Publications received in return for departmental documents		8,455		21,306
Miscellaneous scientific and literary publications sent abroad	168,908		208,184	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		96,400		118,712
Total	1,033,535	113,437	656,510	156,450
Grand total	1,146,972		812,960	

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 2,836, or 730 less than for the previous year. Of these boxes 897 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 212,789.

There was allocated to the International Exchange Service for transportation $41,000. With this amount it was possible to effect the shipment of 800,308 pounds, which was 12,552 pounds less than the weight of publications received during the year. However, approximately 14,000 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 English and European ports were increased 15 percent in April, and the rates to Japanese, Philippine, and other eastern ports were increased 10 percent in May.

The total outgoing correspondence was 2,568 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.

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 a 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 105 (62 full and 43 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.[2]

PEIPING: National Library of Peiping.[1]

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.[3]

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.

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[1] Shipment suspended.

[2] Changed from National Central Library, Nanking.

[3] Name changed from Offentliche Wissenschaftliche Bibliothek, Berlin.

JAPAN: National Diet Library, Tokyo.[4]

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.[4]

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.[4]

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.

HIATI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS:

Biblioteca y Archivo Nacionales, Tegucigalpa.

Ministerio de Relaciones Exteriores, Tegucigalpa.

ICELAND: National Library, Reykjavik.

[4] Receives two sets.

INDIA:

BIHAR AND ORISSA: Revenue Department, Patna.

BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.

UNITED PROVINCES OF AGRA AND OUDH:

University of Allahabad, Allahabad.

Secretariat Library, Uttar Pradesh, Lucknow.

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: Chief Secretary to the Government of Punjab, Lahore.

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 92 copies of the Federal Register and 94 copies of the Congressional Record. This is an increase over the preceding year of 2 copies of the Federal Register and a decrease of 10 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 Congreso Nacional, Buenos Aires.

Biblioteca del Poder Judicial, Mendoza.[a]

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.[a]

WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

[a] Federal Register only.

BRAZIL:
 Biblioteca da Camera dos Deputados, Rio de Janeiro.
 Secretaria de Presidencia, Rio de Janeiro.[6]
 AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manâos.[6]
 BAHIA: Governador do Estado da Bahia, São Salvador.[6]
 ESPERITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.[6]
 RIO GRANDE DO SUL: Imprensa Oficial do Estado, Porto Alegre.
 SÃO PAULO: Imprensa Oficial do Estada, São Paulo.
 SERGIPE: Biblioteca Pública do Estado de Sergipe, Aracajú.[6]
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.[6]
 Taiwan Provincial Government, Taipei, Taiwan.
CUBA: Biblioteca del Capitolio, Habana.
 Biblioteca Pública Panamericana, Habana.[6]
 Biblioteca Martí Cámara de Representantes, Habana.
EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.[6]
EL SALVADOR: Library, National Assembly, San Salvador.
FRANCE:
 Bibliothèque Assemblée Nationale, Paris.
 Bibliothèque Conseil de la République, Paris.
 Library, Organization for European Economic Cooperation, Paris.[8]
 Publiques de l'Institut de Droit Comparé, Université de Paris, Paris.[6]
 Research Department, Council of Europe, Strasbourg.[6]
 Service de la Documentation Étrangère, Assemblée Nationale, Paris.[6]
GERMANY:
 Amerika-Institut der Universität München, München.[6]
 Archiv, Deutscher Bundesrat, Bonn.
 Bibliothek der Instituts für Weltwirtschaft an der Universität Kiel, Kiel-Wik.
 Bibliothek Hessischer Landtag, Wiesbaden.[6]
 Der Bayrische Landtag, Munich.[6, 7]
 Deutscher Bundesrat, Bonn.[6]
 Deutscher Bundestag, Bonn.[6]
 Hamburgisches Welt-Wirtschafts-Archiv, Hamburg.[6]
GOLD COAST: Chief Secretary's Office, Accra.[6]
GREAT BRITAIN:
 Department of Printed Books, British Museum, London.[6]
 House of Commons Library, London.[6]
 Printed Library of the Foreign Office, London.
 Royal Institute of International Affairs, London.[6]
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.

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[6] Congressional Record only.
[7] Three copies.
[8] Added during year.

INDIA:

Civil Secretariat Library, Lucknow, United Provinces.[c]

Indian Council of World Affairs, New Delhi.[c]

Jammu and Kashmir Constituent Assembly, Srinagar.[c]

Legislative Assembly, Government of Assam, Shillong.[c]

Legislative Assembly Library, Lucknow, United Provinces.

Legislative Assembly Library, Trivandrum.[c]

Madras State Legislature, Madras.[a, c]

Parliament Library, New Delhi.[c]

Servants of India Society, Poona.[c]

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.[c]

International Institute for the Unification of Private Law, Rome.[c]

JAPAN: Library of the National Diet, Tokyo.

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.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.[c]

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.[c]

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.[c]

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.[c]

PUEBLA: Secretaría General de Gobierno, Puebla.

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

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

SINALOA: Gobernador del Estado de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

MEXICO—Continued

TABASCO: Secretaría de Gobierno, Sessión 3a, Ramo de Prensa, Villahermosa.[8]

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.[8]

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

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NETHERLANDS: Koninklijke Bibliotheek, The Hague.[8]

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Library of the Norwegian Parliament, Oslo.

PAKISTAN: Punjab Legislative Assembly Department, Lahore.

PANAMA: Biblioteca Nacional, Panama City.[8]

PERU: Cámara de Diputados, Lima.

POLAND: Ministry of Justice, Warsaw.[8]

PORTUGAL: Secretaria de Assembla National, Lisbon.[8]

PORTUGUESE TIMOR: Repartição Central de Administração Civil, Dili.[8]

SWITZERLAND: Bibliothèque, Bureau International du Travail, Geneva.[8]

International Labor Office, Geneva.[5, 8]

Library, United Nations, Geneva.

UNION OF SOUTH AFRICA:

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

TRANSVAAL: State Library, Pretoria.

UNION OF SOVIET SOCIALIST REPUBLICS: Fundamental'niia Biblioteka Obschestvennykh Nauk, Moscow.[8]

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE SERVICES

Exchange publications for addresses in the countries listed below are forwarded by freight to the exchange services of those countries. Exchange publications for addresses in other countries are forwarded directly 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.[10]

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.

[8] Two copies.

[10] Changed from National Central Library, Nanking.

GERMANY (Western): Notgemeinschaft der Deutschen Wissenschaft, Bad Godesberg.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 83/84 Berwick Street, London, W. 1.[11]

HUNGARY: National Library, Széchényi, Budapest.

INDIA: Government Printing and Stationery, Bombay.

INDONESIA: Minister of Education, Djakarta.[12]

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.

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.

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[11] Between the United States and England only.

[12] Changed from Department of Cultural Affairs and Education, Djakarta.

Report on the National Gallery of Art

SIR: I have the honor to submit, on behalf of the Board of Trustees, the eighteenth annual report of the National Gallery of Art, for the fiscal year ended June 30, 1955. This report is made pursuant to the provisions of section 5 (d) of Public Resolution No. 14, Seventy-fifth Congress, first session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION

The statutory members of the Board of Trustees of the National Gallery of Art are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio. The five general trustees continuing in office during the fiscal year ended June 30, 1955, were Samuel H. Kress, Ferdinand Lammot Belin, Duncan Phillips, Chester Dale, and Paul Mellon. The Board held its annual meeting on May 3, 1955. Samuel H. Kress was reelected President and Ferdinand Lammot Belin Vice President, to serve for the ensuing year.

All the executive officers of the Gallery continued in office during the year. The executive officers of the Gallery as of June 30, 1955, are:

Huntington Cairns, Secretary-Treasurer.
David E. Finley, Director.
Ernest R. Feidler, Administrator.
Huntington Cairns, General Counsel.
John Walker, Chief Curator.
Macgill James, Assistant Director.

The three standing committees of the Board, as constituted at the annual meeting May 3, 1955, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Earl Warren, Chairman.
Samuel H. Kress, 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.
Samuel H. Kress.
Ferdinand Lammot Belin.
Paul Mellon.

ACQUISITIONS COMMITTEE

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

PERSONNEL

On June 30, 1955, full-time Government employees on the staff of the National Gallery of Art numbered 301, as compared with 306 employees as of June 30, 1954. The United States Civil Service regulations govern the appointment of employees paid from appropriated public funds.

APPROPRIATIONS

For the fiscal year ended June 30, 1955, the Congress of the United States appropriated for the National Gallery of Art $1,300,000, 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), and a supplemental appropriation of $23,264 to meet the Gallery's requirements for the fiscal year under the "Federal Employees Salary Increase Act of 1955." The total appropriation for the fiscal year was $1,323,264. The following expenditures and encumbrances were incurred:

Personal services	[1] $1, 173, 681. 41
Printing and reproduction	3, 082. 05
Electricity, supplies, equipment, etc	146, 500. 54
Total	1, 323, 264. 00

ATTENDANCE

During the fiscal year 1955 there were 814,932 visitors to the Gallery—an average daily attendance of about 2,245.

ACCESSIONS

There were 842 accessions by the National Gallery of Art as gifts, loans, or deposits during the fiscal year. Most of the paintings and a number of the prints were placed on exhibition.

[1] This includes the $23,264 of the supplemental appropriation and $2,572 of the otherwise unobligated balance of the regular appropriation.

GIFTS

During the fiscal year 1955 the following gifts were accepted by the Board of Trustees:

PAINTINGS

Donor	*Artist*	*Title*
Mrs. Charles D. Draper	Stuart	George Washington
Mrs. Charles D. Draper	Stuart	Ann Barry.
Mrs. Charles D. Draper	Stuart	Mary Barry.
Mrs. Charles D. Draper	Raeburn	Jean Christie.
Mrs. Margaret S. Lewisohn	Renoir	The Vintagers.
Mrs. Dwight Davis	Romney	Captain Forbes.
Mrs. Leland Harrison	R. Peale	Thomas Sully.
Mrs. Wm. D. Vogel	Pater	On the Terrace.
Lessing J. Rosenwald	Blake	The Last Supper.
Lewis Einstein	Rosalba Carriera	Portrait de Femme, Comtesse Orzelska.
Lewis Einstein	Pater	Scene Champêtre.
Arthur Sachs	Goya, attr. to	The Bullfight.

SCULPTURE

Mrs. Margaret S. Lewisohn	Renoir	Coco.
Miss Mildred Howells	J. Q. A. Ward	Wm. Dean Howells.
Lessing J. Rosenwald	Daumier	Le Bourgeois qui flâne.
Lessing J. Rosenwald	Daumier	L'Amoureux.

PRINTS

Lewis Einstein	"Jeu de Cartes" by Du Rameau.
Mrs. W. Murray Crane	27 prints.
George Matthew Adams	56 prints.
Lessing J. Rosenwald	253 prints.
People of the Federal Republic of Germany	64 prints.

EXCHANGE OF WORKS OF ART

The Board of Trustees during the year accepted the offer of Lessing J. Rosenwald to exchange the following prints for superior impressions of the same works:

Artist	*Title*
Mantegna	Bacchanalian Group with a Press.
Mantegna	Entombment.
Zoan Andrea	A Nereid and Two Children Playing Musical Instruments.
Zoan Andrea	Griffins and Two Cupids Crossing Halberds.
Zoan Andrea	A Nereid Ridden by Two Children.
Zoan Andrea	Three Children Blowing Horns.

WORKS OF ART ON LOAN

During the fiscal year 1955 the following works of art were received on loan by the National Gallery of Art:

From—	*Artist*
Chester Dale, New York, N. Y.:	
Chrysanthemums	William Chase.
Portrait of a Young Woman	David D'Avignon.
Edward T. Wailes, Washington, D. C.:	
Italian Landscape	Jan Both.
Robert Thayer, Washington, D. C.:	
Harrison Gray	Copley.
Elizabeth Gray Otis	Copley.
Samuel Alleyne Otis	Stuart.
Edgar William and Bernice Chrysler Garbisch, New York, N. Y.:	
Sixty-three early American paintings.	
Robert Woods Bliss, Washington, D. C.:	
Nineteen objects of Pre-Columbian art.	

LOANED WORKS OF ART RETURNED

The following works of art on loan were returned during the fiscal year 1955:

To—	*Artist*
Chester Dale, New York, N. Y.:	
Ralph Waldo Emerson	Thomas Sully.
The Seine at Giverny	Monet.
Mrs. Charlotte Fuerstenberg, Johannesburg, South Africa:	
Bread and Eggs	Cézanne.
The Bridge of Langlois	Van Gogh.
La Toilette	Toulouse-Lautrec.
John S. Broome, Oxnard, Calif.:	
Lost on the Grand Banks	Homer.
Mr. and Mrs. Charles B. Wrightsman, Palm Beach, Fla.:	
Girl with a Cat	Renoir.

WORKS OF ART LENT

During the fiscal year 1955 the Gallery lent the following works of art for exhibition purposes:

To—	*Artist*
Kennedy Galleries, New York, N. Y.:	
Arctic Hare	J. J. Audubon.
Sharp-Tailed Sparrow	J. J. Audubon.
Yellow Warbler	J. J. Audubon.
Orchard Oriole	J. J. Audubon.
Farmyard Fowls	J. J. Audubon.
John James Audubon	J. Woodhouse Audubon.
Armed Forces Medical Library, Washington, D. C.:	
Christ Healing the Sick (print)	Rembrandt.
The White House, Washington, D. C.:	
Ships in the Scheldt Estuary	Storck.

To—	*Artist*
The Morgan Library, New York, N. Y.:	
Philosophy (print)	Dürer.
Man of Sorrows (print)	Dürer.
Young Woman (Costume Study) (print)	Dürer.
The Pennsylvania Academy of Fine Arts, Philadelphia, Pa.:	
Timothy Matlock	Charles Willson Peale.
Lady with a Harp; Eliza Ridgely	Sully.
Young Woman in White	Henri.
The Supreme Court, Washington, D. C.:	
Vue general des Alpes et Glaciers	Descourtis.
Vue de Schadau	Descourtis.
Chute de Staubbach	Janinet.
Vue de Thun du Côte du Midi	Janinet.
Boston Museum of Fine Arts, Boston, Mass.:	
Storm over Taos	Marin.
Phillips Memorial Gallery, Washington, D. C.:	
Storm over Taos	Marin.
The San Francisco Museum of Art, San Francisco, Calif.:	
Storm over Taos	Marin.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year 1955:

American Primitive Paintings. From the Collection of Edgar William and Bernice Chrysler Garbisch. Continued from previous fiscal year, through July 11, 1954.

Renaissance Prints by Lucas van Leyden, Marcantonio Raimondi and Jean Duvet. From the Lessing J. Rosenwald Collection. October 24, 1954, through February 6, 1955.

Austrian Drawings and Prints. From the Albertina Museum, Vienna. February 20 through March 20, 1955.

Goya Drawings and Prints. From the Prado Museum and the Lazaro Galdiano Museum, Madrid. April 2 through April 24, 1955.

American Primitive Paintings. From the Collection of Edgar William and Bernice Chrysler Garbisch. Opened May 29, 1955.

Miniatures and Prints. From the Lessing J. Rosenwald Collection. Opened May 29, 1955.

TRAVELING EXHIBITIONS

Rosenwald Collection.—Special exhibitions of prints from the Rosenwald Collection were circulated to the following places during the fiscal year 1955:

Milwaukee Art Institute, Milwaukee, Wis.:
- Prints for an exhibition, "Music in Art."
- September 1954.

The Print Club of Philadelphia, Philadelphia, Pa.:
- Exhibition of prints from the collections of Board Members. Anonymous German, "Christ's Entry into Jerusalem."
- September 1954.

Portland Art Museum, Portland, Oreg.:
Exhibition of Early German Prints.
October 1954.
Toledo Museum of Art, Toledo, Ohio:
Renoir, "Portrait of Wagner" (lithograph). Lent to "Composer Portraits and Autograph Scores."
October 3–November 7, 1954.
The Cleveland Museum of Art, Cleveland, Ohio:
Two Huber drawings lent to the Chinese Landscape Exhibition.
November 4, 1954–January 2, 1955.
Smithsonian Institution, Washington, D. C.:
Loans to the exhibition, "American Drawings," sent to Munich, Rouen, and London, by the United States Information Agency.
1954–55.
Smithsonian Institution, Washington, D. C.—Traveling Exhibition:
Goya Drawings and Prints. Rosenwald Goya prints added to those from Madrid.
1955.
The Pierpont Morgan Library, New York, N. Y.:
Dürer Prints and Drawings.
March–April 1955.
Davidson Art Center, Middletown, Conn.:
Early French Prints.
Modern French Monotypes.
April 1955.
Fogg Museum of Art, Harvard University, Cambridge, Mass.:
Early prints showing musical themes to illustrate two concerts called "Love Songs of the Renaissance."
April 1955.
Marion Kogler McNay Art Institute, San Antonio, Tex.:
Daumier Drawings.
May 1955.
Tyler School of Art, Elkins Park, Philadelphia, Pa.:
Hobby Show—Four American Contemporary prints.
May 12–14, 1955.
American Federation of Arts—Traveling Exhibition:
Nuremberg and the German World.
1955–1956.

Index of American Design.—During the fiscal year 1955, 33 traveling exhibitions of original watercolor renderings of this collection, with 60 bookings, were sent to the following States:

State	Number of exhibitions
Arkansas	1
Colorado	3
Connecticut	1
District of Columbia	6
Florida	2
Georgia	1
Illinois	1
Iowa	11
Kansas	1

State	*Number of exhibitions*
Massachusetts	3
Michigan	2
Missouri	3
Montana	3
New York	1
North Carolina	4
Ohio	3
Pennsylvania	3
Tennessee	2
Texas	2
Virginia	3
Wisconsin	5

CURATORIAL ACTIVITIES

The Curatorial Department accessioned 417 gifts to the Gallery during the fiscal year 1955. Advice was given regarding 365 works of art brought to the Gallery for expert opinion, and 65 visits to collections were made by members of the staff in connection with offers of gift or for expert opinion. About 1,500 inquiries requiring research were answered verbally and by letter. John Walker, Chief Curator of the Gallery, gave a lecture at the Seattle Museum of Art on the occasion of the opening of the Samuel H. Kress Collection in that museum. Mr. Walker also lectured on masterpieces of painting in the National Gallery of Art to the Woman's Club in Richmond, the museum class at the Boston Museum of Fine Arts, and the Twentieth Century Club in Pittsburgh. Miss Elizabeth Mongan gave a series of five lectures on the history of printmaking at the Pennsylvania Academy of Fine Arts. She gave a lecture at Wesleyan University on the First French Engraving. She also conducted a symposium at Bryn Mawr College on Piranesi and one at Swarthmore College on Rembrandt. Charles M. Richards conducted two courses in art history under the auspices of the Department of Agriculture.

Mr. Richards, as chairman, prepared the program for the registrar's section of the American Association of Museums meetings held in Washington this spring. He attended the Southeastern Museums Conference in Miami, and Miss Katharine Shepard was the official delegate to the General Meeting of the Archaeological Institute of America in Boston.

William Campbell selected reproductions of Gallery paintings which are to be installed in new domiciliary buildings of the U. S. Soldiers' Home, Washington, D. C.

Mr. Walker served as trustee for 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

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Committee, Art Committee of the New York Hospital, Harvard Committee on the Visual Arts, Committee for the Exhibition of Nineteenth Century French Paintings from American Collections in Paris. Mr. Walker was also a member of the United States National Commission for UNESCO. Perry B. Cott served as President of the Washington Society, Archaeological Institute of America. Miss Shepard was secretary of this organization.

Mr. Cott served on the following art juries: Corcoran Alumni Association, Arts Club, National Museum Sculpture Exhibition.

RESTORATION AND REPAIR OF WORKS OF ART

Necessary restoration and repair of paintings and sculpture in the Gallery's collection were made by Francis Sullivan, resident restorer, at the Gallery.

PUBLICATIONS

During the year Huntington Cairns contributed an article on "Legal Theory" to a Jurisprudential Symposium in Memory of Felix S. Cohen, published in the Rutgers Law Review, and reviews of "Aesthetics and the Gastalt," by Ian Rawlins, to Philosophy and Phenomenological Research; "Definition and Theory in Jurisprudence," by H. L. A. Hart, to the Philosophical Quarterly; "The Age of Ideas," by George R. Havens, to the Washington Post and Times Herald; and "The Law of Primitive Man," by E. Adamson Hoebel, to the Journal of Politics.

Mr. Walker wrote an article on a painting by Delacroix in the National Gallery, London, for the Ladies Home Journal. He also prepared the text for a "pocketbook" of works of art in the Gallery's collection to be published by the Harry N. Abrams Company. Mrs. Fern R. Shapley wrote an article on Bingham's "Jolly Flatboatmen" for the Art Quarterly. Mr. Cott wrote an article for the Gulf Oil Orange Disc publication on Della Robbia sculpture. An article by Miss Mongan entitled, "New Acquisitions in the Lessing J. Rosenwald Collection" appeared in Arts Digest, and she also wrote an article on Norma Morgan for the International Graphic Arts.

A total of 125,000 leaflets describing paintings in galleries 8, 52, and 57 have been printed and are being distributed to the public in the respective galleries.

Mr. Walker's monograph on Bellini's "Feast of the Gods" has gone to press.

Publications in process include Mr. Walker's text for a portfolio of works of art in the Gallery's collection to be published by the Harry N. Abrams Co., an article written by Mrs. Shapley for The Studio, and a book she is preparing to be published by the Phaidon Press.

Gallery publications in process include the catalog of paintings and the catalog of paintings and sculpture acquired by the Samuel H. Kress Collection since 1951 for the exhibition in 1956.

During the past fiscal year the Publications Fund published seven new 11- by 14-inch color reproductions and acquired five new Christmas card color plates. Two large collotype reproductions of paintings in the collection and nine sculpture reproductions distributed by two New York publishers were placed on sale.

A new Portfolio No. 4 entitled "Landscape Paintings in the National Gallery of Art" (containing text by a staff member and twelve 11- by 14-inch color reproductions, of which seven were completely new prints) is in the process of publication. The catalog of "Twentieth Century French Paintings from the Chester Dale Collection" was reprinted during the year. The Fund made available to the public a National Gallery of Art engagement calendar.

Exhibition catalogs of the Austrian Drawings and Prints, and Goya Drawings and Prints, were distributed.

Representations of Gallery works of art in 2- by 2-inch color slides and in "stereo" color slides are now being sold in the Gallery Information Rooms. These slides, which are all original photographs, are an entirely new type of item in Publications Fund stock.

EDUCATIONAL PROGRAM

The attendance for the general, congressional, and special tours, and the "Picture of the Week" totaled 41,023, while that for the 44 auditorium lectures on Sunday afternoons was approximately 10,025 during the fiscal year 1955.

Tours, lectures, and conferences arranged by appointment were given to 256 groups and individuals. The total number of people served in this manner was 6,042. This is an increase of 110 groups and 2,586 people served over last year. These special appointments were made for such groups as representatives from leading high schools, universities, and museums, other governmental agencies, wives of members of the Cabinet and of Congressmen, women's clubs, store supervisors, and attaches from foreign embassies.

Three separate training programs for volunteer docents from the Junior League, the American Association of University Women of Arlington County, and members of the Parent-Teacher Association of the Barrett School of Alexandria were carried forward during the year by several members of the Education Department.

Lecture programs on "American Cultural Life" have been prepared for librarian members of the United States Information Agency, and for members of the Department of State, who may act as cultural attaches on overseas duty. The wives of the officers in the Departments

of State, Army, and Navy at Fort McNair, who are preparing for overseas duty, also attended these programs.

The staff of the Education Office delivered 14 lectures in the auditorium on Sunday afternoons, and 30 were given by guest speakers. During March and April, Dr. Étienne Gilson, Director of Studies at the Pontifical Institute of Mediaeval Studies at Toronto, delivered the Fourth Annual Series of the six A. W. Mellon Lectures in the Fine Arts on the theme, "Art and Reality."

During the past year 150 persons borrowed 4,697 slides from the lending collection. The 16 centers throughout the country that distribute the National Gallery of Art film, report that approximately 42,564 viewers saw the film in 260 bookings.

Members of the Education Office prepared and gave 32 broadcasts to accompany the Sunday night concerts over Station WGMS. The Curator of Education prepared and produced a half-hour television program entitled "Rembrandt and the Art of the Dutch Homeland" as part of the project of the Citizens Committee on Educational Television.

The printed Calendar of Events announcing all Gallery activities and publications is distributed monthly to a mailing list of 5,316 names.

LIBRARY

The most important acquisitions to the Library during the fiscal year 1955 were 1,940 books, pamphlets, periodicals, subscriptions, and photographs purchased from private funds made available for this purpose. Gifts included 639 books, pamphlets, and periodicals, while 717 books, pamphlets, and bulletins were received on exchange from other institutions. There were more than 540 visits and phone calls to the Library by persons other than Gallery staff during this fiscal year.

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 by the curatorial and other departments of the Gallery; for the dissemination of knowledge to qualified sources; for exchange with other institutions; and for sale at the request of interested individuals.

INDEX OF AMERICAN DESIGN

In March 1955 the Gallery began to take part in the orientation program for United States Information Agency personnel about to be sent overseas. The Index was included in this program, and once a month the group listened to an illustrated lecture given by the Curator in charge of the Index. The Index material was also studied during the year by 638 persons who were interested in the material

for publication, for special research, exhibitions, designers, and those who wanted an idea of the collection as a whole.

There were 33 sets of 2- by 2-inch slides (consisting of 1,416 color slides) circulated in 22 States and Alaska.

MAINTENANCE OF THE BUILDING AND GROUNDS

The usual care of the building and its mechanical equipment and the grounds was maintained at the established standard throughout the year.

Contracts were entered into with Eggers & Higgins, architects, and Vermilya-Brown Co., Inc., general contractors, for the alteration of a portion of the library area in the Gallery building. The remodeled space is intended for the exhibition of the Samuel H. Kress Collection of Renaissance Bronzes.

Alterations were made in gallery 11 so that the opening in the north wall of that gallery now matches in architectural design the openings in the east and west walls. These modifications were made to enable the more effective and suitable exhibition of the Donatello "David," which stands in the center of gallery 11. Eggers & Higgins were the architects, and Vermilya-Brown Co. the general contractor.

The Gallery staff constructed an L-shaped, 3-compartment greenhouse within the southwest moat wall; and the staff is now constructing a cold-conditioning unit to be used in conjunction with the greenhouse. These facilities will enable the horticultural staff to supply suitable flowering and foliage plants for the garden courts and for special exhibitions at almost any time of the year.

A new plaque of Andrew Mellon, sculptured by Walker Hancock, was installed in the Constitution Avenue Lobby.

OTHER ACTIVITIES

David E. Finley, Director, delivered the following speeches during the fiscal year: "The Museum in the Cold War" at a luncheon meeting prior to the opening of the Kress Wing at the Denver Art Museum in September 1954; the principal address at the annual meeting of the National Trust for Historic Preservation in Chicago in October 1954; in May 1955, in New York, he delivered a speech entitled "A Bridge for the Arts" at a meeting of the Columbia Associates of Columbia University; and at the annual meeting of the American Association of Museums in Washington in June 1955 he spoke on "Museums and their Public Relations."

Forty Sunday evening concerts were given during the fiscal year 1955 in the West and East Garden Courts. The National Gallery Orchestra, conducted by Richard Bales, played 10 concerts at the Gallery, with additional performances at the United States Naval

Academy at Annapolis, Md.; at the Corcoran Gallery of Art; and in Alexandria, Va. Two of the orchestral concerts at the National Gallery were made possible by the Music Performance Trust Fund of the American Federation of Musicians. A preseason concert was played by the National Gallery Orchestra on Tuesday, September 7, 1954, sponsored by the International Congress of Clinical Pathologists at a reception held at the National Gallery.

During April and May, six Sunday evenings were devoted to the Gallery's Twelfth American Music Festival. All the concerts were broadcast in their entirety by Station WGMS–FM, Washington, and the Good Music Network. The intermissions, during these broadcasts, featured discussions by members of the curatorial staff on painting and sculpture in the National Gallery of Art, as well as on musical subjects by Richard Bales.

In October 1954, the Columbia recording of "The Confederacy" by the National Gallery Orchestra with the Church of the Reformation Cantata Choir, soloists, and speaker was released. It has received widespread press notice, including an article in the Saturday Review of March 19, 1955, by former President Truman.

The photographic laboratory of the Gallery produced 7,368 prints, 366 black-and-white slides, 20,101 color slides, 105 color transparencies, in addition to 1,820 negatives, color-separation negatives, infrared and ultraviolet photographs and X-ray shadowgraphs; also 2,936 lantern slides were bound.

During the fiscal year, 1,289 copies of press releases were issued in connection with Gallery activities, and 302 permits to copy and 141 permits to photograph in the Gallery were also issued.

OTHER GIFTS

Gifts of money were made during the fiscal year 1955 by the Old Dominion Foundation and the Avalon Foundation.

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, 1955, 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, 1955:

The library owes its growth in strength and in the richness of its collections primarily to the extension and continuity of its exchange relations with scientific and other learned and cultural establishments and societies throughout the world, and the larger number of the 71,179 publications recorded in the receiving room during the past year came in exchange for Smithsonian publications. There were 654 new exchanges arranged, and 5,038 volumes and parts needed to complete sets of serial publications were obtained by writing special requests for them to the issuing agencies.

The continuing generosity of the American Association for the Advancement of Science and of the American Association of Museums accounted for a very large number of the 24,801 pieces recorded as gifts, but other organizations and more than 150 individual donors sent gifts of important and much-appreciated books and periodicals as well.

The high cost and ever-rising prices of much-needed books and journals not obtainable by exchange permitted the purchase of only 488 volumes and 419 periodical subscriptions this year.

Additions to the Smithsonian Deposit at the Library of Congress numbered 6,348 publications, chiefly volumes and parts of long-established sets of serial publications issued by foreign institutions and societies. Other current accessions sent to the Library of Congress were 3,106 doctoral dissertations, mostly from European universities, 6,201 foreign and State documents, and 21,382 miscellaneous publications on subjects not immediately connected with the work of the Institution.

Because of their special subject interest to other agencies of the Government, 5,133 incoming publications were transferred to their respective libraries. Most of them went to the Armed Forces Medical Library and to the libraries of the Geological Survey, the Department of Agriculture, and the Naval Observatory.

By the employment of part-time temporary helpers for a few weeks during the summer good progress was made in putting the library's large collection of duplicates in order. From among this newly arranged material the Library of Congress selected 38,906 pieces for

use in its own collections, and 61,017 others were sent to the United States Book Exchange for exchange credit.

The catalog section classified and cataloged 4,949 volumes, entered 21,305 periodicals, and filed 32,371 cards. The important work of combining into a single comprehensive dictionary catalog the two separate Smithsonian union and Museum catalogs was finished, but there is still a great deal of revisionary work to be done on it. This catalog cannot be a fully effective key to all the library's resources until the many thousands of incompletely or wholly uncataloged volumes in bureau and sectional libraries and in special collections have been cataloged in full.

The use of the library which, with its branches and sectional libraries on special subjects, is a series of reference and research collections, is always difficult to show statistically, even in those areas where it is possible to keep accurate records at all. The library is freely open to anyone who wishes to use it for reference, but circulation of its books and periodicals is restricted to individual members of the staff of the Institution and, within certain necessary limitations, to other libraries; therefore 10,263, the recorded number of loans during the year, represents only a fractional part of the large and continuous use of library books in evidence all day, every day, in the main reference rooms, in the bookstacks, and in the many decentralized units throughout the Institution.

Demands on the staff of the reference section for reference and bibliographical assistance were heavy, as usual, and it was especially gratifying to receive recognition from outside as well as from within the Institution of the painstaking and time-consuming skill of the staff in answering difficult questions. Visiting scientists and other scholars from Europe and South America, as well as from institutions throughout the United States, made more or less extensive reference use of the library, and the sphere of its usefulness was further extended by loans to 94 different libraries.

There were 1,527 volumes, mostly of serial publications, prepared and sent to the bindery for binding or rebinding, and 1,540 volumes were repaired in the library. Most of these latter were old and rare volumes in the Bureau of American Ethnology which had been acquired through the years, not at all because of their rarity, but because they were rich and sometimes unique sources of material on the American Indians.

The installation of 200 feet of shelving in the National Collection of Fine Arts library helped a little to relieve the congestion there, but was only a temporary palliative to the serious overcrowding that threatens deterioration to many beautiful books, and handicaps the ease of their use.

Understaffing continues to be the most immediately serious obstacle to giving the Institution better library service, based on orderly, well-kept, and well-cataloged collections. With so many of the larger decentralized units left without regular full-time attendants it is impossible to give proper custodial care and supervision of the books.

SUMMARIZED STATISTICS

ACCESSIONS

	Volumes	Tota lrecorded volumes, 1955
Smithsonian Deposit at the Library of Congress	1,002	585,592
Smithsonian main library (includes former Office and Museum libraries)	4,020	297,277
Astrophysical Observatory (includes Radiation and Organisms)	480	14,701
Bureau of American Ethnology	78	35,590
National Air Museum	12	335
National Collection of Fine Arts	254	13,709
National Zoological Park	1	4,205
Total	5,847	951,409

Unbound volumes of periodicals, and separates and reprints from serial publications, of which there are many thousands, have not been included in these totals.

EXCHANGES

New exchanges arranged 654
316 for the Smithsonian Deposit.

Specially requested publications received 5,038
906 to fill gaps in Smithsonian Deposit sets.

CATALOGING

Volumes cataloged 4,949

Catalog cards filed 32,371

PERIODICALS

Periodical parts entered 21,305
5,314 sent to the Smithsonian Deposit.

CIRCULATION

Loans of books and periodicals 10,263
Circulation in sectional libraries is not counted except in the Division of Insects.

BINDING AND REPAIR

Volumes sent to the bindery 1,527

Volumes repaired in the library 1,540

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, 1955:

The publications of the Smithsonian Institution, comprising 14 different series, 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 first volume in this series was issued during the year. In addition, the Smithsonian publishes a guide book, a picture pamphlet, postcards and a postcard folder, a color-picture album, and color slides 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 17 papers and title page and contents of 3 volumes in the Miscellaneous Collections, 1 Annual Report of the Board of Regents and separates of 19 articles in the Report appendix, 1 Annual Report of the Secretary, and 4 special publications.

The United States National Museum issued 1 Annual Report, 8 Proceedings papers, and 2 Bulletins.

The Bureau of American Ethnology issued 1 Annual Report and 4 Bulletins.

The Astrophysical Observatory published Volume 7 of the Annals of the Astrophysical Observatory.

The Smithsonian Institution Traveling Exhibition Service, under the National Collection of Fine Arts, published catalogs for 5 of the circulating exhibits.

The Freer Gallery of Art issued 1 paper in the Occasional Papers series, 1 booklet, and Volume 1 of Arts Orientalis.

There were distributed 428,286 pieces of printed matter—192,108 copies of the publications and 226,178 miscellaneous items. Publications: 40 Contributions to Knowledge, 37,495 Miscellaneous Collec-

tions, 10,907 Annual Reports and 20,620 pamphlet copies of Report separates, 579 War Background Studies, 26,595 special publications, 232 reports of the Harriman Alaska Expedition, 40,069 publications of the National Museum, 24,533 publications of the Bureau of American Ethnology, 24,243 publications of the National Collection of Fine Arts, 699 publications of the Astrophysical Observatory, 1,339 publications of the Freer Gallery of Art, 3,515 Reports of the American Historical Association, and 1,242 publications not issued by the Smithsonian Institution. Miscellaneous: 7 pictures of the Harriman Alaska Expedition, 7 sets and 613 prints of North American Wildflowers and 2 Pitcher Plant volumes, 23,388 picture pamphlets, 71,378 Guide Books, 122,498 postcards, 2,003 postcard folders, 3,222 photo sets, 3,806 color slides, and 9,257 color picture albums.

The 1955 allotment from Government funds of $93,000 for printing and binding was entirely obligated at the close of the year.

POPULAR PUBLICATIONS

The Institution published during the year the first of a series of popular publications on scientific and historical subjects related to its important exhibits and collections. Designed for both young and adult readers, the booklet, entitled, "Masters of the Air," depicts in story and pictures the progress of aviation from the first glider flight by the Lilienthal brothers of Germany in the 1890's to the superjets of today that fly faster than sound. Included are the stories of the Smithsonian's own former Secretary Samuel P. Langley; flying planes of the first World War; the early flights across the ocean and around the world; and the achievements of the famous "firsts," such as Lindbergh, Wiley Post, and Sikorsky. The text of the booklet was prepared by Prof. Glenn O. Blough of the University of Maryland and formerly science and education specialist of the U. S. Office of Education, with the technical assistance of Paul E. Garber, head curator of the National Air Museum, and was designed by William D. Crockett, of the staff of the Editorial and Publications Division. The publication was made possible by a grant from the Link Foundation.

SMITHSONIAN PUBLICATIONS

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 121

Title page and table of contents. (Publ. 4220.) 1955.

VOLUME 122

No. 14. A new genus and species of plankton diatom from the Florida Straits, by Paul S. Conger. 8 pp., 4 pls. (Publ. 4171.) July 15, 1954. (30 cents.)

Title page and table of contents. (Publ. 4219.) 1955.

VOLUME 123

No. 2. The dragonfly larva, by R. E. Snodgrass. 38 pp., 11 figs. (Publ. 4175.) September 21, 1954. (35 cents.)

No. 3. A method for the measurement of atmospheric ozone using the absorption of ozone in the visible spectrum, by Oliver R. Wulf and James E. Zimmerman. 14 pp. (Publ. 4177.) October 27, 1954. (25 cents.)

No. 4. Revision of the flea genus *Peromyscopsylla*, by Phyllis T. Johnson and Robert Traub. 68 pp., 131 figs. (Publ. 4178.) November 23, 1954. (65 cents.)

No. 5. Concerning Smithsonian pyrheliometry, by C. G. Abbot, L. B. Aldrich, and A. G. Froiland. 4 pp. (Publ. 4179.) November 2, 1954. (5 cents.)

No. 6. A new pictographic autobiography of Sitting Bull, by Alexis A. Praus. 4 pp., 7 pls. (Publ. 4180.) January 20, 1955. (35 cents.)

No. 7. Early Cenozoic vertebrates in the red conglomerate at Guanajuato, Mexico, by Carl Fries, Jr., Claude W. Hibbard, and David H. Dunkle. 25 pp., 1 pl., 6 figs. (Publ. 4181.) February 17, 1955. (30 cents.)

Title page and table of contents. (Publ. 4218.) 1955.

VOLUME 124

The material culture of Pueblo Bonito, by Neil M. Judd. With appendix, Canid remains from Pueblo Bonito and Pueblo del Arroyo, by Glover M. Allen. 398 pp., 101 pls., 101 figs. (Publ. 4172.) December 29, 1954. ($5.00.)

VOLUME 125

No. 1. The black flies (Diptera, Simuliidae) of Guatemala and their role as vectors of onchocerciasis, by Herbert T. Dalmat. 425 pp., 44 pls., 21 figs., 14 maps. (Publ. 4173.) April 5, 1955. ($5.00.)

No. 2. The pyramidellid mollusks of the Pliocene deposits of North St. Petersburg, Florida, by Paul Bartsch. 102 pp., 18 pls. (Publ. 4186.) May 5, 1955. ($1.40.)

VOLUME 126

No. 2. The archeological and paleontological salvage program in the Missouri Basin, 1950–1951, by Paul L. Cooper. 99 pp., 12 pls., 1 fig. (Publ. 4188.) April 28, 1955. ($1.35.)

No. 3. A revision of some glanduline Nodosariidae (Foraminifera), by Alfred R. Loeblich, Jr., and Helen Tappan. 9 pp., 1 pl. (Publ. 4189.) February 3, 1955. (20 cents.)

VOLUME 128

No. 1. Amphipoda collected at the Arctic Laboratory, Office of Naval Research, Point Barrow, Alaska, by G. A. MacGinitie, by Clarence R. Shoemaker. 78 pp., 20 figs. (Publ. 4209.) June 21, 1955. (75 cents.)

No. 2. Washington, D. C., precipitation of 1954 and 1955, by C. G. Abbot. 3 pp., 1 fig. (Publ. 4210.) March 1, 1955. (10 cents.)

No. 3. Sixty-year weather forecasts, by C. G. Abbot. 22 pp., 11 figs. (Publ. 4211.) April 28, 1955. (25 cents.)

No. 4. Periodic solar variation, by C. G. Abbot. 20 pp., 5 figs. (Publ. 4213.) June 14, 1955. (25 cents.)

No. 6. A revision of the chiggers of the subgenus *Gahrliepia* (Acarina: Trombiculidae), by Robert Traub and Mary Lou Morrow. 89 pp., 194 figs. (Publ. 4215.) June 30, 1955. ($1.00.)

ANNUAL REPORTS

Report for 1953.—The complete volume of the Annual Report of the Board of Regents for 1953 was received from the printer September 2, 1954:

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, 1953. 481 pp., 83 pls., 27 figs. (Publ. 4149.)

The general appendix contained the following papers (Publs. 4150–4168):

Science, art, and education, by R. E. Gibson.
Recent progress in astronomical photography, by C. E. Kenneth Mees.
Radioisotopes—New keys to knowledge, by Paul C. Aebersold.
The push-button factory, by Frank K. Shallenberger.
The science of musical instruments, by E. G. Richardson.
Genetics and the world today, by Curt Stern.
Climate and race, by Carleton Coon.
Vegetation management for rights-of-way and roadsides, by Frank E. Egler.
Applied systematics: The usefulness of scientific names of animals and plants, by Waldo L. Schmitt.
The geological history and evolution of insects, by F. M. Carpenter.
The coelacanth fishes, by Errol White.
Barro Colorado—Tropical island laboratory, by Lloyd Glenn Ingles.
Norsemen in North America before Columbus, by Johannes Brøndsted.
The mountain village of Dahr, Lebanon, by Raymond E. Crist.
The problem of dating the Dead Sea Scrolls, by John C. Trever.
Kinreizuka—The "Golden Bells Tomb" of Japan, by Motosaburo Hirano and Hiroshi Takiguchi.
The archeology of colonial Williamsburg, by Thomas J. Wertenbaker.
The story of the Declaration of Independence desk and how it came to the National Museum, by Margaret W. Brown.
Charles Bird King, painter of Indian visitors to the Nation's Capital, by John C. Ewers.

Report for 1954.—The Report of the Secretary, which will form part of the Annual Report of the Board of Regents to Congress, was issued January 14, 1955:

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, 1954. 175 pp., 4 pls. (Publ. 4182.)

SPECIAL PUBLICATIONS

History under the sea, by Mendel L. Peterson. 16 pp., 7 pls. (Publ. 4174.) [August 9], 1954. (25 cents.)

Bess Wallace Truman, by Margaret W. Brown. (Supplement to "Dresses of the First Ladies of the White House," by Margaret W. Brown. Publ. 4060.) 4 pp., 2 pls. [September 1], 1954. (50 cents.)

Masters of the Air, by Glenn O. Blough. 32 pp., illustr. (Publ. 4183). [December 16], 1954. (50 cents.)

First Ladies Hall, by Margaret W. Brown. 10 pp., 8 pls. (Publ. 4212.) [May 25], 1955. (25 cents.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The National Museum issued 1 Annual Report, 8 Proceedings papers, and 2 Bulletins, as follows:

ANNUAL REPORT

The United States National Museum annual report for the year ended June 30, 1954. ix+100 pp. [January 14, 1955.]

PROCEEDINGS

VOLUME 103

No. 3334. A supplement to W. M. Tattersall's review of the Mysidacea of the United States National Museum, by Albert H. Banner. Pp. 575–583. July 8, 1954.

No. 3335. On the anatomy and relationships of glossy cuckoos of the genera *Chrysococcyx*, *Lampromorpha*, and *Chalcites*, by Andrew H. Berger. Pp. 585–597, figs. 69–71. January 19, 1955.

No. 3336. Supplement and corrections to J. A. Hyslop's genotypes of the elaterid beetles of the world, by Ross H. Arnett, Jr. Pp. 599–619. April 14, 1955.

No. 3337. Neotropical Miridae, LXIV: New bugs of the subfamily Cylapinae (Hemiptera), by José C. M. Carvalho. Pp. 621–632, figs. 72–76, pl. 15. March 2, 1955.

VOLUME 104

No. 3338. Revision of the vittate species of the chrysomelid beetle genus *Disonycha* from the Americas south of the United States, by Doris Holmes Blake. Pp. 1–86, figs. 1–75. April 4, 1955.

No. 3339. A revision of the Nearctic species of the beetle genus *Meligethes* (Nitidulidae), by Alan M. Easton. Pp. 87–103, figs. 76–78. February 25, 1955.

No. 3340. Four new Venezuelan reduviid bugs, by Maldonado Capriles. Pp. 105–113, figs. 79, 80. March 28, 1955.

No. 3341. Some polyclad flatworms from the West Indies and Florida, by Libbie H. Hyman. Pp. 115–150, figs. 81–89. May 2, 1955.

BULLETINS

205. List of North American Recent mammals, by Gerrit S. Miller, Jr., and Remington Kellogg. xii+954 pp. March 3, 1955.

206. Frogs of southeastern Brazil, by Doris M. Cochran. xi+423 pp., 28 figs., frontispiece and 34 pls. June 22, 1955.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

There were issued 1 Annual Report and 4 Bulletins, as follows:

ANNUAL REPORT

Seventy-first Annual Report of the Bureau of American Ethnology, 1953–1954. ii+17 pp. 1955.

BULLETINS

Bulletin 157. Anthropological Papers, Nos. 43–48. iii+415 pp., 76 pls., 23 figs. 1955.

No. 43. Stone monuments of the Río Chiquito, Veracruz, Mexico, by Matthew W. Sterling.

No. 44. The Cerro de las Mesas offering of jade and other materials, by Philip Drucker.

No. 45. Archeological materials from the vicinity of Mobridge, South Dakota, by Waldo R. Wedel.

No. 46. The original Strachey vocabulary of the Virginia Indian language, by John P. Harrington.

No. 47. The Sun Dance of the Northern Ute, by J. A. Jones.

No. 48. Some manifestations of water in Mesoamerican art, by Robert L. Rands.

Bulletin 158. River Basin Surveys Paper No. 7. Archeological investigations in the Oahe Dam area, South Dakota, 1950–51, by Donald J. Lehmer. xi+190 pp., 22 pls., 56 figs., 6 maps. 1954.

Bulletin 159. The horse in Blackfoot Indian culture, with comparative material from other western tribes, by John C. Ewers. xv+374 pp., 17 pls., 33 figs., 1955.

Bulletin 160. A ceramic study of Virginia archeology, by Clifford Evans. With an appendix on An analysis of projectile points and large blades, by C. G. Holland. viii+196 pp., 30 pls., 23 figs., 1 chart. 1955.

PUBLICATIONS OF THE ASTROPHYSICAL OBSERVATORY

Annals of the Astrophysical Observatory, vol. 7. 184 pp., 8 pls., 13 figs. (Publ. 4138.) 1954.

PUBLICATIONS OF THE NATIONAL COLLECTION OF FINE ARTS

Brazilian landscape architecture. New designs by Roberto Burle Marx. (Smithsonian Institution Traveling Exhibition Service catalog.) 16 pp., illustr. [July 1954.]

Nineteenth century American paintings, 1815–1865, from the private collection of Maxim Karolik. (Smithsonian Institution Traveling Exhibition Service catalog.) 22 pp., including 11 pls. [October 1954.]

Watercolors and prints by Redouté. (Smithsonian Institution Traveling Exhibition Service catalog.) 12 pp., 1 pl. [December 1954.]

Austrian drawings and prints from the Albertina, Vienna. (Smithsonian Institution Traveling Exhibition Service catalog.) 27 pp., 6 pls. [February 1955.]

Goya. (Smithsonian Institution Traveling Exhibition Service catalog.) [April 1955.]

PUBLICATIONS OF THE FREER GALLERY OF ART

Abstracts of technical studies in art and archaeology, 1943–1952, by Rutherford J. Gettens and Bertha M. Usilton. Occasional Papers, vol. 2, No. 2, 408 pp. (Publ. 4176.) 1955. ($3.00.)

The Freer Gallery of Art. (Rev. ed.) 16 pp., 8 pls., 3 figs. (Publ. 4185.) 1955. (15 cents.)

Ars Orientalis, vol. 1. 267 pp., 93 pls., 80 figs. (Publ. 4187.) 1954. ($16.00.)

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 1952. Vol. 2. Writings on American History, 1950. xiii +609 pp. 1955.

Annual Report of the American Historical Association for the year 1953. Vol. 1. Proceedings. 52 pp. 1955.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Fifty-seventh Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, on March 21, 1955.

DIVISIONAL ACTIVITIES

The chief of the division continued to represent the Institution on the board of directors of the Greater Washington Educational Television Association, Inc., of which the Smithsonian is a member. During the year the Association produced a series of educational television programs broadcast over Washington stations, and the Smithsonian participated in two of these.

The assistant chief of the division, John S. Lea, devoted considerable time during the last half of the year to the preparation of a brochure explaining the history, purposes, and accomplishments of the Smithsonian Institution. Mr. Lea also served as chairman of a committee formed to assist the Washington Area School Study Council, representing the school boards of the area, in working out a method of making more effective use of the educational potential of the Institution.

Members of the division, particularly Ernest E. Biebighauser, assisted the Personnel Division in planning and inaugurating publication of *The Torch*, a multigraphed house organ for Smithsonian employees superseding the monthly newsletter of the Smithsonian Employees Federal Credit Union. The first number appeared in March 1955.

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, 1955

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 1955	Income 1955
Parent Fund (original Smithson bequest, plus accumulated savings)	$729,112.87	$43,735.37
Subsequent bequests, gifts, and other funds, partly deposited in the U. S. Treasury and partly invested in the consolidated fund:		
Abbott, W. L., special	16,960.64	729.45
Avery, Robert S., and Lydia	61,655.14	3,330.03
Endowment	426,417.89	22,290.66
Habel, Dr. S	500.00	30.00
Hachenberg, George P., and Caroline	4,852.15	253.31
Hamilton, James	2,987.02	175.43
Henry, Caroline	1,459.14	76.24
Hodgkins, Thomas G	152,547.21	8,869.61
Porter, Henry Kirke	345,528.58	18,054.12
Rhees, William Jones	1,160.79	65.24
Sanford, George H	2,174.00	122.11
Witherspoon, Thomas A	155,696.68	8,135.27
Total	1,171,939.24	62,121.47
Grand total	1,901,052.11	105,856.84

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 1955	Income 1955
Abbott, William L., for investigations in biology	$126, 133. 83	$6, 658. 00
Arthur, James, for investigations and study of the sun and annual lecture on same	48, 251. 29	2, 552. 98
Bacon, Virginia Purdy, for traveling scholarship to investigate fauna of countries other than the United States	60, 445. 71	3, 198. 16
Baird, Lucy H., for creating a memorial to Secretary Baird	29, 048. 33	1, 536. 97
Barney, Alice Pike, for collection of paintings and pastels and for encouragement of American artistic endeavor	34, 603. 85	1, 830. 87
Barstow, Frederick D., for purchase of animals for Zoological Park	1, 206. 20	63. 81
Canfield Collection, for increase and care of the Canfield collection of minerals	46, 144. 43	2, 441. 50
Casey, Thomas L., for maintenance of the Casey collection and promotion of researches relating to Coleoptera	15, 122. 61	800. 16
Chamberlain, Francis Lea, for increase and promotion of Isaac Lea collection of gems and mollusks	33, 975. 14	1, 797. 62
Dykes, Charles, for support in financial research	51, 949. 32	2, 748. 27
Eickemeyer, Florence Brevoort, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr	13, 114. 20	693. 89
Hillyer, Virgil, for increase and care of Virgil Hillyer collection of lighting objects	7, 929. 25	419. 56
Hitchcock, Albert S., for care of the Hitchcock Agrostological Library	1, 903. 73	100. 72
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	42, 591. 09	2, 125. 40
Hughes, Bruce, to found Hughes alcove	23, 093. 68	1, 221. 90
Loeb, Morris, for furtherance of knowledge in the exact sciences	105, 148. 40	5, 563. 39
Long, Annette and Edith C., for upkeep and preservation of Long collection of embroideries, laces, and textiles	655. 11	34. 68
Maxwell, Mary E., for care and exhibition of Maxwell collection	23, 664. 64	1, 252. 11
Myer, Catherine Walden, for purchase of first-class works of art for use and benefit of the National Collection of Fine Arts	24, 369. 74	1, 210. 05
Nelson, Edward W., for support of biological studies	15, 481. 54	697. 44
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, 159. 14	61. 35
Pell, Cornelia Livingston, for maintenance of Alfred Duane Pell collection	8, 943. 00	473. 18
Poore, Lucy T. and George W., for general use of the Institution when principal amounts to $250,000	187, 379. 67	9, 600. 62
Rathbun, Richard, for use of division of U. S. National Museum containing Crustacea	12, 832. 12	678. 96
Reid, Addison T., for founding chair in biology, in memory of Asher Tunis	33, 057. 38	1, 813. 97
Roebling Collection, for care, improvement, and increase of Roebling collection of minerals	145, 608. 17	7, 704. 13
Roebling Solar Research	41, 358. 82	953. 75
Rollins, Miriam and William, for investigations in physics and chemistry	113, 285. 62	5, 993. 93
Smithsonian employees' retirement	31, 506. 84	1, 703. 67
Springer, Frank, for care and increase of the Springer collection and library	21, 635. 66	1, 144. 76
Strong, Julia D., for benefit of the National Collection of Fine Arts	12, 062. 97	638. 27
Walcott, Charles D. and Mary Vaux, for development of geological and paleontological studies and publishing results of same	576, 151. 56	29, 674. 11
Walcott, Mary Vaux, for publications in botany	69, 837. 46	3, 695. 10
Younger, Helen Walcott, held in trust	76, 483. 45	3, 765. 36
Zerbee, Frances Brincklé, for endowment of aquaria	1, 144. 42	60. 55
Total	2, 137, 278. 37	110, 909. 19

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 $7,230,968.48.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes	$1,901,052.11
Invested endowment for specific purposes other than Freer endowment	2,137,278.37
Total invested endowment other than Freer endowment	4,038,330.48
Freer invested endowment for specific purposes	7,230,968.48
Total invested endowment for all purposes	11,269,298.96

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	$1,144,322.62	
Stocks	1,872,085.09	
Real estate and mortgages	5,936.00	
Uninvested capital	15,986.77	
		3,038,330.48
Total investments other than Freer endowment		4,038,330.48
Investments of Freer endowment (cost or market value at date acquired):		
Bonds	$4,374,757.31	
Stocks	2,835,878.90	
Uninvested capital	20,332.27	
		7,230,968.48
Total investments		11,269,298.96

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1955 [1]

Cash balance on hand June 30, 1954		$867,671.10
Receipts, other than Freer endowment:		
Income from investments	$233,712.18	
Gifts and contributions	355,562.07	
Books and publications	76,751.72	
Miscellaneous	37,105.24	
Proceeds from real estate	45.00	

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1955—Continued

Receipts, other than Freer endowment—Continued		
Proceeds from sale of securities (net)	($338, 782. 94)	
Proceeds from sale of cash securities (net)	(1, 450. 00)	
Total receipts other than Freer endowment		$362, 943. 27
Receipts from Freer endowment:		
Income from investments		346, 395. 48
Total		1, 577, 009. 85
Disbursements other than Freer endowment:		
Administration	$98, 438. 50	
Publication	60, 837. 53	
Library	535. 47	
Custodian fees and servicing securities	2, 538. 12	
Miscellaneous	2, 069. 44	
Payroll withholdings and refund of advances (net)	1, 073. 65	
Researches and explorations	473, 806. 28	
S. I. Retirement System	2, 375. 10	
Total disbursements other than Freer endowment		641, 734. 09
Disbursements from Freer endowment:		
Salaries	$122, 868. 40	
Purchases for collection	175, 435. 00	
Custodian fees and servicing securities	12, 678. 14	
Miscellaneous	37, 440. 84	
Total disbursements from Freer endowment		348, 422. 38
Total disbursements		990, 156. 47
Cash balance June 30, 1955		586, 853. 38
Total		1, 577, 009. 85

ASSETS

Cash:			
United States Treasury current account	$192, 330. 69		
In banks and on hand	394, 522. 69		
	586, 853. 38		
Less uninvested endowment funds	36, 319. 04		
		$550, 534. 34	
Travel and other advances		10, 555. 00	
Cash invested (U. S. Treasury notes)		725, 960. 92	
			$1, 287, 050. 26

ASSETS—Continued

Investments—at book value:				
Endowment funds:				
Freer Gallery of Art:				
Stocks and bonds	$7,210,636.21			
Uninvested cash	20,332.27			
		$7,230,968.48		
Investments at book value other than Freer:				
Stocks and bonds	$2,939,736.63			
Uninvested cash	15,986.77			
Special deposit in U. S. Treasury at 6 percent interest	1,000,000.00			
Other stocks and bonds	76,671.08			
Real estate and mortgages	5,936.00			
		4,038,330.48		
			$11,269,298.96	
Total			12,556,349.22	

UNEXPENDED FUNDS AND ENDOWMENTS

Unexpended funds:			
Income from Freer Gallery of Art endowment			$535,740.89
Income from other endowments:			
Restricted		$325,014.80	
General		222,876.06	
			547,890.86
Gifts and grants			203,418.51
			1,287,050.26
Endowment funds:			
Freer Gallery of Art		$7,230,968.48	
Other:			
Restricted	$2,137,278.37		
General	1,901,052.11		
		4,038,330.48	
			11,269,298.96
Total			12,556,349.22

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 $3,162.17.

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 Museum of Natural History, additional gift, for a study of the ethnology of the Tsimshian Indians of the British Columbia coast.

American Philosophical Society, for studies on the behavior and life histories of solitary wasps.

Dr. Robert A. Vines, Director of the Museum of Natural History of Houston, for improvement of the United States National Herbarium Collections.

Agnes Chase, additional gift, for copying the index to grass names.

The Washington Fashion Group, additional gift, for the costumes collection.

Geological Society of America, for services of a scientific illustrator.

Johns Hopkins University, additional gift, for publications on Arctic research.

Link Foundation, additional gift, for preparation and distribution of materials related to the contributions of the National Air Museum to aviation education.

E. A. Link, Link Aviation, Inc., additional gift, for historical research (marine archeology).

Merck & Co., Inc., for preparing a vitamin exhibit.

National Academy of Sciences, for typing the manuscript of the second edition of the Flora of Okinawa.

National Geographic Society, to establish the Olmec Archeological Fund.

National Geographic Society, additional grant, for the publication of "The Material Culture of Pueblo Bonito."

National Science Foundation, for the publication of "Annotated Subject-Heading Bibliography of Termites."

National Science Foundation, grant to provide maintenance and operation of the Canal Zone Biological Area, Barro Colorado Island, Canal Zone.

National Science Foundation, grant for research on "Taxonomy of the Bamboos."

J. Townsend Russell, to secure archeological series from the Scandinavian countries.

Harvard University, for the Peabody Museum, Harvard–Smithsonian Institution Kalahari Expedition.

Malcolm MacGregor, for "The Philatelic Fund."

I. A. O'Shaughnessy, for publication of Sister Inez Hilger's manuscript of her study of Araucanian Child Life and its Cultural Background.

Mr. and Mrs. Bruce Bredin, for an expedition to the Belgian Congo.

State Department, grant to cooperate on Educational Exchange Services.

Guggenheim Foundation, additional grant, for the wax metabolism fund.

The Wenner–Gren Foundation, for use in connection with a seminar on the role of physical anthropology in the identification of human remains.

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.

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 1955:

Salaries and expenses	$3, 048, 146. 00
National Zoological Park	648, 000. 00

These figures include supplemental appropriations to pay salary increases of approximately 7½ percent voted by Congress effective March 13, 1955.

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	$52, 700. 00

The Institution also administers a trust fund for partial support of the Canal Zone Biological Area, located on Barro Colorado Island in the Canal Zone.

AUDIT

The report of the audit of the Smithsonian private funds follows:

WASHINGTON, D. C., August 8, 1955.

TO 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, 1955. 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, 1955 (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
VANNEVAR BUSH
ROBERT V. FLEMING

Executive Committee.

Salaries and expenses .... [illegible]
Salaries and expenses .... [illegible]

These figures include supplemental appropriations to pay salary increases of approximately [illegible] as granted by Congress effective March [illegible], 19[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:

Washington, D. C., August [illegible], 195[illegible].

To the Board of Regents,
Smithsonian Institution,
Washington 25, D. C.

We have examined the accounts of the Smithsonian Institution relating 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, 195[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.

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 similar 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, 195[illegible] (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
Vannevar Bush
Robert V. Fleming
Executive Committee.

GENERAL APPENDIX

to the

SMITHSONIAN REPORT FOR 1955

ADVERTISEMENT

The object of the General Appendix to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by staff members and collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, the purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report of 1889, a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1955.

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.

Science Serving the Nation[1]

By Lee A. DuBridge

President, California Institute of Technology

We are sometimes inclined to think that the phenomenon of science being of service to the Nation is a development of recent years—say since 1940. However, as a matter of fact, science has always been a national asset and has always been in the Nation's service. Science and technology indeed have been among the decisive influences that have improved the condition of the American people, and thus made this Nation fine and strong.

However, even if we think of science directly serving the government, rather than serving the people generally, we are still not dealing with a new phenomenon. Beginning with the day Benjamin Franklin invented the postage stamp, the United States Government has needed and has used science and technology, not only to promote the general welfare of the people but also to advance the special functions of the Federal Government, including, of course, the function of national defense.

This long experience has led this Nation to the conclusion—a conclusion not always expressed or adequately implemented, but nevertheless definite—that the Government and the Nation are heavily dependent for strength, welfare, and security on science and technology. Hence, it follows that the Government must do two things: (1) Make provision for the carrying on of scientific and technological activities within the framework of government to serve specific government needs, and (2) encourage and support throughout the country a strong nongovernment science and technology. Both of these activities are necessary for a strong and prosperous nation in time of peace; both are vital to bring military strength in time of war.

However, it is one thing to recognize these two facts and obligations; it is quite another thing to do anything sensible about them. The history of government relations with science is replete with examples

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[1] **Address delivered at opening ceremonies of new building of The Johns Hopkins University Applied Physics Laboratory, Howard County, Maryland, October 16, 1954. Reprinted by permission of the Laboratory.**

of good intention and bad implementation. A desirable agency is established and is then deprived of funds. Laws enunciating high-sounding ideals are passed, and then the men who are appointed to implement them are denied secretarial help and travel funds. Scientists are saluted as being essential to the Nation's progress, and are then drafted as privates in the army, or employed by the Government under policies set up for postal clerks.

I am told that men who have been in politics for many years do not expect political institutions in a democracy to be either reasonable or consistent on any policy matter. The implementation of policy, they say, will always be in the hands of many people who have differing views on various aspects of the policy, and these people will change with time; hence there is bound to be confusion. Those of us who are less experienced, however, still think of "the Government" as an entity with a mind and a purpose. And we shall never get over the shock of seeing the Government do one thing with one hand and a wholly contradictory thing with the other. Some people react to this paradox by turning their backs on government entirely, refusing to have anything whatsoever to do with it—except when forced to serve in the army or to pay an income tax. Such people often come to despise the Government to such an extent that they castigate anyone having anything to do with it.

Most reasonable people, however, though they sigh sadly at the vagaries of a democratic government, still realize that it is the only government we have and that we should try to put up with it, to help it and to try to make it better and more consistent. In time of war we all do this. In time of peace it is more difficult to do, but—on a smaller scale—no less necessary.

If this be our desire then it is certainly necessary to be very frank and very objective. We must ask penetrating questions about what is wrong—and what is right. We must be very free to discuss these matters with others in a spirit of good will—never throwing doubt on another's ideas or suggestions by questioning his patriotism or integrity. We must be willing to speak frankly and to listen to frank talk.

For purposes of simplicity it will be necessary for me to ignore now a large portion of the areas of government where problems relating to science may lie. I shall not speak at all of the many civilian agencies of our Government which may deal with science—the Bureau of Standards, the Public Health Service, the Smithsonian Institution, the Departments of Agriculture and of the Interior, and all the rest. I shall confine myself to one question: What are the problems relating to improving the ways by which science and technology can contribute to making the Nation so strong that it

can achieve its national aims and ideals in the face of opposition from potential enemies? In short, what are the ways in which science promotes national security?

Even this simple question does not have a simple answer. The roots of national strength extend deeply into the national pattern of living, into the Nation's industrial, social, educational, and economic systems. We cannot trace all these roots. But we may select a few essential items that are necessary to answer our question.

In the first place, we now understand that both a strong military technology and a strong industrial technology must rest upon a solid base of *fundamental* science. This is a fairly obvious remark, of course, since all technology grows out of discoveries in basic science. But it immediately follows that the Government should encourage the building of a strong science. There are several specific reasons for this:

1. New knowledge is essential to future progress.

2. The corps of scientists engaged in basic science are among the most able and imaginative in the country. Their number should increase, not only because of the scientific advances they will produce but because they stand as a "ready reserve" available to accelerate the development of military technology when emergencies arise.

3. Basic science carried on in universities is the sole source of education of future scientists and technologists. Those wellsprings of future talent must be maintained and enlarged.

4. Basic science in relevant fields has an important place in laboratories of applied science. It improves the intellectual tone, it stimulates the imagination, satisfies the curiosity, helps attract new scientists, and, of course, fills in essential gaps in knowledge.

How do we stand in this area of basic science? Are we as a nation doing all right?

I am convinced that the answer is in the negative. But I am also aware that great progress has been made. There have been important forwards steps during the postwar years. For example:

1. The military services, realizing the importance of scientists to wartime technology, aided mightily after the war in financing a rehabilitation of university research. The funds made available for equipment, for services, and for graduate student support stimulated a spectacular postwar development in university science laboratories. We will forever owe a debt, particularly to the Office of Naval Research, for what was done in this respect. The Atomic Energy Commission and the Public Health Service have also made important contributions. They have shown that government can encourage university science without the necessity of unwise political interference, provided, of course, the universities themselves remain alert.

2. Most American industries have increased their research expenditures by an amount which, for the country as a whole, adds up to a very large factor. Industries have increased the amount of basic research in their own laboratories, and they have made substantial grants to support basic research in universities. This is excellent and I hope the latter practice especially will greatly increase.

3. The Government itself, especially the military agencies and the AEC, have put their own applied research programs on a long-term stable basis and have made provision within the Government laboratories for such basic research as is appropriate and relevant in each case. (I am not saying there is agreement on how much and what kind of basic research is proper or relevant in each laboratory, but I do say that the principle has been recognized.)

4. The Congress finally passed the National Science Foundation Act and gave the Foundation modest funds to get its program started. The Foundation Fellowship program has been an outstanding contribution.

All these steps have helped to strengthen basic research, have helped in the education of students, have helped to attract young men into science, and have also brought about a degree of contact, of friendship, of understanding between the scientists and the military which was unheard of before 1941, and which will be a mighty element of strength in future (and current) conflicts. But there is much that has been left undone, much that has been done inadequately or unwisely.

Someone, for example, started the idea that the purpose of the National Science Foundation was to "eliminate the tremendous duplication in basic research." This is one of the most tragically mistaken delusions of recent years, and I must take a moment to deal with it.

Duplication in basic research is, in the first place, a contradiction of terms. Research is the seeking for new knowledge. If the knowledge has already been found no one else will seek for it—so duplication is impossible. If someone wished to check up on a discovery and repeat an experiment, this is certainly not duplication because science, by definition, deals with those phenomena which anyone can duplicate at will.

Should one say then that it is duplication for two people to be searching for the same knowledge? This is like saying that it is duplication for more than one person to search for a child that is lost in the woods. We all know that when many people participate in the search it is greatly accelerated, and if two searchers should come upon the child at the same time do we complain of duplication? Even more, when one is searching the infinite wilderness of the unknown for an uncountable number of undiscovered pieces of knowledge, it is clearly evident that the more people engaged in the hunt

the better. And if, once in 10 years, two scientists happen to run onto the same discovery at the same time this is good, not bad, for it gives an immediate confirmation of the validity of the finding. As long as science is carried on in the open, not in secrecy, then duplication is, by the very nature of science, nonexistent—indeed it is impossible.

But the duplication idea leads to another illusion: that science will be more efficient or effective if it is all under one management. To move in this direction, when Congress increased the National Science Foundation funds this year, it imposed an almost equal decrease in the funds allocated to other agencies. This, it seems to me, was unfortunate, for it caused disruption of existing programs and a net decrease in the amount of research in progress. In science—as in education—diversity is our most precious asset. No single agency with a particular policy, a particular program, a particular group of advisers, and a particular staff can possibly accommodate all the diverse needs of science. It is almost as bad as trying to decree that all children should have the same father.

So I suggest that in the field of basic research we all have an educational job to do. We need to convince the public of the value of encouraging basic reasearch. We need to convince both the executive and legislative branches of the Government that all agencies concerned with science and technology should encourage and support basic reasearch in their own laboratories and in universities; that the more agencies that are doing it the more effective and productive our program will be; that the dividends which will be repaid in new knowledge, in additional scientists trained, and in more scientists brought into contact with the Government will be worth a thousand times the investment. The dividend may indeed be the survival of the Nation.

Let us now turn to some problems of *applied* research conducted by the Government—confining our attention to research carried out for military purposes by the Defense Department and the AEC.

Applied research is in many ways a very different animal from basic research. It is true that the scientific training required is much the same and that quite similar techniques and equipment are involved. But the eastbound and westbound sections of a streamlined train look similar too. It's just that they are not headed for the same place.

Applied research is research aimed at a goal, i. e., a better or improved weapon, a new industrial product, a cure for a disease. Because the goal is established or agreed upon (this is important of course!) it is possible to organize the attack on the problem, to assign a number of specific tasks or areas of investigation to different individuals or groups. In contrast to basic research it is desirable in

applied research to take steps to avoid duplication—since for two groups to be assigned the problem of developing the same weapon is usually less efficient than for them to combine forces. Also, since applied military research is usually necessarily secret, it is important to establish coordinating mechanisms to avoid the waste of unknowingly repeating what another laboratory has done.

For these and many other reasons it is important, when talking about government activities in science, to distinguish sharply between pure and applied science. What is good for one may not be good for the other.

Now it is not surprising to note that the military services and the AEC have developed not one but many patterns for carrying on applied research. A democracy never does anything in a unified or monolithic way. This is both our strength and our danger. The strength is that diversity of approach and individuality are conducive to new ideas. The danger is that resources will be scattered and ineffective, policies will be confused, and high priority tasks will be neglected.

In applied research, as in basic research, it is not necessarily efficient to have it all under a single management. But to an extent not desirable in basic research, applied military research must be under relatively few agencies, and they must be closely coordinated to avoid wasteful repetition. Thus, for example, it is quite proper that the direction of all military development has *not* been consolidated under one office in the Department of Defense. But it is proper also that there has been created there one office to give guidance and coordination to all the service agencies.

It is also not surprising to find the research pattern different in the three services—nor is this disturbing. Yet each service needs one office which gives rather close attention to the supervision of the whole program of that service. Also each service needs an effective mechanism for keeping new developments closely tied to plans—to requirements—to logistics—to tactical development. This is probably the area in which there is greatest weakness. New weapons are often produced in ignorance of tactical requirements; they are introduced without adequate study of their tactical possibilities, without adequate logistics and maintenance and training. Military plans, on the other hand, are sometimes drawn up without taking into account new weapons that will shortly be available. There is, in short, inadequate attention given to clarifying the goals of the military research program and making clear to every agency its part and purpose in the program.

There are many people aware of these shortcomings, and many in the military establishment are trying to remedy them. It is not my task today—or any day—to tell them how to do the job. We certainly do wish them success.

I turn now to a discussion of the mechanisms by which military research is carried out. These show great diversity, and this is both desirable and troublesome.

Broadly speaking, military research may be carried on either in a government-owned and government-operated laboratory, in a government-owned–contractor-operated laboratory, or in a contractor-owned–contractor-operated facility. In true military style these are, I understand, called respectively: GOGO, GOCO, and COCO.

Examples of GOGO would be the Naval Research Laboratory, the Army Ordnance Arsenals, the Fort Monmouth Signal Corps Laboratories, the Naval Ordnance Test Station (Inyokern), the Wright-Patterson Air Base Laboratories, and many others. In each case the facility is under the command of a military officer, and there is normally a chief civilian scientist to whom varying degrees of responsibility for the technical program may be delegated.

In the GOCO class we have such laboratories as Los Alamos, Argonne, and, indeed, all the AEC laboratories, plus such facilities as the Jet Propulsion Laboratory, operated by the California Institute of Technology, the Lincoln Laboratory operated by the Massachusetts Institute of Technology, etc. In these laboratories the land, buildings, and equipment are owned by the Government. However, after the general goals of the technical program have been agreed on jointly between the Government and the contractor, the contractor is given managerial responsibility for all operations. For example, all personnel and other administrative policies are set by the contractor—normally to be in line with those he employs in other operations.

Finally, in the COCO class come the great mass of contractual projects in industries and in universities. Some of these are small basic research projects only remotely related to a military problem. At the other extreme are vast industrial projects for development of a new airplane, a new radar, or a guided missile. Then there are establishments like this new Applied Physics Laboratory, and the Rand Corporation of Santa Monica, Calif., in which a privately owned facility is wholly devoted to government work—in these cases to a broad program of applied research rather than to the development of a single device.

Now it is easy enough to classify military research centers in this way. But it is not easy to draw any general conclusions from such a classification. It would be simple if we could say that all laboratories of one class were dismal failures while all of another were great successes. But in human affairs things are generally not so simple. We can find examples of successful and productive centers of all three kinds. We can also find members of each class which, let us say, have not been as productive as could be expected.

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The reason for this is not hard to find: research success in either basic or applied research is the product of good ideas; and ideas cannot be manufactured like automobiles on a production line. Ideas arise in the brains of individual people, and they arise under circumstances which no one—not even the individual himself—fully understands. We *do* know how to increase the *probability* of new ideas arising—and therefore increase their frequency. There are some simple rules for this:

1. Find some well-trained people who have been successful in getting ideas in the past.

2. Give them full information about the nature and importance of the problem being tackled.

3. Keep them in close touch with each other and with others engaged in similar work in such a way as to allow the maximum interchange of ideas—for out of such interchange and stimulation are new ideas frequently born.

4. Provide these people with the facilities and the help which they need in developing and testing their ideas.

5. Keep the environment, the atmosphere, and the administrative arrangements such that there is the maximum stimulation to imaginative thought processes and the minimum of interruption and frustration.

Even these rules are not very specific. They do not tell you how to find the right people, just how they are to be thrown together, what facilities they will need, or just what administrative arrangements provide maximum stimulation and minimum frustration. All these are delicate and subtle matters. They are also variable; a combination that works in one set of circumstances with one set of people may not work with others. Arrangements which are most satisfactory during an all-out war may prove hopelessly unsuitable in time of peace. An organization which is operating beautifully under one director may sink into mediocrity or worse under another. A research team which has delivered an outstanding contribution in the form of one new weapon falls to pieces when that job has been done, and never quite "clicks" on another.

All these are, as I have said, subtle and difficult problems. Their solution depends on the ability, the intuition, the adaptability, the imagination of relatively few people, possibly of only one person, in each organization. One person who can judge people, who can sense and who can *set* the spirit of the group, who can anticipate difficulties and avoid them, who can stimulate enthusiasm—such a person can make a successful team under almost any circumstances. And whenever you find a highly successful group I suggest you seek the causes for its success not in the organization chart, not in the budget

book, not by counting uniforms or rank, but by finding a man or a small group of men who have created the spirit of the place and who know how to preserve that spirit.

There really haven't been very many spectacularly productive applied research organizations—civilian or military—in this country. And the reason is just that so few men have been found who have this inner feeling for the spirit of organized research. It is something that cannot be advertised for, cannot be explained to Congress or to the Chiefs of Staff. But it is there, and it is very real, and it is vitally important that we seek it out and exploit it to the fullest when it does appear.

If one keeps in mind the essentiality of this intangible "spirit" of a research organization, one can understand why there are so many arguments about the best way to "manage" military research. There are in fact many ways to "manage" it—if the spirit is there. There is *no* way to manage it if the spirit is absent. From this point of view many of the familiar arguments fall into proper perspective.

For example, the argument about whether it is best in a laboratory to have a military or a civilian director misses the point. A *good* military officer will clearly be better than an incompetent civilian and vice versa. The main advantage of a civilian—assuming equal competence—is the matter of *continuity*—and continuity is very important in maintaining spirit. Also one is more *likely* to find able, inspired research directors among civilians, because many years of experience *in research* is helpful in developing this innate feeling for its spirit. Experience in a fighting organization is not intended to develop this same characteristic.

Again, the arguments about the relative merits of government operation versus contractor operation now fall into perspective. The Government can and does find and employ good civilians—and it has created some excellent applied research centers. However, the difficulties are somewhat greater. A government civil service bureau geared to employ a million clerks and secretaries may not be an efficient mechanism for employing a few hundred scientists. And a government financial system geared to a budget of 70 billion dollars a year may lack some of the flexibility needed for the rapidly changing needs of a research laboratory. For these reasons the Government, when it delegates applied research operations to a contractor, buys an important asset in additional flexibility of the administrative, personnel, and financial policies which a contractor may supply. And this flexibility is, in turn, an attraction to good scientists—thus increasing the probability of finding and maintaining high-quality leadership and performance.

We must, however, keep in mind that there are many types of so-called "research and development" enterprises under the military services, and each kind carries its own set of special circumstances, its own problems and restrictions. For example, if a new fighter aircraft is needed the only possible mechanism to obtain it is through a development contract with an aircraft company. No one thinks of any other scheme. On the other hand, if one needs a testing facility whose prime function is to test and evaluate many different kinds of ordnance equipment, say, and to evaluate their military usefulness, then a military establishment would appear to be appropriate. For the wide range of activities in between these on the one hand, and the pure research projects on the other, there is a range of choice of methods of operation. If one is starting from scratch he will, of course, if possible, choose a *modus operandi* which has the highest probability of success for that operation. The objective must always be to find a mechanism which is appropriate to the task and which has the greatest probability of developing and encouraging the creative spirit of research, and bringing that spirit to bear on the specific military problem at hand. An able team, ably led, which understands where it is going and why, will surely get there.

This brings me to a problem which I think neither scientists nor the military agencies have solved, namely, the problem of trying, at every stage in the development and use of new weapons, to bring together scientific *and* military experience. Every time an intensive effort has been made to do this in a particular area the results have been most fruitful—sometimes spectacularly so. I think of the Hartwell project, for example. But this should be a *continuous* process. It seems to me that it is the responsibility of every scientist and engineer who is working in a laboratory devoted to military purposes to keep himself continuously informed of the Nation's broad military problems and of the specific ones in his area. If he is working on a radar he should inform himself fully of the military situations in which it is to be or could be used. If he is working on a missile he should know what it is for, what other equipment it will be used with, what military problems it is intended to solve. A weapon designed in the dark, no matter how technically clever it is, may be of little or no military utility.

Conversely, of course, the military agencies have a responsibility. A weapon dreamed up as desirable by a soldier who is without access to knowledge about technological possibilities may also be a dud—or at least less effective than it could be. The point is that military and scientific people should do their dreaming together. They should be continually exchanging ideas about defense problems. The scientist may then hear of military situations he did not know existed—and

potential aids to meeting them may come to mind. Similarly the military officer, hearing about new weapon developments may see new possibilities for their tactical use or how they could be adapted to new situations.

The idea that the function of the military is to tell the scientists what weapons they need, and that the function of the scientists is to deliver them without argument, is as obsolete as the idea that the scientist can toss new weapons at random at the military and that it is their job to find a use for them.

We must face the fact that weapon development which will keep us ahead of our enemies is a tough business, and it requires the best combined talents we can muster at all stages of the enterprise. We have no talent to waste on either the military or civilian side. If military secrecy is interfering with this intimate meeting of minds then secrecy is working against national security, and it is time that *real security* considerations come first.

If I were to express a hope for the future of this Laboratory which we are dedicating here today, it would be that, as it maintains and develops the spirit of research that I have been talking about, it also becomes a meeting place where scientists and military men discuss broadly, intimately, and vigorously the problems of the military defense of this country. Out of such discussions will come, we can be sure, new and important concepts in the field of military weapons and their uses. Your business and my business is not just a better device for this or that purpose; it is, rather, nothing less than the safety of this Nation. And it is your responsibility and mine—not someone else's—to insure that each of us is making his most effective contribution to that end.

potential aids in meeting them may come to mind. Similarly the military officer, learning about new weapon developments, may see new possibilities for their tactical use which they could be employed in new directions.

The idea that the function of the military is to tell the scientists what weapons they want, and that the function of the scientists is to deliver them without argument, is as obsolete as the idea that the scientist can do a proper weapons job without close contact with the military and insight into their job to which weapons function.

We must face the fact that weapon development, which still lags in the field of conservative, is a tough business, and it requires the best combined talent we can muster at all stages of the development. We have no talent to waste on either the military or civilian side. Military secrecy is interfering with this, before the spreading of each other's secrecy is working against national security, and it is here that real security considerations come first.

If I were to convey a hope for the future of the laboratory which we are dedicating here today, it would be this, as it maintains and develops the spirit of research that I have been talking about, it also becomes a meeting place where scientists and military men discuss broadly, intimately, and intelligently the problems of the military defense of this country. Out of such discussions and ideas, must be carried out important research in the field of military weapons and defense. Your interest and my interest is not for a better device for this or that purpose; it is, rather, nothing less than the safety of this Nation. And it is your responsibility and mine—the people's—to insure that each of us is making his most effective contribution to that end.

The Development of Nuclear Power for Peaceful Purposes[1]

By Henry D. Smyth
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The structure of modern industrial society depends on plentiful supplies of energy. There is never enough. We are always seeking new sources. Yet we have not tapped the most generous sources of energy that nature has supplied to us—the winds, the tides, the rays of the sun. We have not yet learned how to harness these great natural forces.

Fifteen years ago a new natural force was discovered, the fission of uranium. Within the first 2 months of 1939 the idea of uranium fission was suggested, communicated, proved experimentally, and published. The speed and importance of this discovery constitute one of the most spectacular events in the history of science. It involved men of many nations, free communication, high imagination, and precise experiment.

In a world at war, the potential use of nuclear fission in bombs meant that vast sums of money were soon available for its exploitation. In 1945, only 6 years later, an atomic bomb marked the end of the second World War.

We are now engaged in an effort to harness this same atomic energy for peaceful purposes. It is a great effort and indeed should be so, for success in it may materially change the lives and conditions of men. The accident of history has placed the major responsibility for this effort on the Government of the United States. As its agent, the Atomic Energy Commission has brought together an array of scientific and engineering talent never before equaled. Private industry already is carrying a major share of our enterprise under

[1] Talk delivered at the national meeting of the American Institute of Chemical Engineers, March 9, 1954. Reprinted by permission from Electrical Engineering, vol. 73, No. 6, June 1954.

contract to the Government and is now becoming more and more active on its own initiative. This is as it should be.

Those of us engaged in this effort believe we shall be successful. We are so confident of success that we do not begrudge the years and the skill and the millions of dollars that are being spent to make available to man the kind of energy that heats the stars. But the road to success will be a long one. We know that it will have many dead ends and wrong turnings and many dull and dreary stretches. The barriers to be surmounted or bypassed are formidable.

By now we think we know what these barriers are, what kinds of problems have to be solved if nuclear power is to be significant in our economy. We should know these problems, for it is now 15 years since nuclear fission was discovered, 10 years since the first large-scale nuclear reactor was started, and 5 years since the Atomic Energy Commission announced its first program of nuclear reactors aimed at power. Energy from nuclear powerplants will be just like energy from coal-burning powerplants. Except for special purposes, the sole criterion of comparison will be cost.

The problems of reactor development today are best explained in terms of those which faced the designers of the first great reactors at Hanford. They are so fundamental that they will continue to be of major importance even though the emphasis may shift from time to time. Once I have defined the problems, I shall outline our present state of knowledge and the next major steps we are planning for their solution.

THE GENERAL PROBLEMS OF A NUCLEAR POWER REACTOR

Let me recall to you the three major facts of nuclear fission: First, that enormous amounts of energy are released; second, that the products of fission are radioactive; and third, that fission is caused by neutrons and results in the production of further neutrons, thereby making a chain reaction possible.

These basic facts confront the designers of reactors with a series of technical questions which can be grouped in five general areas. These general areas that have to be considered are, first of all, what we call neutron economy; second, the effects of nuclear radiation; third, heat transfer or removal; fourth, control and instrumentation; and fifth, chemical processing of fuel both before and after it goes into the reactor. Let me go into some detail about these five areas.

NEUTRON ECONOMY

It is evident that the first requirement of a nuclear reactor is that the nuclear chain reaction shall occur. In other words, if a uranium nucleus in a structure containing uranium does undergo fission, it must

produce neutrons in sufficient quantity to cause other nuclear fissions in the vicinity and to set up a self-propagating nuclear chain reaction. Actually the number of neutrons produced by a single fission is not very large. On the average, for every neutron used up in producing a fission, about 2½ new neutrons are released, a net gain of 1½ neutrons per fission. At first sight, this would appear plenty to produce a multiplication of fissions. Unfortunately, from the point of view of neutron economy, all the neutrons produced in a single fission are not absorbed in uranium 235 to produce additional fissions.

There are, in fact, four things that can happen to the neutrons that are produced in the fission process. First of all, since neutrons are extremely penetrating, they may simply escape to the outside environment. A second way in which they disappear is by capture by uranium 238 without causing fission. A third possibility is that they may be captured by impurities in the uranium or by the structural materials that have to be introduced for cooling or other purposes. The fourth possible process that can occur is, of course, the capture of neutrons by uranium 235 resulting in fission. If the fourth process produces more neutrons than are lost by the first three processes, the chain reaction occurs. Otherwise, it does not. Evidently, in a given arrangement the first three processes may have such a high probability that the extra neutrons created by fission will be insufficient to keep the reaction going.

One obvious way to reduce the probability of the escape of neutrons is to increase the amount of uranium present. The more uranium there is, the more likely it is that the neutrons will be absorbed in it and cause fission rather than escape. This leads, of course, to the concept of critical mass, which is familiar to many and which I will not discuss any further.

The second process we need to minimize is the capture of neutrons by uranium without producing fission. There are several things that can be done to minimize this process. Two of them depend on the great effect which the speed of the neutrons has on the probability of their absorption in uranium 238. This probability is reduced by using a slowing-down material, called a moderator, and arranging the uranium in a lattice. Another way to reduce nonfission capture by uranium is to eliminate part or all of the uranium 238 isotope, since it contributes very little to the fission process and does absorb many neutrons. Of course, in the Hanford reactors, this was not desirable because one of the objectives of the Hanford reactors was to produce plutonium by absorption of neutrons in uranium 238.

To reduce the third process, the nonfission capture of neutrons by impurities or structural materials, requires that the uranium itself be very highly purified in the first place and that structural materials be

used which have a low capacity for the absorption of neutrons. This last consideration puts many restrictions in the path of the designer of a nuclear chain reactor.

THE EFFECTS OF NUCLEAR RADIATION

The effects of nuclear radiation have several aspects that the designer needs to keep in mind. Perhaps the most important one technically is the fact that the constant bombardment of structural materials and of uranium itself causes changes in their properties. A piece of uranium, a piece of steel or aluminum in a nuclear reactor is continually bombarded by neutrons, by gamma radiation, and to some extent by other nuclear radiations. The result of such bombardment may be a change of shape, an embrittlement, a change in thermal conductivity, or of almost any other property of the material. The rate of corrosion of a material is affected by the presence of nuclear radiation.

Nuclear radiation is dangerous to health. Consequently, the whole reactor structure must be surrounded by a shield which will not be penetrated by the neutrons and other radiation. Radiation is present not only while the reactor is running, but induces a lasting radioactivity in the materials of the reactor. In particular, fuel elements in the reactor become highly radioactive, and when they are unloaded for chemical processing, they have to be handled by remote control. It is unsafe for any personnel to handle them directly. Similarly, maintenance must be held to an absolute minimum, and actual direct access of the operators to the heart of the reactor must be avoided.

HEAT TRANSFER OR REMOVAL

The principal interest in establishing a nuclear reaction is because the fission processes release such enormous amounts of energy, millions of times the amount of energy released in chemical reactions in corresponding amounts of material. To be sure, the Hanford reactors were not designed for the purpose of producing energy but for the purpose of producing plutonium. Nevertheless, the production of large amounts of energy is inescapably associated with the fission process, and, therefore, the designers of the Hanford reactors had to provide some means of removing that energy. It was a simpler problem for them than for the designers of a reactor intended to produce energy. The Hanford designers had merely to get rid of the energy in some way.

The designers of a power reactor must extract the energy in a form which can be put to use. Nevertheless, many of the problems are the same. They differ from ordinary heat transfer problems for reasons that have already been suggested, namely, that the choice of materials is limited by neutron economy, that corrosion effects may be enhanced

by the radiation present, and, finally, that the replacement of parts is difficult or impossible because of the health dangers involved. In a power-producing reactor, the temperature should be as high as possible so that the heat energy removed can be converted efficiently into useful power. This is a real difficulty as we shall see later on and is one point where the Hanford designers had a considerable advantage.

CONTROL

When the first reactors were designed, the question of control was a very critical one. No one knew very certainly whether it would be possible to prevent the reactor from running away with itself. We do not want to have a reactor heat up to the point where it will melt and destroy itself. We wish to avoid this for two reasons: first, we do not want to lose the reactor; and second, we do not want to spew radioactive material all over the countryside. By now we have had enough experience to relieve our concern about essential difficulties of control. We are perfectly sure that we can build a reactor which we can control. In fact, as I shall mention later, some types of reactor are self-controlling. There does remain, however, a problem of convenience, efficiency, and cost in designing the proper controls to start, stop, or maintain at a desired operating level the nuclear chain reaction.

CHEMICAL PROCESSING OF FUEL

Ideally, we would like to put into a nuclear reactor a certain amount of uranium and leave it there until all the uranium had been converted into heat energy and fission products. If that were possible, we would be concerned with chemical processing only in preparing the fuel. Unfortunately, the difficulties both of neutron economy as affected by the growth of fission products and of the corrosion or radiation damage of structural materials or fuel elements make it quite out of the question to consume more than a fraction of a nuclear charge in any known design of reactor. After a certain length of time—and one of the problems in the design of reactors is to make that length of time as great as possible—it is necessary to remove the fuel. It is too valuable to throw away, since it will probably still contain some 90 percent or more of the fissionable material. Consequently, we have to reprocess it chemically, separating out the fission products and refabricating the uranium into new fuel elements. This turns out to be one of the most costly processes in the whole business of operating a reactor for power.

I believe it is possible that the nuclear power industry will stand or fall economically depending on the success which chemists and chemical engineers have in developing cheap processes for purifying and refabricating nuclear fuel.

THE HANFORD REACTORS

I have been speaking of the general technical problems of reactor design. To be more concrete, let me recall briefly in specific terms how these problems are met in the Hanford reactors.

For neutron economy, the reactor is large. It uses graphite as a moderator, and the natural uranium fuel elements are arranged in a lattice. Both graphite and uranium are very highly purified. Cooling channels and protecting coatings of the uranium fuel elements are aluminum of minimum dimensions.

To shield operating personnel, the reactor is surrounded by heavy composite walls and all control and operations are from outside the shields. To reduce corrosion of the aluminum, the cooling water is purified and the temperatures held relatively low. To avoid corrosion or distortion of the uranium, it is canned in aluminum and not left in the reactor very long.

Heat is removed by large volumes of Columbia River water with relatively low exit temperature. The water is then held in retention basins before returning to the river.

Control is by neutron-absorbing rods that move in and out of the reactor. The position of the rods is recorded at the control desk and varied by the operators or automatically in response to instruments.

Chemical processing by a solvent extraction process is done in a separate plant to which the fuel elements are transported in shielded railroad cars, with all operations remotely controlled.

Fundamentally, it is the low exit temperature of the cooling water and the short life of the fuel elements that make this plant impracticable as a power source.

BREEDING

Uranium 235 is the isotope of uranium in which fission occurs most readily. Unfortunately, it is present in natural uranium only 1 part to 140. Natural uranium is none too plentiful, and to be able to use only seven-tenths of a percent of it is frustrating. Neutrons absorbed in the other uranium isotope, uranium 238, lead to the production of plutonium and plutonium is readily fissionable. This fact early suggested the possibility that a reactor could simultaneously produce heat energy from the uranium 235 in natural uranium, and produce plutonium from the uranium 238, and that then the plutonium could be used as fuel for further production of energy. It was even suggested that the plutonium produced might be greater in quantity than the uranium 235 burned up. Such a process is called a breeding process, since more fuel can be produced than would be burned.

This is, of course, a very fascinating idea. It turns out, however, that it may not be so very important whether actually more material is produced than is burned. It is obviously possible to produce some plutonium, since that is what the Hanford reactors are for, and it should be possible to take that plutonium and use it as fuel for power reactors. Whether the amount of plutonium produced is slightly less or slightly greater than the amount of uranium 235 burned up is not very important. We do, however, make a distinction in nomenclature whereby we call a reactor that produces plutonium in smaller quantity than uranium burned a converter, and one where the quantity produced is greater than that of uranium burned a breeder. In either case, it should be possible eventually to convert the fission energy of both isotopes of uranium to useful power. In the case of the converter, there would be some loss; in the case of the breeder, the losses in the reactor would be zero, but in either case there will be losses in chemical processing so that the difference is not very significant. The difference, however, between using just the uranium 235 and eventually using all the uranium in natural uranium is enormous and may well make the difference between an ample supply of nuclear fuel for many years to come and a rather scanty one.

THE FIRST ATOMIC ENERGY COMMISSION REACTOR PROGRAM

When the Atomic Energy Commission took over the plant and equipment of the Manhattan District in January 1947, the problems that I have been reviewing were already clear. Although the Commission's first responsibility was to prosecute the atomic weapons program with vigor, it soon turned to the possibility of atomic power, both for special military purposes and for ultimate peacetime uses. Early in 1949, Dr. Bacher, my predecessor as the scientific member of the Commission, made a speech in which he outlined the ways in which the Commission was attacking the problems I have reviewed. Essentially, the program consisted of a plan to build four major reactors. Let me describe three of these that have been finished at our Idaho Test Site and explain why they were built.

The first of them was the so-called materials-testing reactor, MTR. It was aimed primarily at getting information on the effects of radiation on uranium fuel elements or other materials that might be used as tubes for cooling water, or as coolants, or containers for uranium fuel elements. The object of this reactor then was to provide very high intensity radiation in a machine so designed that many experimental samples could be placed in it. It has now been running for about 2 years, and it has in fact proved exceedingly useful. Incidentally, it also was a novel kind of reactor and therefore was in itself a step toward the development of new types of reactors.

The second reactor built at Idaho was the so-called experimental breeder reactor, EBR. As the name implies, it was specifically aimed at demonstrating whether or not breeding was possible. It has demonstrated that breeding is possible and has had a number of other incidental interesting results.

The third reactor was a special-purpose one aimed at providing power for a submarine. You have heard a great deal about that one and about the submarine in which a similar reactor is now being installed.

In all three of these reactors, the neutron economy problem was solved by using uranium from which much of the uranium 238 isotope has been extracted. Whether or not, in the long run, this is the kind of reactor we will build for power purposes will be largely a question of economics. Personally, I doubt it, but I do not doubt the wisdom of having built these three reactors and the value of the results we have obtained from them.

A more modest undertaking initiated later is the homogeneous-reactor experiment at Oak Ridge. From the atomic point of view, the homogeneous reactor is misnamed. In reality, one can think of it as a lattice where the spacing is very small and the size of the fuel elements is of atomic dimension. To put it more simply, and in more familar terms, the homogeneous reactor is a solution of uranyl sulphate in water. The water serves as the moderator, and the uranyl-sulphate molecules serve as the fuel elements in which the chain reaction is set up.

The immediate and obvious advantage of the homogeneous reactor is that fuel fabrication and processing is enormously simplified. The solution is pumped continuously through the reactor chamber and then cooled in outside heat exchangers, and some of it can be continually bled off for purification and then reintroduced into the circulating stream of combined fuel and moderator. One of the interesting features of the homogeneous reactor is that it turns out to be self-regulating. As the temperature of the reactor rises, its reactivity decreases and therefore it controls itself. One difficulty that was anticipated in the homogeneous reactor was that the water itself would be dissociated by the radiation. This does occur, but it has been found possible to recombine the hydrogen and oxygen formed without too great difficulty.

In addition to the results obtained with the three reactors I have been discussing, and the homogeneous-reactor experiment, there has, of course, been an extensive program of study of the various associated problems in the laboratory. These range from fundamental studies of what causes radiation damage, or of the absorption probabilities of various materials for neutrons of various energies, to component testing in heat loops, and experimental fabrication of fuel elements. Some of

these studies use the various low-power research reactors that have been built.

One of the most interesting experiments that has been done was carried out last summer at the Idaho Test Site by Dr. Zinn, director of our Argonne Laboratory, and his associates. We had long worried about what would happen to a water-cooled reactor if the flow of water should be cut off. We were afraid that if the water supply was cut off or if the temperature of the reactor rose too rapidly boiling would occur and that this might have disastrous results. Dr. Zinn decided to make a direct approach to this problem and built a small reactor with the deliberate intention of producing boiling. When it was set up at the Idaho testing station, it had an arrangement in it which suddenly ejected the control rods so that the power generated by the chain reaction went up in a fraction of a second from a few watts to many thousands of watts. This had the expected effect on the water. It boiled. It boiled so violently in fact that it was ejected from the reactor in a small geyser. Repeated trials showed that in every case the boiling reduced the power of the reactor so rapidly that no serious damage was done.

This particular experiment illustrates very well the reasons for choosing an isolated area as a site for experimental reactors. It was not only that some of the reactors might be inherently dangerous, but it was felt that an experimental reactor, one built primarily for the purpose of obtaining information, should be operated to extremes, and that it was desirable to have such reactors in an isolated location for that reason. In other words, if you want to get as much information as you can out of a reactor, you need to push it to the point where it might conceivably run into trouble.

RESULTS OF THE PAST FIVE YEARS AND PRESENT STATUS OF THE ART

Let me summarize some of the major results that we have obtained in the past 5 years either directly from the reactors we have built and operated or from laboratory work. I will take them in terms of the five general areas that I enumerated at the start. So far as neutron economy is concerned we have learned a great deal about the probabilities of various nuclear events, including the relationship between the probability of fission and the energy of the neutrons. (This, for example, was tested in the experimental breeder reactor.) We have found that we can use a number of different substances as moderators, specifically beryllium, light water, and heavy water in addition to the familiar graphite.

As to the effects of radiation, the MTR has, of course, been of the greatest value as one might expect, since it was designed for that purpose. But we also have the benefit of studying the fuel elements

that have been in the EBR and in the submarine thermal reactor. These, too, have been valuable. We have a great variety of alloys and have tested various fuel elements. In particular, the submarine thermal reactor has shown that fuel elements sheathed in zirconium will resist corrosion and radiation effects over considerable lengths of time and represent a great improvement over the aluminum-sheathed fuel elements in the Hanford reactors. Radiation effects have also been studied in a variety of coolants including sodium and heavy water.

In the matter of heat transfer we have found we can remove the heat from a reactor by circulating molten sodium-potassium alloy through it. This is the system of heat removal used in the EBR. We have also done a great deal of work on pure sodium as a possible coolant and are using it in the second type of submarine reactor now under construction. We have also found that we can use a cooling system of pressurized water. This is the system used in the submarine thermal reactor. We have run reactors at much higher temperatures than we were ever able to run them at Hanford, and, therefore, we have moved in the direction of efficient use of the energy from nuclear fission.

As to control and instrumentation, the most striking results have been those already mentioned where we have found that certain types of reactors are in fact self-regulating as a result of boiling or near boiling as the temperature rises. The only other result I will mention is the use of hafnium as a material for control rods. Hafnium is present as an impurity in zirconium and has to be removed before zirconium cladding can be used for fuel elements because it absorbs neutrons. For the same reason it is very useful as a control material.

In the matter of chemical processing, perhaps it is fair to say that most of the work has been accomplished in the laboratory, although we have had experience with actual processing of the various types of fuel elements in the new reactors, none of which is exactly like those at Hanford. We have also proved that the homogeneous reactor will work, at least on a small scale, and we therefore know that that is one direction in which to hope for improvement.

In the matter of costs, we still have much work to do. None of the reactors we have actually put up is cheap, either to build or to operate. The submarine thermal reactor probably costs somewhere around \$1,500 or \$2,000 per kilowatt to build, which is to be compared with the cost of a modern steam plant—somewhere around \$180 per kilowatt. But the submarine thermal reactor does prove one over-all major result, namely, that it is possible to build a reactor for the production of power that will run continuously and efficiently for at least reasonably long times.

QUESTIONS STILL TO BE ANSWERED

The fundamental question still to be answered is whether a power-producing uranium reactor can be built which will compete with other sources of energy. The answer to that question will be found in the choice of some one of the kinds of reactors we have already built or thought about. None of them has yet been proved to be the ideal or even the best choice. The homogeneous reactor, for example, does simplify chemical processing, but it requires enriched fuel and it is not yet certain that the corrosion problems can be solved. The breeder has not yet been proved on any large scale so that we do not know at all how expensive that may be. The submarine thermal reactor uses such expensive materials for cladding the fuel elements that it is almost certainly not competitive, even though we may be able to produce zirconium at lower and lower costs. It also uses enriched material. And so it goes all through the list.

PROPOSED FIVE-YEAR PROGRAM

In the past few months we have been reviewing the results that we have obtained up to the present time and planning what would be best to do over the next few years in order to arrive at an economical solution of the problem of nuclear power. We have decided that there are six programs that we should pursue. One of these is the general program that we must obviously continue, the program of research on fundamental properties of materials, on nuclear reactions, on components that might go into the reactors of the future, and on chemical processes. This work will be continued principally in our Argonne and Oak Ridge laboratories. In addition to this general research and development work, we wish to build five reactors of varying size and cost. The Commission has recently submitted to the Joint Committee on Atomic Energy a special report on the reactor program prepared at the request of the Committee.

The first of these reactors in our new program has already been publicly announced. It is the so-called PWR reactor which is designed to generate at least 60,000 kilowatts of electric power. It will use slightly enriched uranium as fuel, ordinary water as a moderator and coolant. The reactor will be operated under reasonably high pressure and temperature—not nearly so high as are used in modern steam plants, but as high as we feel to be safe in terms of our present knowledge. Specifically, the water in the reactor will be under 2,000 pounds per square inch pressure and at a temperature between 500° and 600° F. Steam will be delivered to the turbine at about 600 pounds per square inch. The temperature is limited by the corrosion of the fuel elements and piping and container, and the pressure is

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limited by the strength and size of the vessel in which the reactor must be contained. One of the difficult problems in this reactor will be that of getting control mechanisms to operate in a high-pressure vessel. Principally, we hope to learn from this reactor how such a plant may stand up under ordinary operating conditions of a central-station electric powerplant and how much it costs to build and operate it. We have no expectation that this reactor will produce power as cheaply as a modern coal-burning plant, but we hope to learn how costs can be cut in later plants.

The second new reactor which we wish to build is a breeder of intermediate size. It will not be of direct interest from the point of view of economic power, but it will be much larger and much more nearly a power-producing, continuously-operating reactor than the small experiment we have been running out in Idaho. The scale-up planned is from 1,400 to 62,500 kilowatts of heat, and from 170 to 15,000 kilowatts of electric power. Temperatures and steam pressure will be increased to values appropriate to a full-scale power breeder reactor. Auxiliaries such as pumps, heat exchangers, valves, etc., will be of sizes suitable to a full-scale reactor.

Our third step is based on the boiling experiment that I have already described. It will be an attempt on an intermediate scale actually to use boiling of the water as a method of heat extraction. We hope in this way to get a very cheap method of getting the heat out of the reactor and possibly of eliminating one step between the coolant in the reactor and the turbines which turn the generator. It is planned to feed the steam generated in the reactor directly to the turbines. Present plans call for 20,000 kilowatts of heat and 5,000 kilowatts of electric power.

The fourth reactor which we intend to build is a larger version of the homogeneous reactor. Again, it will be a step in the direction of a practical power-producing unit and should give us information about corrosion, chemical processing, and operating conditions that cannot be obtained with the small machine now in use at Oak Ridge. Present specifications call for only 3,000 kilowatts of heat in this reactor experiment compared to 1,000 in the present experiment. The next step, already planned, calls for 65,000 kilowatts of heat in a homogeneous reactor which will breed uranium 233 in a blanket of thorium surrounding the chain reacting core.

The fifth reactor experiment which we plan to build is a little different from any that I have described. I have mentioned that the breeder reactor uses sodium-potassium alloy as a coolant. The Hanford reactors use graphite as a moderator. We hope to be able to combine these two materials, getting the advantage of high temperature without high pressure from the sodium coolant. To test this combination,

we will build a reactor generating about 20,000 kilowatts of heat but without any electric generating plant attached.

In addition to these new proposals, we shall continue several other programs already under way. These include the so-called intermediate submarine reactor now under construction at West Milton, N. Y., near Schenectady, and the development of a reactor to propel aircraft. Though the aims of both of these projects are special, they will undoubtedly contribute to the general technology.

COSTS

It is evident that we can build powerplants which will convert the energy released in nuclear fission into electrical energy to be fed into transmission lines. The question that has not been answered and may not be conclusively answered even by the program I have outlined is whether this power can be produced cheaply enough to be of general use. The Atomic Energy Commission believes that it can be done and this is the opinion also of the several private industrial groups that have been studying the problem for several years at the invitation of the Commission. At present, the power delivered by the submarine reactor at our Idaho plant costs about ten times as much as it would if we bought it from the Idaho Power Company. From this figure you can see that it will require all the ingenuity of our staff, our contractors, and private industry working together to get costs down, but it is reasonable to assume that eventually this will be done.

INDUSTRIAL PARTICIPATION

These private industrial groups I have mentioned are interested in more than just cost studies. They have assigned able members of their staffs to design studies of nuclear powerplants and in some cases are doing considerable amounts of research at their own expense. But it is a mistake to think that private industry can or will pick up the burden of development of nuclear powerplants in the present state of the art. It is a field in which knowledge and competence are still largely confined to government laboratories and in which the financial risks are still too great for private industry to carry alone.

The Commission hopes for greater and greater participation by industry both technically and financially and for a gradual transfer of the nuclear power part of the Commission's responsibilities to private enterprise. The many problems of such a transfer are too numerous for discussion here. Personally, I feel they are just about as difficult as the technical problems of getting cheap nuclear power. Time, money, and thought will be needed for both sets of problems. I believe they can be solved.

CONCLUSION

To establish a nuclear power industry in this country will be a great achievement. If power becomes cheaper and more plentiful, our material standard of living will be raised. In other countries the effect may be even greater. By the accident of history the first use of this great new discovery has been in the development of weapons of war, weapons of appalling magnitude. The nations of the world have today the means to destroy each other. They also have, in this same nuclear energy, a new resource which could be used to lift the heavy burdens of hunger and poverty that keep masses of men in bondage to ignorance and fear. Toward this peaceful development of nuclear power we have, all of us, a high obligation to work with all the ingenuity and purpose we possess.

Reprints of the various articles in this Report 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 Time Scale of Our Universe[1]

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INTRODUCTION AND HISTORY

The average scientist of half a century ago did not ponder much the question of the beginning and age of the universe. For lack of observational approach this problem remained outside the realm of exact science. It was generally felt that the universe should have neither beginning nor end, a viewpoint which was more influenced by opposition to former mythological or religious ideas of creation than by impartial reasoning.

Indeed, the second law of thermodynamics was well established at that time. According to this law, the universe is steadily running down toward equalization of the energy content of its parts. The ultimate state is that of universally constant temperature, "Wärmetod" or thermal death, where, in the absence of temperature differences, no exchange of energy, no relative motion except that of molecules could take place. Organic life, the metabolism of which consists in exchange of energy, could not exist then, even were the temperature favorable for life—which, in all probability, it would not be. The mere fact that temperature differences exist, that suns shine and planets carry life in the face of the immensities of cold space (into which heat energy is lost in the form of radiation), would point to the youthfulness of our world, to a beginning a finite interval of time ago.

Scientists of the beginning of this century preferred to ignore this writing on the wall. There were some reasons or, rather, pretexts which seemed to justify this eluding of the fundamental problem. The second law of thermodynamics, or that of increasing "entropy," determines only the direction, not the speed with which equalization is approached. The speed, depending on a number of unknown

[1] Armagh Observatory Leaflet No. 26. Reprinted, with some revision as of July 1955, by permission from the Irish Astronomical Journal, vol. 3, No. 4, December 1954.

processes, being itself unknown, no definite calculations of the time intervals involved could be made.

When going back in time, the second law leads to ever-increasing energy concentrations in the past; an unlimited past would lead to infinite energy concentrations, a concept which is physically unacceptable. Certainly some uneasiness was felt in this respect by those who did not want to draw the logical conclusion of a finite age for the present universe. But, then, there was Maxwell's demon, an imaginary intelligent being who could, at will, regulate molecular processes and thus do away with the law of entropy. This sufficed to show that the law is not absolute. The law is only of a statistical nature, exceptions being always possible although more or less improbable. Further, its validity for unlimited intervals of space and time was questioned. A perhaps not very justifiable complacency about the beginnings and ends of the world was thus sustained.

During the second quarter of this century a great change in the scientific outlook in this respect took place. The recession of the extragalactic nebulae, coupled with the finite age of the radioactive elements, suggested that there was a beginning a few thousand million years ago, the same for the galaxies and for the atomic material of which our planet is built. Following the above-mentioned phenomena back in time, moments could be reached beyond which the recession of nebulae and the decay of radioactive isotopes could not continue in the same manner as they do now. The two time limits were not found to be equal although they were of the same order of magnitude; but, within the uncertainties of theory and observation, they could be adjusted to each other. The idea of a finite age for the universe emerged. A stage, some 3,000 million years ago, was visualized at which the universe was closely packed together, when the temperature and density were high enough to invert the radioactive processes and to cause the building up of the heavy unstable isotopes at a rate equal to, or faster than, their total rate of decay (spontaneous+induced) in these conditions.

One view considered this stage merely the remotest phase of evolution of our world, beyond which extrapolation from the present state is not possible. It was not meant to be necessarily an absolute beginning—more likely it was not. The concept of age is thus reduced to that of a time scale, or a time interval during which the properties of the universe have radically changed. This definition appears to be somewhat vague; but it would imply nothing short of a complete absence, at the early stage, of all the classes of celestial bodies which are familiar to us now. In such a form the definition is stringent enough. Therefore, even if we could assign an upper limit of age to all existing stars, this would be only a subordinate time scale—that of stellar evo-

lution—unless we could prove the total absence of any stars before that date, and not only of those existing at present.

A more drastic view preferred the concept of an absolute beginning, perhaps identifiable with an act of creation. The definition of the time scale remained the same as before, but additional meaning was attached to it as that of the absolute age of the universe. The initial stage, a singularity from which the universe started expanding, was the limit of extrapolation not only from the present, but from any state of the universe, however close to the initial stage.

The difference between the two viewpoints is a matter of principle, and not of how the initial state of the universe is pictured. Although Eddington's primeval nebula, assumed to have preceded the present expanding state of the universe, could have existed indefinitely, it could equally well have been the first created object, called into being in a peculiar state of almost exact equilibrium between gravitational attraction and the hypothetical force of cosmic repulsion. On the other hand, Lemaître's primeval atom, "the egg from which the universe hatched," is most simply interpreted as the result of an act of creation; yet it could also have been the final outcome of collapse of a previous universe, oscillating indefinitely in alternating expansion and contraction. The choice between the two, continuous existence or creation, will remain a matter for esthetic judgment, not for positive science defined as theory verified by observation.

There is no proof in purely esthetic matters. This does not mean that esthetic methods of approach to scientific problems are worthless. On the contrary, scientific theories are created by intuition, or by an essentially esthetic process. However, without the flesh and bone of experiment such theories remain mere shadows of possibilities.

To remain on solid ground, in the following we will pay little attention to esthetic considerations, however important these might appear from the standpoint of philosophy or religion. We will, further, be guided by the principle of minimum hypothesis, or economy of thought, which requires that new laws of nature must not be used for the explanation of phenomena which can be accounted for by known laws. This is a safeguard against becoming lost in the blind alleys of guesswork. The chances are small that a theory not supported by facts would prove to be correct.

As already mentioned, the fundamental fact requiring a short time scale was, and remains, the red shift of the extragalactic nebulae. With the existing laws of nature this phenomenon is explained in the most straightforward way as recession. There are yet no facts known which would contradict this explanation. The Hubble-Humason law (1928) of proportionality of the red shift, or velocity of recession to distance, led to a time scale for the universe equal to a few thousand

million years. The uncertainty of the estimate depended upon how the rate of expansion of the universe, as revealed by recession, was assumed to vary with time. Nevertheless, various models of the expanding universe, based on different assumptions (de Sitter, Einstein, Friedmann, Lemaître, Eddington), gave figures within the same order of magnitude for the time of rapid change.

The new "short" time scale of some 3,000 million years was like a bombshell amidst the complacent "permanentists." At that time the pundits as well as the rank and file accepted a thousand times longer time scale for the stellar content of our galaxy alone, no mention being made of the universe as a whole. This "long" time scale, a multiple of a million million years, was mainly the outcome of mathematical investigations by Jeans into the statistics of stellar motions and the distribution of the orbits of double stars. Jeans assumed a state of "statistical equilibrium," or that the present motions of the stars are essentially influenced by their mutual gravitational action in past close encounters. A close encounter would mean the passage of another star through our planetary system at a distance—say, between Mercury and Neptune. Such a passage would leave both suns physically intact (although its effect on planetary orbits might be disastrous), yet their motions would be changed in much the same manner as those of two gas molecules after an elastic collision. Jeans actually applied the kinetic theory of gases to the stellar universe. Because of the great distances separating individual stars, close encounters can happen only about once in several million million years, a figure which can be arrived at by elementary calculation if the average velocity and distance between the stars is known. The "long" time scale was thus not a result of Jeans' elaborate mathematical theories, which were undoubtedly correct, but follow merely from his basic assumption of statistical equilibrium, implying that each star during its lifetime had a fair chance of undergoing several close encounters with other stars. In trying to prove his basic assumption, Jeans selected only certain statistical data which, superficially, seemed to agree with it, and, strangely enough, overlooked numerous more important criteria which contradicted his assumption. Thus, while carefully considering the effects of encounters on close binary stars, he disregarded the wide pairs and star clusters upon which the effects, according to his own theory, should have been thousands of times stronger. Indeed, with the long time scale these objects should have ceased to exist long ago, in contradiction to observation which reveals numberless wide double stars and loosely bound clusters in the sky. The evidence against statistical, "gas-kinetic" equilibrium is overwhelming, and there is no foundation whatever for the "long" time scale in our stellar universe. The battle of "short" versus "long"

time scale is definitely won by the former, although the latter did not yield without a struggle.

In the course of the controversy, arguments based on subordinate time scales were produced. These subordinate time scales—of the earth, the radioactive elements, stellar evolution, stability of binaries and star clusters—all fell below a not too large multiple of one thousand million years; as, moreover, some were obvious overestimates, they were considered as supporting the short time scale of the universe itself. An early, apparently the first, synoptic account of the evidence relating to the age of the universe concludes as follows (1) [2]: "the combined evidence presented by meteorites, by statistical data relating to wide double stars, by the distribution of stellar luminosities in globular clusters . . . , and by the observed recession of spiral nebulae . . . points to an age of the stellar universe of the same order of magnitude as the currently accepted age of the solar system: not much more than 3,000 million years." In this account stress was laid on radioactive age determinations of meteorites by Paneth (whose results were later greatly changed), and on the abundance of lead isotopes in the earth's crust as testifying to the age of the radioactive elements (results which have been corroborated since). Subsequent synoptic reviews invariably arrived at practically similar conclusions, formulated sometimes more, sometimes less cautiously, although, with the changing aspect of our knowledge and different personal approach, the emphasis was on different phenomena: radioactivity and the age of the earth, and stellar evolution with a hydrogen-helium source of energy (2); galactic dynamics (3); the stability of star clusters and binaries (4, 5); the red shift of nebulae and the radioactive age of the earth's crust (6).

The survival of the idea of the short time scale over two decades of intense astronomical and physical research is in itself a measure of its worth; it serves now as a generally accepted working basis in widely different fields of study.

In the following an attempt is made to draw an up-to-date balance for the problem of the time scale or age of the universe.

THE AGE OF THE EARTH

The continental shields of northeastern Europe, Canada, South and Central Africa, and others, where mountain building ceased at an early age of our planet's history, represent the oldest undisturbed portions of the earth's crust. All these regions are lowlands or plateaus devoid of mountain chains, and are free from earthquakes which are the sign of continuing upheavals. The age of these old formations

[2] Numbers in parentheses are references to the literature cited at end of text.

is expected to come nearest to that of the earth's crust or the earth itself.

The most suitable method of age determination of rocks consists in a comparison of the abundance of radioactive isotopes, such as those of uranium, with the abundance of their end products, e. g., lead isotopes. Pure minerals in the form of crystals are chosen for samples; there must be a guaranty that no exchange of substance between the sample and its surroundings has taken place, in which respect only individual crystals can be considered as reliable. Knowing the rate of decay of the radioactive substance, the time during which decay has been going on can be calculated from the amount of end product accumulated. The determinations are accurate to within 8 to 10 percent, much more accurate than the other astrophysical age estimates referred to below.

Radioactive age determinations yielded, indeed, high values for some mineral samples from the shields. Pegmatites from northern Karelia, in the so-called Baltic shield, gave an average age of 1,950 million years according to the lead method, but without isotope analysis (7). In the Canadian shield, lead isotope determinations for pegmatites from southeastern Manitoba resulted in an average age of 2,100 million years (8); for the same an average of 2,240 million years was derived by the radioactive rubidium-strontium method (7), in good agreement with the former value. At that remote epoch, unlike the present conditions, volcanic activity was prominent in the Canadian shield. The Manitoba pegmatites are associated with granitic intrusions into older rocks which reveal traces of a long previous geological history, and whose age can be estimated at 2,550 million years (12, 22). Recent very consistent lead-isotope age determinations (9) have yielded still higher values of age for some samples from the continental shields:

LOCALITY OF SAMPLE	AGE *Millions of years*
Ivigtut, Greenland	1,830
Yellowknife Area, N. W. T., Canada	2,140
Horseshoe Island, Great Slave Lake, Canada	2,180
Phoenix Mine, Norseman, W. Australia	2,190
Borderline Mine, Busia, E. Province, Uganda	2,220
Risks Mine, Kenya	2,220
Copperhead Mine, W. Australia	2,300
Inguladhal, Mysore, India	2,300
Sioux Lookout, Ontario	2,310
Steel Rock Lake, Ontario	2,360
Rosetta Mine, South Africa	2,860
Sierra Leone, Br. W. Africa (13)	2,930

Pegmatites from the Rhodesian shield, near Bulawayo, yield an age of 2,640 million years (10), yet the surrounding rocks—sediments

and lavas—are still older; and, what is more remarkable, remains of primitive plants—algal structures—are found there in graphitic limestone (Macgregor 1940, 1941). This provides "indubitable evidence that life has existed for at least 2,600 million years and probably for considerably longer than 2,700 million years" (10). Similarly, signs of organic remains are either found or strongly suspected in the rocks of Lake Superior and Manitoba, which are 2,000 to 2,500 million years old (11, 12).

Thus, direct measurements set the minimum age of the earth's crust at 2,900 million years, the oldest specimens being found in Africa. This confirms also a long-maintained belief that Africa was the first continent to be formed.

It is but natural to expect that the oldest rocks have not yet found their way into man's laboratories, and that the age of the earth's crust is greater than the presently known oldest sample.

An ingenious method, based on data for rocks of widely different ages from 25 to 1,330 million years as determined by Nier, led Holmes (14) to the calculation of the true age of the earth, or the time during which radiogenic lead has been produced in its materials. The method is one of extrapolation, consisting in the study of the observed relative isotopic abundances within one age group and their theoretical variation with time. The moment when the isotopic ratios, calculated backward for various age groups, become equal is the "beginning." Holmes found in such a manner 3,350 million years for the age of the earth. The oldest analyzed sample used in his calculation was 2,000 million years younger than this figure—a gap which might have caused considerable error in the extrapolation, as was pointed out by Jeffreys (15).

Recent data as quoted above push the directly observed age limit much farther back in time, and nearer the beginning. Applying the method of extrapolation to modern data, the probable age of the earth results as 3,500 million years (16), in excellent agreement with Holmes' former figure, but more reliable, the range of extrapolation being now only a few hundred million years.

The figure of 3.5 thousand million years can at present be accepted as a close approximation to the age of the earth—the time elapsed since its elements were uniformly mixed, probably in a molten state. The same figure, or one perhaps only slightly greater, can be considered the age of the solar system; the formation of the planets and of the earth's crust must have taken relatively short intervals of time (17).

The uranium and thorium content of iron meteorites is so small that their lead can be assumed to be of primeval isotopic composition, no radiogenic lead having been added in the course of time. If this

is so, the present average isotopic composition of lead, uranium, and thorium in the earth's crust indicates an age of 4,500 million years (18, 19), in remarkable agreement with a similarly determined age of stony meteorites (20). This would be the time elapsed since the separation of the iron from the silicate phase, which may have taken place in a diffuse state of matter and may have preceded the formation of the planets.

THE AGE OF THE ELEMENTS

Time intervals can be calculated only for radioactive elements with a known rate of decay. According to the well-known laws of radioactive decay, the amount of these elements decreases exponentially with time; calculating their amounts for distant epochs in the past, one inevitably arrives at time limits beyond which the calculated abundances of radioactive isotopes become unreasonably large—greater than those of the presently observed end products, or even greater than the total amount of matter in the universe. Clearly, the radioactive elements can only be of finite age. Now, the rate of decay of radioactive elements is not influenced by external conditions if the temperature remains below 1,000 million degrees and the density below, say, one million times that of water. Neither in the interior of normal (dwarf or "main-sequence") stars, nor in interstellar clouds from which suns and planetary systems are believed to have sprung, do such extreme conditions exist. We may well say that the state of matter in the observable universe requires radioactive decay to proceed relentlessly. As this could happen only for a finite interval of time, it would mean that the observable agglomerates of matter in the universe could also have existed for only a limited time.

Thus, at a remote epoch a building up of the radioactive isotopes must have taken place, in addition to their spontaneous or forced decay. Now, conditions leading to the formation of the heavy radioactive isotopes will throw the rest of the lighter elements into a melting pot, too—will cause their rapid building up and disintegration; this is a trivial consequence of the theory of nuclear structure. The age of the radioactive isotopes is thus almost synonymous with the age of the elements.

According to a method proposed by Russell (21), a maximum age for the elements can be derived from the relative terrestrial abundances of a radioactive isotope and its end product. It yields a maximum age, because some of the end product must have been created nonradiogenically in the initial "melting pot," when all the elements came into being under extreme conditions of temperature and density. Of the different isotopes, that leading to the lowest estimate of age is to be taken. The upper limit of age of the terrestrial elements thus found

equals 5 to 6 thousand million years, less than the double of the age of the earth (1, 16, 22, 23). The sharpest margin results from the uranium 235–lead 207 ratio. The closeness of the order of magnitude of the upper limit to the age of the earth is significant and makes it likely that the true age of the elements does not differ much from that of the earth—a figure of about 4,500 million years appearing to be plausible.

In these estimates there is some uncertainty from the unknown composition of the earth's interior, which, however, is hardly significant in view of the exponential law of variation of abundance ratios with time. Even a large error in the present ratio will not affect the order of magnitude of the resulting age. The mere presence of radioactive substances is a proof of the temporal origin of the terrestrial elements.

Except for meteorites, there are no data available as to the abundance of radioactive isotopes outside the earth; the above-mentioned time limit refers therefore strictly only to the sample of matter represented by our globe.

Although the relative abundances of the elements (excluding the lightest, which have escaped from small bodies like our planet) in the earth's crust and in the atmospheres of the sun and most stars are very similar, this does not necessarily mean a simultaneous origin for their elements. Only a similar mode of origin is implied.

Several attempts have been made to explain, with more or less success, the origin and relative abundances of the elements by equilibrium conditions inside superdense stars (Klein, Beskow, and Treffenberg; Hoyle; van Albade). Supernova explosions inject the mixture into space, whence it condenses again into new-born stars (24). Observations of the Crab Nebula (25), a former supernova, suggest that the product of explosion—the amorphous core of the nebula—is poor in hydrogen, whereas its hydrogen fringe appears to be interstellar gas pushed ahead of the expanding core. We may thus have a double origin for the elements: hydrogen already present in space with an unknown original content of other elements; and the heavier elements enriching the mixture through supernova explosions.

Old stars — those of "Population II" — seem to show, indeed, a smaller metal content than those believed to be more recently formed (26), suggesting a gradual change in the composition of the medium of which stars are built. If this is so, we need not go to the beginnings of the universe to account for the radioactive isotopes on earth: they may be the products of supernova explosions that preceded the formation of the solar system.

Nevertheless, serious doubts with respect to the latter conclusion are justified. The theory of stellar structure would admit the building

up of the lighter metal nuclei in superdense stellar cores (27, 28), as well as during the hydrogen explosion of a star that has become hydrodynamically unstable (24). From this, however, it is a long way to the extreme conditions at which uranium and similar elements of high atomic number can begin to be produced. Although light metals can, indeed, be currently supplied by the above-described mechanism, it is doubtful whether the heavy radioactive isotopes could originate in stellar interiors. More likely, these isotopes have come into being in a more powerful "explosion" which involved the whole universe, namely, that which happened at an early stage of its expansion. In that case the age of at least the heavier terrestrial elements would still be synonymous with the age of the world.

This leads us to another group of theories which explain the observed abundances of all elements, including the heaviest, by their building up from a nonequilibrium, extremely hot mixture (chiefly neutron gas) at an early stage of an exploding universe (Alpher, Bethe, Gamow).

It is possible that the lighter elements (say, those lighter than iron) have originated from two different processes—during the primordial explosion, and currently in stellar interiors—whereas the heavy isotopes were all created at the "beginning of the world"; in such a case, as shown above, the "radioactive" age of the universe, or the time elapsed since the big explosion, is about 4.5 thousand million years. However, unless the possibility of formation of the heavy elements in superdense stellar interiors can be definitely disproved, a certain ambiguity will remain attached to the meaning of this figure.

METEORITES

The pioneer work of Paneth 20 years ago raised hopes that radioactive age determinations of meteorites, based on their helium content, might yield a clue to the age of the solar system at least, or even to that of the whole universe (1). Unfortunately, the meteorites did not come up to original expectations. Paneth's struggle with this problem, which is not concluded yet, led over disappointments and disclaimers of former results; e. g., he announced that all his determinations prior to 1940 were technically unreliable. Paneth's researches are a remarkable example of a gallant fight for the truth, without bias toward his former work, some of which he rejected as soon as it was found that it did not comply with his own high standards.

The leakage of helium from meteorites to space was one of the many difficulties, and for this reason stony meteorites proved unreliable, so that only data referring to iron meteorites could be fully trusted. From refined analysis of the helium content of the latter Paneth found the ages of meteorites to lie between 100,000 and 9 thousand million

years. The higher values represented a puzzle as, for example, they considerably exceeded the upper limit of age for the earth and the solar system as set by the abundances of radioactive isotopes (cf. preceding section).

Now came the latest act of the drama. Bauer (29) and Huntley (30) pointed out that part of the helium in meteorites must have been produced by nuclear transmutations, caused by cosmic rays during millions of centuries. This suggestion has now become an established fact, as otherwise the presence in meteorites of the isotope He^3 in considerable amounts (18 to 32 percent of He^4) cannot be explained: radioactive disintegration leads to He^4 only, not to He^3. On the other hand, cosmic rays produce both isotopes in the approximate proportion of 10 He^4 to 3 He^3 atoms (Le Couteur). This ratio being given, an analysis by the mass spectrograph leads to the determination of the amount of purely radiogenic He^4, which is very much less than the total amount of helium. As a result, the estimated ages of meteorites are greatly reduced and, from the provisional data available, hardly attain 1,000 million years (31). This is much less than the well-established age of the earth and the solar system; therefore, the method is of no avail in estimating the age of the universe. It has been suggested that the meteorites lost their original helium when passing near the sun and melting in its heat; their orbits are sometimes likely to become highly eccentric from perturbations at close approaches to the planets, in which case near passages to the sun become possible. However, unpublished calculations by the writer show that such happenings are very rare, and that the explanation is invalid.

Urey (32) pointed out that iron meteorites are unlikely to contain enough radioactive elements to account for measurable amounts of radiogenic helium. The correlation between the total amount of helium and its isotopic ratio in iron meteorites is highly remarkable (31). In the opinion of the author of this review the simplest explanation of Paneth's results could be that all the helium is produced by cosmic rays, the absolute amount and isotopic ratio depending upon the original thickness of the protective layer, subsequently lost through ablation in our atmosphere. The time of separation of the stone and iron of meteorites, as determined from the isotopic composition of lead, is consistently found to be 4,500 millions years (20). This may refer to a preplanetary stage. Potassium-argon-40 ages of stony meteorites are found to be 1,900 to 3,800 million years (33) and 4,700 to 4,800 million years (34). Evidently there has been little or no escape of argon from stony meteorites. The argon ages would date from the moment of last solidification, thus probably from a planetary or postplanetary stage. Also, these high argon ages of stone seem to indicate again that the helium ages of iron inclusions, often connected with stone, are unreliable.

Meteorites point to an age of the solar system, or its parent nebula, close to 4,500 million years.

THE AGES OF THE STARS

At present there is little doubt that main-sequence ("dwarf") stars depend upon the conversion of hydrogen into helium for their energy source. The correlation of radius and mass, indicating central temperatures of precisely the range required by the corresponding slow nuclear reactions, can hardly be interpreted in a different manner. This knowledge is so well founded that it furnishes a reliable basis for the calculation of time rates of stellar evolution.

To cover radiation losses to space, the sun has to spend an amount of hydrogen very nearly equal to 1 percent of its mass in 1,000 million years. Sirius, a typical star of spectrum AO quite common in the galaxy, emits 13 times more energy per unit mass than the sun, consuming thus 13 percent hydrogen by weight in 1,000 million years. With 60 percent hydrogen originally, the store of energy would last 4,600 million years. There is probably not much mixing in stars outside their central regions (35, 36, 37, 38); therefore, only about 25 percent of the fuel is available (from the central regions where the temperature is high enough for nuclear reactions to proceed at a not-negligible rate), and the lifetime of Sirius becomes 1,150 million years. It may then become a giant (35), and ultimately collapse—possibly by throwing off its outer shell in a supernova explosion, leaving behind a remnant which ultimately becomes a white dwarf. The success in calculating "composite" models of red giants (39, 40), as well as Trumpler's classification of star clusters, lends support to this concept of stellar evolution. The more massive B stars will have a lifetime of a few hundred million years only. This being much shorter than the lifetime of the galaxy, which cannot be younger than the earth, it is concluded that the early-type stars are currently replaced by new stars condensing out of diffuse matter (35). Where diffuse matter is no longer available, early-type stars are absent and only giants of the corresponding luminosity remain, as is actually observed in globular clusters. Using Baade's terminology (41), Population II of the globular clusters, the galactic center, and the general galactic background, consists of aging members born at a remote epoch; whereas Population I, connected with the diffuse matter and spiral structure of the galaxy, contains young early-type stars steadily coming into being and dying, in addition to the background of less massive young and old stars, some of the latter existing from the very beginning of the galaxy (35, 42).

The absence of normal B and A stars from the globular clusters sets their age, as well as that of the galaxy, at more than 1,500 million years.

The energy source of the giants remains a puzzle. If we take their

persistent appearance in globular clusters as an indication of their longevity, a more powerful source of energy must be assumed for their maintenance (35)—either gravitation of their superdense cores, or annihilation of matter. On the other hand, these giants may represent short-lived objects in "statistical equilibrium" with the rest of the stellar population—those which blow up or collapse being replaced by others becoming giants. This latter concept would agree with the calculated red-giant models (39, 40) which are supposed not to draw on unknown sources of energy and are short-lived, their luminosities being abnormally high as compared with their masses. The giants of the globular clusters, as well as the short-period variables which should represent a phase preceding the giant stage, would then correspond to stars of more or less similar mass for which the exhaustion of hydrogen has reached a critical limit (35). Taking the observed luminosities with Schwarzschild's models, the limiting mass would be from 3.0 to 2.0 solar mass, indicating for the clusters an age between 800 and 2,500 million years.

The fork-shaped H-R (Hertzsprung-Russell) diagram of the globular clusters represents apparently the result of aging, in contrast to the continually rejuvenated Population I of our galactic surroundings (the difference in metal content having only a secondary effect). The globular clusters, which are all well outside the galactic plane and are not sharing in galactic rotation, will necessarily oscillate on both sides of the galactic plane, the period of oscillation being less than 100 million years (Oort). Thus, they must have repeatedly gone through the galactic plane. While passing for the first time through the plane, they must have been stripped of all their diffuse matter—which could have been but loosely bound by a gravitational potential of only 1/1000th that of the galaxy—through collision with the diffuse matter near the galactic plane; the mechanism is similar to that visualized by Spitzer and Baade (43) for collisions of galaxies. This would have prevented the subsequent formation of new stars in them. The stellar population of the globular clusters must therefore consist of members of almost the same age, which came into being when the galaxy was formed, and represents thus one of the oldest time indicators. The lower branch of their H-R fork appears to join the H-R diagram of Population I at absolute bolometric magnitude +2 (41); this should be the luminosity of old stars which have now arrived at the end of their career as dwarfs.

The evolution of dwarf stars, without much mixing of their substance, amounts to chemical changes around their central cores, where hydrogen is converted into helium; the composition of the outer regions remains unchanged. Öpik (27) has followed the evolution of such stellar models by numerical integrations. From these calcula-

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tions it can be estimated that stars which have nearly exhausted their central store of hydrogen yet remain dwarfs should be about 0.5 mag (or by 60 percent) brighter than "normal" dwarfs of equal mass. If we take this into account, it is estimated that the above-mentioned "ultimate" dwarfs in globular clusters, about 10 times brighter than our sun, should have a mass of 1.7☉. The total duration of the dwarf stage at this mass would be around 4,000 million years.

The numerical value of this estimate may be considerably in error; yet, qualitatively there is little doubt about the soundness of the interpretation which ascribes to the stellar population of the globular clusters the same age as that of the galaxy itself. By essentially the same method, but on the basis of more recent observational data, Sandage (44) finds an age of about 5,000 million years for the globular clusters. We may take the average of the two estimates, 4.5 thousand million years, as the probable age of the globular clusters, as well as of our galaxy.

Among the many data concordantly pointing to an age of the stellar universe of a few thousand million years, there is one which seemingly strikes a note of discord—some uneasiness may be felt about the high frequency of white dwarfs. If they are remnants of supernovae, which appear only once in a few hundred years, they would have required perhaps 100,000 million years to accumulate. However, at the beginnings of the galaxy, at the time when Population II was formed, star formation must have proceeded at a faster rate than now. The frequency of supernovae, directly related to the frequency of formation of massive stars, may then have been much higher (26). Further, the possibility of white dwarfs being formed in another way cannot be ruled out. Doubts as to the time scale cannot be maintained on such slender evidence.

Besides, a direct estimate of the age of individual white dwarfs can also be made, and this turns out to be in agreement with the other estimates. The energy source of white dwarfs can consist only in the thermal agitation of atomic nuclei (45) or upon explicit heat—like a kettle of hot water gradually cooling. The time of cooling, until the present state is reached, or the age of a white dwarf can be easily calculated when A, the mean atomic weight of this material, is known. Considering that all hydrogen must previously have been converted into helium, and that, before the "degenerate" stage of a white dwarf is reached, triple collisions at temperatures of a few hundred million degrees will convert all the helium into carbon, and then into lighter metals such as magnesium, we find that $A=24$ can be assumed, and Mestel's highest values for the ages of white dwarfs become equal to 4,000 million years. This may be near the age of Population II and the galaxy, in thrilling agreement with other estimates (27, 28).

STABILITY OF STAR CLUSTERS AND DOUBLE STARS

The dynamical stability of clusters has been investigated repeatedly, with the result that most galactic clusters will dissolve, either under the tidal action of the galactic center or through encounters with field stars or other members of the cluster, in time intervals of the order of 1,000 million years (46, 47). Although this statement refers to the future and, theoretically, is compatible with an unlimited past, the probability of simultaneous occurrence of a great number of old clusters which just now have come to the verge of disruption is very small. We may expect an average cluster to be observed in the middle of its lifetime, and assume, therefore, that the age of most clusters is some 1,000 million years or less. Yet, most of them contain early-type stars which cannot be very old. Consideration of the dynamical stability of clusters confirms thus the youth of their members, and adds another argument in favor of the theory that stars are being born continually. Apart from that, no new criterion of age for the galaxy is forthcoming—clusters which are older than their stellar content cannot be observed.

The situation is similar with wide double stars. The distribution of the distances between their components (48, 49) indicates that equipartition of energy cannot have taken place (50), and that the binaries could not have been subjected to encounters with field stars for longer than, say, 5,000 million years (4). On the other hand, the statistical material from which this conclusion is drawn is based chiefly on the relatively luminous A-type binaries which, according to the preceding, cannot have lived to so great an age, anyway.

Thus, conclusions as to age based on the dynamical stability of clusters and double stars are overruled by the shorter lifetime of their components, and can be used only to reaffirm the short time scale of stellar evolution.

THE RED SHIFT OF EXTRAGALACTIC NEBULAE

The observations by V. M. Slipher, Hubble, and Humason, if interpreted in a straightforward manner, indicate a recession of the extragalactic nebulae proportional to distance, or an expansion at a uniform rate of the visible portion of the universe.

Recent developments have shown, in a manner that leaves practically no doubt, that Hubble's scale of distances should be at least doubled. The distances of the nearest nebulae were determined by Hubble from the period-luminosity relation of the long-period cepheids. The zero point of this relation depended upon space absorption in low galactic latitudes, and was known to be inaccurate, but, for lack of better data, it was accepted and used during the past quarter of a century as a basis for work on the structure of the universe. Some cosmological theories

actually depended upon the particular value of the zero point and the resulting scale of distances. The unexpectedly large correction in the scale is a shock to all theories involving the so-called cosmological constant. We need not express regret that these theories were created—they were fully justified by the esthetic value alone—but, from the standpoint of economy of thought, the cosmological constant (equivalent to a repulsion) must be suspended from active duty for the time being and put in cold storage until new observational facts sound the trumpet for its revival. It is rather doubtful whether this ever will happen.

The zero point of cepheid luminosities affects only the distances of extragalactic nebulae. Within the galaxy, including the globular clusters, a more reliable criterion of distance is offered by the known luminosities of the short-period cepheids, the so-called cluster-type or RR Lyrae variables. The average luminosity of these Population II high-velocity objects does not depend so much upon space absorption, and is well determined. They were too faint to be observed in the nebulae by Hubble. In the Magellanic Clouds, whose estimated distances depended also upon long-period cepheids, persistent Harvard Observatory searches failed to reveal cluster-type variables, a circumstance sometimes interpreted even as indicating the actual absence of these objects.

Now, as last, numerous cluster-type variables have been found in the Magellanic Clouds (51), but about 1.3 mag (or 3.3 times) fainter than expected from the magnitudes of the long-period cepheids. Thus, the long-period cepheids are 1.3 mag brighter and all distances based on them 1.8 times greater than was formerly assumed. The apparent diameters and integrated luminosities of globular clusters in external galaxies call for a similar correction (52), and independent support for these conclusions is forthcoming from other sources (Baade).

This, however, is not the whole story. The recession constant of the nebulae depends entirely on the more distant objects, for obvious reasons; yet in these no variable stars could be observed. Their distances were linked to the cepheid scale of the nearer galaxies through intermediate criteria—the magnitudes of the brightest stars and of the nebulae themselves. Both criteria are of a statistical nature and not only involve various photometric errors, but also depend upon the true dispersion (variety) of the magnitudes of the objects used as standards; the dispersions, and therefore the distances, seem to have been underestimated by Hubble. A comprehensive survey of the problem has been given by Behr (53). He concludes that those of Hubble's intrinsic luminosities of the nebulae which are not based on variable stars should be increased by 1.7 mag. Behr was not aware of the need for adjustment of the cepheid scale of the nearest nebulae, and this

correction, evidently, must be added to that found by him. The total correction amounts thus to $1.7+1.3=3.0$ mag, or an increase in the distances of nebulae (except the nearest, which are based on cepheids) in a ratio of 4 to 1. The constant of recession, or the rate of increase of velocity with distance as based on observed red shifts, now becomes 145 km./sec. per magaparsec (3.25 million light-years), only one-quarter of the formerly assumed value. The expansionistic time scales are increased fourfold, and even the shortest will yield more than the lower limit—the age of the earth.

The retention of the cosmological constant by Eddington and Lemaître was justified by the need to extend the time scale; the slow phase of expansion, when gravitational attraction and cosmic repulsion nearly balanced each other, allowed this to be done almost indefinitely. Now, with the increased distances, cosmic repulsion becomes a superstructure of a purely esthetic nature, serving no practical purpose. Besides, Einstein, the originator of the concept, has disavowed the cosmological constant ever since, in spite of the then favorable numerical aspect of the problem.

Without the cosmological constant, the Friedmann-Einstein cosmological models (54) furnish a working hypothesis best suited to deal with the expanding universe. These models are very similar to an ordinary gravitating sphere in uniform expansion. Gravitation, working against expansion, is slowing it down. When the velocity of expansion is below a certain limit, the expansion will be ultimately stopped by gravitation, and contraction will start; when the velocity of expansion equals or exceeds the limit (velocity of escape), gravitation will be unable to stop it and the sphere will disperse into space, expansion never ceasing. According to the general theory of relativity, and without cosmological repulsion, a similar state of affairs in the expanding universe prevails. The first case, when expansion is ultimately stopped by gravitation, would correspond to positive curvature of space, or to closed space and a relapse of the universe, after maximum expansion, into the original state of high density (atom or nebula). The second case would correspond to zero or negative curvature, to open and infinite space, and to a one-way development of the universe by perpetual expansion.

For an expansion constant of 145 km./sec. per megaparsec the line between the two cases is set by a certain limiting value of the *average* density of matter in space (i. e., if all the matter of the universe were spread uniformly over its entire volume, instead of being concentrated into galaxies, stars, and atoms), equal to 3.9×10^{-29} gm./cm.^{3} The volume of the earth filled with matter of so low a density would contain only a mass of 42 milligrams.

The probable value of the average density of matter in space can be estimated in the following way. There are in the universe, on the

average, 12 nebulae per cubic megaparsec (55). The average mass per nebula, including intergalactic matter, can be estimated from the internal motions in clusters of galaxies according to the "virial theorem" (mean kinetic energy per unit mass proportional to the potential of gravitation); this, of course, depends upon the assumption that the clusters are held together by gravitation. The assumption can nowadays hardly be subjected to doubt, considering that otherwise, with the velocities observed, the clusters would have dispersed long ago; on the contrary, they are gathered so closely together that numerous interpenetrations or "collisions" of the member galaxies of a cluster must have happened during the lifetime of the universe (43). Repeated collisions must have led to "statistical equilibrium" in the distribution of velocities of the member galaxies; the similarity between the radial density distribution of nebulae in these clusters and that of an isothermal gas sphere (56) supports this assumption and the validity of the virial theorem. For the Virgo cluster a mass of 500,000 million suns per nebula results with Hubble's scale of distances (5), and four times as much with the corrected scale. These data lead to a world density of 2.5×10^{-29} gm./cm.^{3} or 64 percent of the critical density. If the result is taken literally, this would mean negative curvature, an open and infinite space into which the universe is irreversibly expanding.

However, the calculations are not exact enough to warrant unreserved acceptance of such a conclusion. The estimate has come astonishingly close to the critical density, and therefore, within the limits of uncertainty in the data, the alternative case of closed space and limited expansion followed by collapse is also possible. Indeed, Zwicky (57) finds considerable amounts of matter in the space between the galaxies, and favors a world density about 25 times that of our estimate, which would bring it far above the critical value. However, Zwicky's value is a very rough estimate, not based on the virial theorem. Our estimate of 2 million million suns per nebula would ascribe 90 percent of the mass to intergalactic matter (that between the galaxies) and only 10 percent to the galaxies themselves; this figure seems to be more realistic than Zwicky's, which would set the percentages at 99.5 and 0.5, respectively.

It is, perhaps, permissible to speculate on the closeness of the world density to its critical value, and to suggest an intrinsic reason for this near equality of the kinetic energy of expansion and the absolute value of the gravitational potential. The reason should be sought in the past history of the world. For example, an oscillating universe whose maximum world radius greatly exceeds the present value would lead to the above-mentioned near equality except when close to the phase of greatest expansion (which should be far ahead of present

time). In that case the time of expansion from the state of greatest density until today is insensitive to the precise value of world density, and depends only upon the rate of expansion; it is practically equal to that of uncurved (Euclidean) space and, with the revised value of the expansion constant, becomes

$$t = 4{,}500 \text{ million years.}$$

The figure is surprisingly close to the other estimates, although a considerable uncertainty is involved, the extreme admissible values being, perhaps, from 3 to 6 thousand million years.

This would represent the age of the universe in a restricted sense, or the time elapsed since it was in a highly condensed state. This state cannot yet be described. Lemaître's primeval atom is one of the possibilities. The theory of the origin of the elements, as shown above, does not provide a clue. The same is true of the cosmic rays, which appear to be of stellar origin and whose connection with the prestellar stage of the universe seems to be improbable (58, 59).

SPACE REDDENING OF THE GALAXIES

This phenomenon, announced by Stebbins and Whitford (60), and consisting in an increase of the color index of distant galaxies, not accounted for by the red shift, led to far-reaching speculations on observable effects of stellar evolution. The effect seems to be restricted to elliptical nebulae (purely Population II), whereas spirals (mixed populations) do not show reddening (61). The distant nebulae are observed at an earlier stage of evolution (on account of light time), and it has been suggested that the effect could be accounted for by the red giants of Population II disappearing with time (blowing up or collapsing), which would tend to make the population bluer. However, a multicolor study of the spectral-energy distribution of a distant elliptical nebula has shown that "the result is definitely not that expected from the death of red giants" (62). The effect continues to the greatest distances (63).

Vaucouleurs (64) suggested that the effect is due to the depression in the ultraviolet produced by absorption lines and bands. With the red shift the ultraviolet depression is displaced into the blue, making the blue-red color index redder. At least part of the effect can be accounted for in such a manner (65).

As to the spirals, they are known to contain a considerable amount of nebulosity in emission (66); this, especially that due to hydrogen, will fill the ultraviolet depression, counterbalancing the absorption. The absence of the reddening for spirals is thus explained without invoking stellar evolution. Over the time intervals involved, evolution may well affect individual stars, but considerable effects upon the entire Population II are unlikely.

In any case, the present evidence is inconclusive as to the reality of the space-reddening effect. Some residual reddening from absorption by intergalactic matter may exist. The question may be decided by two-color observations in yellow and red, avoiding the unreliable violet-blue spectral regions.

ALTERNATIVE HYPOTHESES

It has been repeatedly stressed that the nebular red shift may not indicate recession, and alternative suggestions have been made recently (Freundlich, Shelton). It is difficult to imagine a collisional process of reddening without simultaneous blurring of the nebular images (67). Further, the nonexpanding universe will be unstable and will end in collapse; or in expansion, if the cosmological repulsion is introduced. Thus, the present state would be exceptional, the normal state being one of Doppler shifts corresponding to real approach or recession. It does not seem advisable to sacrifice the solid concept of recession to a piling up of *ad hoc* new laws and improbable states.

Continuous creation of matter under various aspects (Kapp, Jordan, Bondi, Gold, Hoyle) is another alternative which would dispense with a finite age for the universe. It requires the retention of the cosmological constant (repulsion), or a pulsating variety of it (Kapp). For reasons similar to those given above these theories can at present be assessed only from the standpoint of their esthetic value. It is not easy to image observational criteria for them which cannot be explained away.

Perhaps the distribution of masses of the galaxies can provide the least objectionable proof. In Hoyle's expanding universe galaxies will continually grow by accretion, especially large ones with gaseous envelopes firmly bound by gravitation; the envelopes will act as nets catching atoms from interglactic space, or incorporating whole gaseous envelopes of smaller galaxies which happen to be in their way (43). They will grow almost indefinitely with time. Their frequency per unit volume in Hoyle's universe will vary inversely as the cube of age, thus more or less as the cube of mass, too; when selected by apparent magnitude, there will be no upper limit of mass and almost no correlation of distance with magnitude. The available evidence implies a frequency of nebulae in space decreasing with the 4/3 power of mass (68, 69), a definite upper limit of mass (66), and a correlation of distance with apparent magnitude. What evidence there is, is definitely negative.

CONCLUSION

The rate of irreversible processes in different physical complexes—the radioactive elements, the earth and the solar system, the stars, stellar systems, the galaxy, the observable portion of the extragalactic

universe—is such as to suggest an age not exceeding 6,000 million years for the universe in its present form and content. The extragalactic nebulae, with our galaxy and its backbone of Population II, may have been formed some 4,500 million years ago, the sun as a star of Population I coming into being perhaps later.

Cosmological repulsion is a theoretical superstructure which is not necessarily required by the existing observational evidence. The same is true of the continuous creation of matter and the alternative interpretations of the nebular red shift; these are mere possibilities, serving the purely esthetic purpose of denying the universe a temporal origin.

The observed velocities of recession exceed one-fifth of the velocity of light, the energy corresponding to a packing fraction (fraction of mass converted into kinetic energy) of 0.02 per nucleon (proton or neutron). Nothing short of an explosion from the densest-known state of matter—nuclear fluid—could be advocated as the cause. Our knowledge of the present density of matter in the universe is insufficient to decide between the two possibilities: that of open space, in which case the whole universe is an irreversible process of temporal origin, and that of closed space, in which the universe may return to its initial state, implying oscillations—the collapsing universe rebounding from the elastic forces of the nuclear fluid at a state of maximum compression, to begin a new phase of expansion.

It may appear at first sight that, at an advanced stage of collapse, when all individual bodies have melted into a uniform gaseous mass, the gaseous universe may be prevented from further collapsing by the elastic forces of the gas itself, like an oscillating gaseous star of which the cepheids are examples. However, it is likely that, with the enormous kinetic energy of contraction, the universe will first pass quickly through the stage of building up of heavy elements from hydrogen and helium, most of the hydrogen remaining unconverted before the next stage, that of nuclear dissociation and formation of neutron gas, begins—electrons being squeezed into and absorbed by the positively charged atomic nuclei. This is the reverse of the process by which Gamow and others visualized the origin of the elements after the explosion of the primeval atom. Formation of neutron gas absorbs enormous amounts of energy, and this, so to speak, blows the bottom off the resistance of the gas to compression. In such a case, the so-called ratio of specific heats of the gas (mixed with strong radiation) is less than 4/3 and, according to a well-known theorem on the structure of gaseous spheres, the universe becomes intrinsically unstable and cannot cease collapsing while in a gaseous state. Only when the perfect-gas laws no longer are valid, i. e., when the stage of nuclear fluid is reached, will there develop enough resistance to stop the collapse and invert the trend of events.

In the case where open space appears to be required by the physical characteristics of our neighborhood, we never will be sure of its validity for the universe as a whole. The possibility should not be overlooked that what we observe now is merely the metagalaxy—only a step in the hierarchy of physical systems. The observed expansion may refer only to this limited, although large, material system; in other parts of the world conditions may be different. The finite intensity of the sky background has often been advocated to prove the finiteness of the world. However, as shown by C. V. L. Charlier on purely classical lines, an infinite world is compatible with a finite intensity of the sky background if the universe is built on a hierarchical principle, systems of each order (atomic nuclei, atoms, planets, stars, clusters, galaxies, metagalaxies, etc.) being separated by distances considerably greater than their diameters. Such a "hierarchically diluted" infinite universe has a finite and small surface brightness even in the absence of absorption or Doppler shifts.

In the case of closed space the universe (the whole, or the observable metagalaxy), with all its energy content, including radiation, is bound to return to the initial state of nuclear fluid. This course of events is likely to repeat itself, the universe oscillating without external loss, implying an unlimited age in the past and in the future (time here meaning simply a succession of events, irrespective of its numerical value). All the structural phases will return time and again without, however, an "eternal recurrence of all things" in Nietzsche's sense—the individual celestial bodies in successive oscillations would not be identical, nor would their inhabitants. On the contrary, an unlimited variety of combinations and of prospects of evolution would be possible during each phase of the oscillation.

Some have expressed disgust at the idea of an oscillating universe, periodically repeating its general features (2). The present writer cannot see why this great repetition should claim a lesser esthetic value than, e. g., the annual succession of seasons so praised by poet and layman. Besides, not only is the repetition never literally exact, but, alas, we have no say in the matter—the Plan was laid down without our being consulted beforehand.

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Solar Activity and Its Terrestrial Effects[1]

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[With 2 plates]

In the year 1610 Galileo, using the then newly invented telescope, discovered that there were spots on the sun. He observed that they moved from east to west across the face of the sun and that they changed their shape and size from day to day, so establishing that they were not planetary bodies seen in projection upon the face of the sun.

For more than 200 years little more was learned about sunspots. In 1826 Schwabe, an apothecary of Dessau, commenced the systematic observations of the sun which he continued for nearly 50 years, making a record of the spots seen in his telescope on each day that the sun was visible. He soon noticed that the appearance of the spots was not accidental. In some years there were very few days of observation on which no spots were to be seen; in some other years there were many. In 1843 he announced that there was a periodicity in the appearance of the spots and this was fully confirmed by his further observations.

It may be remarked that the discovery of sunspots and their periodicity might have been made before the invention of the telescope, if the sun had been observed systematically when dimmed by haze near the horizon. Large spots are easily visible to the naked eye and a record of the appearance of naked-eye spots is adequate to reveal the periodicity.

The average length of the sunspot period is about 11.2 years, but there is a considerable range in the actual length of the cycle, which may be as short as 8 years or as long as 13 years. The height of the maximum can vary widely from one cycle to another; the maximum of the last cycle was the highest for more than a century. The rise in sunspot frequency from minimum to maximum is usually more rapid than the subsequent fall from maximum to minimum. The last

[1] Twenty-second James Arthur lecture, given under the auspices of the Smithsonian Institution on April 27, 1955.

maximum occurred in 1947 and the last minimum in 1954. The next maximum is likely to occur during the operations of the International Geophysical Year, July 1, 1957–December 31, 1958.

Sunspots occur only within two zones extending northward and southward from the equator to a latitude of about 35°. At the commencement of a new cycle, spots begin to appear in the outer parts of these zones; as the cycle advances they appear in progressively lower latitudes and in increasing numbers, completely leaving the higher latitudes. The mean latitude of the spots in each zone progressively diminishes until, toward the end of the cycle, few spots are found more than 10° from the equator. As the spots near the equator gradually die out toward the end of a cycle, other spots begin to appear in high latitudes, being the first spots of the new cycle. Thus there is always some overlapping between successive cycles. These features of the sunspot cycle are well illustrated by the so-called butterfly diagram (fig. 1) furnished by E. W. Maunder, Greenwich, in which is indicated the latitude of each spot appearing through a sequence of years. The figure shows the butterfly diagram from 1874 to 1954, compiled from the Greenwich Observatory data. Below is shown the mean area of the spots for each solar rotation, together with a curve representing the same data smoothed. The lower section of the diagram will be referred to later.

Strong magnetic fields are associated with sunspots. The intensities of these fields can be determined from the splitting of the lines in the sunspot spectra which they produce, known at the Zeeman effect. During the course of a cycle the polarities of the sunspot fields, which are opposite in the two hemispheres, remain unchanged, with few exceptions; during the next subsequent cycle the polarities in each hemisphere are reversed. Thus it seems that the length of the cycle is really 22 years, divided into the two periods of 11 years.

Various attempts have been made to represent the sunspot numbers over the past two centuries or so by the combination of a number of periodic terms. By taking sufficient terms it has been possible to provide a satisfactory representation of the observed numbers; but the predictions made from these representations have invariably rapidly diverged from the subsequent sunspot numbers and it can be concluded that the representation has no physical reality.

It is not possible to say when or where a spot will appear on the sun. Many spots are small and short-lived, lasting for not more than a few days; others grow rapidly and attain a great size, becoming easily visible to the naked eye; a large spot may last for several weeks, or even for a few months. The five largest spots on the sun during the 80 years of observation at Greenwich all appeared in the course of the recent cycle; the greatest of all appeared in April 1947 (pl. 1, fig. 1)

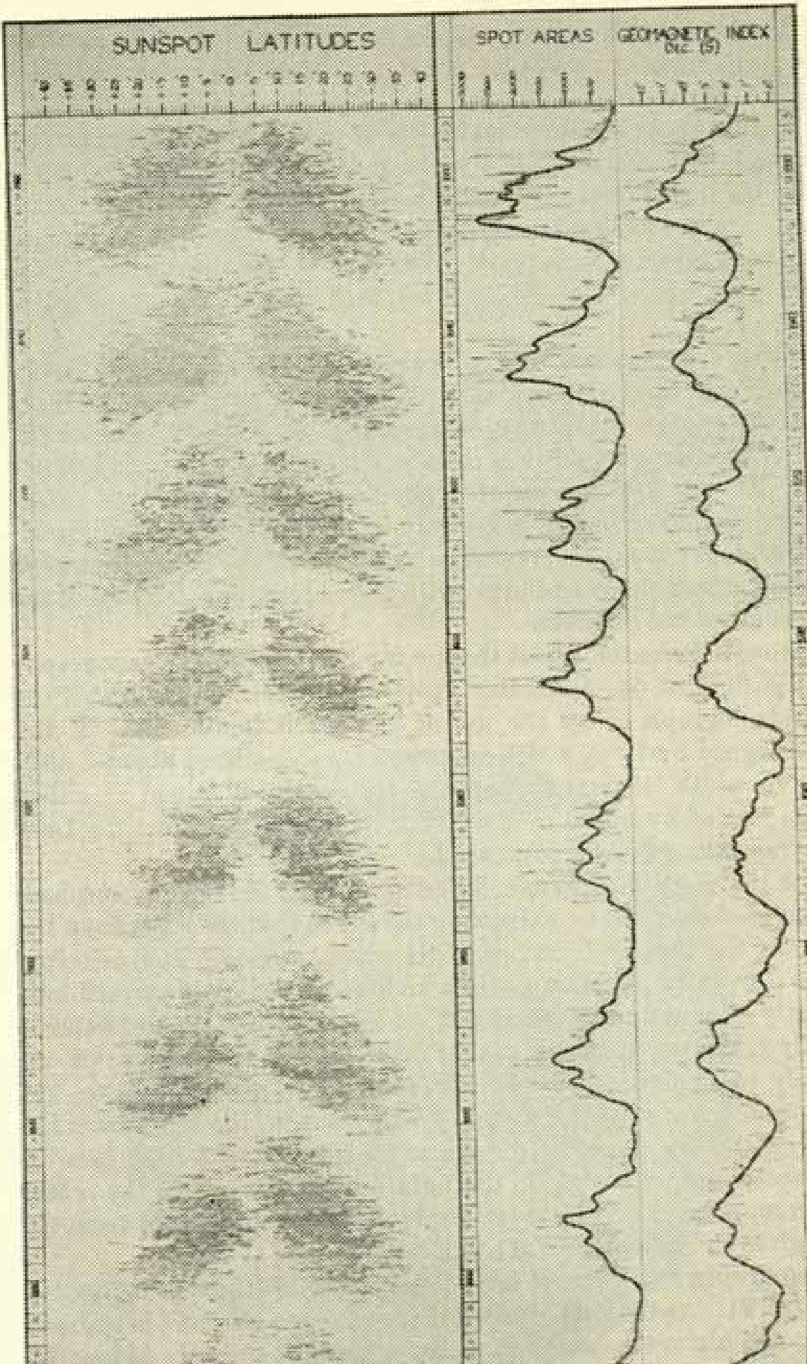


FIGURE 1.—Butterfly diagram, 1874–1954.

and at its stage of maximum development covered an area exceeding 6,000 million square miles, or about 130 times the equatorial cross section of the earth.

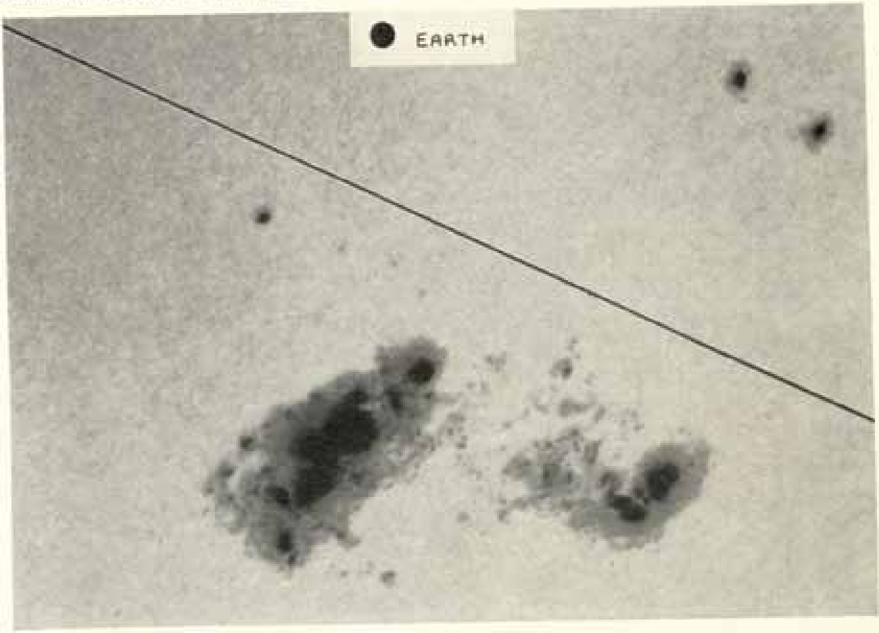
A typical spot consists of an umbra or dark center, surrounded by a penumbra in the form of a more or less complete ring, which is darker than the surrounding solar surface, though not so dark as the umbra. This darkness is only apparent, being the effect of contrast against the brighter surrounding disk, and is the consequence of the temperature of the spots being lower than that of the normal solar surface.

Around every sunspot group there is an irregular bright patch. In integrated light these patches are best seen near the sun's limb, where the surface brightness, because of absorption of light in the sun's outer atmosphere, is less than at the center of the disk. These bright patches are regions of higher temperature and are called *faculae;* they do not occur exclusively around sunspots, often appearing in regions devoid of spots. The total area of the faculae increases and decreases in close correlation with the increase and decrease of the sunspot areas and numbers.

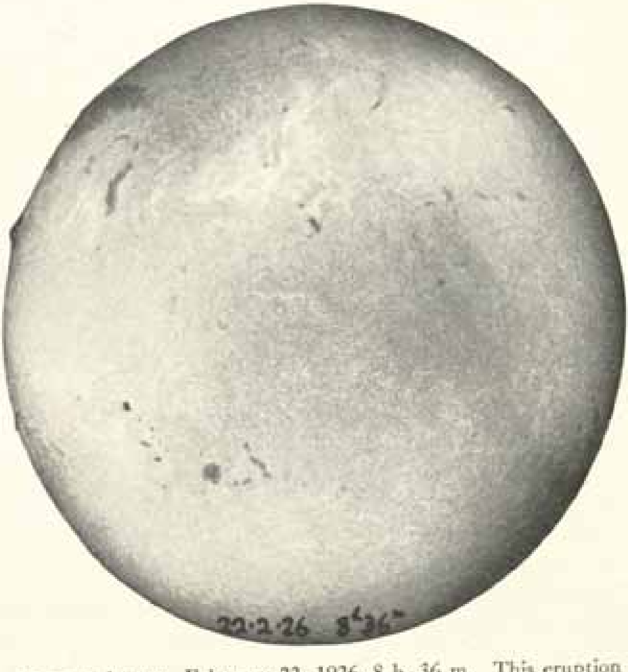
Further information about the sun can be obtained by photographing it in light of one particular wavelength, either by the use of the spectroheliograph or by the use of a monochromatic filter of the type designed by Lyot, which transmits a narrow band about 1 angstrom in width. Spectroheliograms are usually obtained in either the $H\alpha$ line of hydrogen or the K line of ionized calcium; the Lyot filter transmits a narrow band at $H\alpha$.

With the spectroheliograph, different levels in the sun's atmosphere may be photographed by narrowing the slit so that the light from the center of the line, or from one of its wings, is used. The principle can be illustrated as follows: when we look vertically downward into perfectly clear water we are able to see to the bottom; if the water is slightly turbid we can see to a lesser depth; if it is very turbid, we can see only to a small depth. In the center of an absorption line, the absorption is a maximum; a photograph taken in the light from the center of the line therefore gives a representation of a high level in the atmosphere; one taken in the light a little away from the center gives a representation of a lower level; one taken in the light from the wing gives a representation of a still lower level.

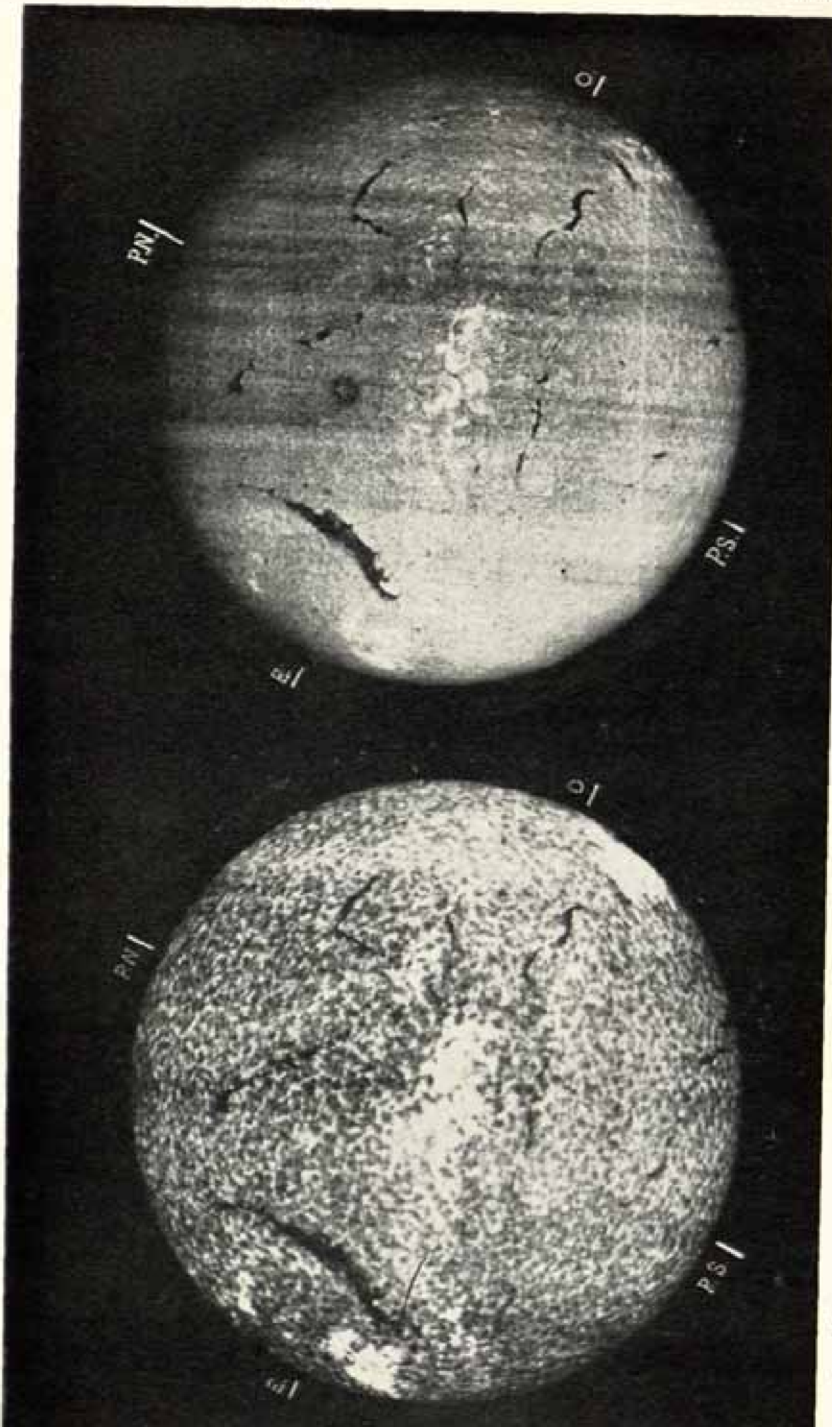
Photographs at the lowest level closely resemble those in integrated light (pl. 2). As the level is raised the faculae become more prominent and at the highest level the spots are usually completely hidden by them. In the K line of ionized calcium a coarse granulation structure appears, giving a mottled appearance, somewhat like the surface of a Seville orange. These clouds, fairly round in shape, are called *floc-*



1. Sunspot group of April 1947, with the earth shown to scale. This is the largest sunspot group to appear since the Greenwich sunspot observations were commenced in 1874. (Royal Greenwich Observatory.)



2. Bright eruption on the sun, February 22, 1926, 8 h. 36 m. This eruption was followed by a great magnetic storm commencing February 23, 16 h. 30 m. (Kodaikanal Observatory.)



Photographs of the sun taken (left) in light of the center of the calcium K line and (right) in light of the hydrogen alpha line. (Meudon Observatory.)

culi. In the Hα light of hydrogen, the flocculi are finer and more threadlike in structure and in the vicinity of sunspots show evidence of circulatory or vortex motions, which are in the opposite direction in the two hemispheres.

In the highest-level photographs, long dark markings, called *filaments*, appear. The filaments are much longer-lived than sunspots and are among the most stable of the solar markings. Many of them are associated with sunspots, from which they spread out in a north-south direction. Because the rotation of the sun is most rapid at the Equator and is slower the higher the latitude, a filament progressively changes its orientation in the course of its lifetime. When a filament comes to the edge of the disk it is seen to project beyond the limb, appearing as a *prominence* at the limb. The prominences, and necessarily also the filaments, consist of flames of incandescent gas at temperatures of from 10,000° to 20,000°, standing up above the surface of the sun, and often extending to heights of many thousands of miles. The prominences absorb light from the solar surface and the atoms of the gaseous matter re-emit it at discrete wavelengths in all directions; they therefore appear dark when seen in projection on the disk.

The frequency and latitudes of occurrence of the prominences vary through the cycle of solar activity. There are two principal prominence zones in each hemisphere. The more important of these coincides with the sunspot zones; prominences commence to appear in latitudes of about 30° N. and S., within a year or two after the epoch of minimum activity and, becoming more frequent as the spots become more frequent, follow the drift of sunspots toward the equator with a lag of several degrees in latitude; like the spots, they die out around minimum activity.

A second prominence zone commences in latitudes of about 45° N. and S. at about the time of sunspot minimum and moves toward the poles, reaching latitudes of 75° N. and S. shortly after sunspot maximum. In this zone the prominences occur most frequently some 2 years before maximum sunspot activity.

The prominences assume a great variety of forms. They may persist in a comparatively stable form for many months and then suddenly develop into an eruptive type, when the whole prominence may be rapidly dissipated away into space with a speed of several hundred miles a second.

In the vicinity of a large spot, particularly when it is in the stage of active development, a limited region of the sun's surface may become intensely bright. The area of the region affected may be as great as a few thousand million square miles. Such a solar eruption or *flare* (pl. 1, fig. 2), as the phenomenon is usually called, normally lasts for about

45 minutes. The first recorded observation of one of these flares was made by Carrington in 1859 and was described by him as follows:

> While engaged in the forenoon of Thursday, September 1, 1859, in taking my customary observation of the forms and positions of the solar spots, an appearance was witnessed, which I believe to be exceedingly rare. The image of the sun's disk was, as usual with me, projected on to a plate of glass . . . I had secured diagrams of all the groups and detached spots . . . when, within the area of the great north group (the size of which had previously excited general remark), two patches of intensely bright light broke out . . . My first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object-glass . . . for the brilliancy was fully equal to that of direct sunlight; but . . . by causing the image to move . . . I saw I was an unprepared witness of a very different affair. I thereupon noted down the time by the chronometer, and seeing the outburst to be very rapidly on the increase, I hastily ran to call someone to witness the exhibition with me, and on returning within 60 seconds, was mortified to find that it was already much changed and enfeebled. Very shortly afterwards the last trace was gone, and although I maintained a strict watch for nearly an hour, no recurrence took place. The instant of the first outburst was not 15 seconds different from 11.18 G. M. T., and 11.23 was taken for the time of disappearance. In the lapse of 5 minutes, the two patches of light traversed a space of about 35,000 miles . . . It was impossible, on first witnessing an appearance so similar to a sudden conflagration, not to expect a considerable result in the way of alteration of the details of the group in which it occurred; and I was certainly surprised, on referring to the sketch which I had carefully and satisfactorily (and I may add fortunately) finished before the occurrence, at finding myself unable to recognize any change whatever as having taken place. The impression left upon me is, that the phenomenon took place at an elevation considerably above the general surface of the sun, and, accordingly, altogether above and over the great group in which it was seen projected.

Carrington, at the meeting of the Royal Astronomical Society in November 1859, pointed out that a moderate but very marked magnetic disturbance was shown on the Kew magnetograms at about 11:20, September 1, of short duration, and that toward four hours after midnight there commenced a great magnetic storm. While the contemporary occurrence might deserve noting, he would not have it supposed that he even leaned toward hastily connecting them.

Carrington drew attention to two magnetic disturbances: the first was of short duration and synchronized with the observation of the outburst; the second followed some 17 hours later and was a great magnetic storm. He evidently suspected that they were connected in some way with the flare. This suspicion was no doubt suggested by the fact that a few years earlier Sabine and Wolf had independently found that there were similarities between the periodic variations in sunspot frequency and the range of diurnal variation in different components of the earth's magnetic field, such as declination, horizontal intensity, and dip.

The lower curve in figure 1 shows the diurnal variation in declination as measured at Greenwich from 1874 to 1923 and since 1923 at the Abinger Magnetic Observatory. The smoothed curve for the

diurnal variation shows a striking similarity to the curve of sunspot frequency, the diurnal range being from 60 to 100 percent greater at sunspot maximum than at sunspot minimum. When, however, the individual values of the sunspot areas and of the diurnal range in declination are compared, the similarity is much less apparent, as will be seen from the unsmoothed curve. The diurnal changes of the earth's magnetism are not therefore to be attributed directly to the spots themselves, though they must be due to some effect originating in the sun.

The daily motion of a suspended magnet needle is such that the needle points to the east of its mean position in the morning, moves westward during the day, and returns during the night. Some effect emanating from the sun and reaching the earth without sensible delay therefore appears to be involved. The passage of a large spot across the central meridian of the sun is often followed after a day or two by a magnetic storm, which suggests that an effect emanating from the sun reaches the earth with a time lag of one or two days. The central meridian passage of a large spot is not invariably followed, however, by a magnetic storm and, on the other hand, a storm may occur when there is no spot on the sun.

The ultraviolet light emitted by the sun causes photoionization (or splitting of molecules and atoms into free electrons and ions). There are two principal ionized layers: the lower, called the E-layer, is at an average height of about 120 kilometers; the upper, called the F-layer, has an average height of about 250 kilometers. During the daytime the F-layer frequently splits into two overlapping layers, referred to as the F_1- and F_2-layers; the F_2-layer is the higher, having an average height of about 350 kilometers, and is very diffuse. There is also a third layer, known as the D-layer, which has an average height of about 80 kilometers. The precise nature of the reactions taking place in these layers is not fully understood, though the photoionization by ultraviolet light from the sun of molecules of oxygen and nitrogen undoubtedly plays an important role. These ionized layers collectively form what is termed the *ionosphere*. Radio waves are able to travel round the curved surface of the earth because they are reflected by one or another of the ionized layers and prevented from escaping into space. Long waves, of wavelength from about 600 meters upward, are reflected principally by the D-layer, medium waves of wavelengths between about 200 and 600 meters principally by the E-layer, while the short waves of wavelengths from about 10 to 200 meters are reflected by the F-layer.

For each layer there is a critical frequency, depending upon the electron concentration in the layer, beyond which the radio waves are no longer reflected but penetrate the layer. Thus waves of medium frequency are able to penetrate the D-layer but are reflected by the

E-layer; those of higher frequency are able to penerate both the D- and E-layers but are reflected by the F-layer. Waves of very high frequency pass through all three layers. The critical frequencies beyond which reflection no longer occurs are subject to marked solar control. They depend not only on the daily and seasonal variations in the sun's altitude but also vary in sympathy with the frequency of sunspots. The dependence upon sunspot frequency implies a variation through the sunspot cycle in the degree of ionization in each layer and therefore also in the intensity of the radiation from the sun in the far ultraviolet, which is responsible for the photoionization; this radiation must be much more intense at sunspot maximum than at minimum, in order to account for the observed variation through the sunspot cycle in the critical frequencies.

The diurnal variations in the earth's magnetic field are associated with this ionization. For simplification we need consider only the lower and more important layer. It has a diurnal motion, due in part to its heating by the sun and consequent expansion and in part to the tidal action of the sun on the atmosphere. The layer, because of its strong ionization, is electrically conducting and behaves somewhat like a metallic conductor. Its diurnal motion in the earth's magnetic field therefore causes, by induction, an electric-current system, which may amount to many thousands of amperes, to circulate in it. This current system can be regarded as fixed with respect to the direction earth–sun, relative to which the earth itself is rotating. The magnetic effect of the current system at any point of the earth's surface therefore varies as the earth rotates, producing the diurnal variations in the earth's magnetic field. The correlation between the mean amplitude of the diurnal variation and the mean sunspot frequency is further evidence of a variation through the sunspot cycle in the emission of ultraviolet light by the sun. At sunspot maximum the emission in the far ultraviolet is of the order of 60 percent greater than at sunspot minimum. The close correlation between sunspot frequency and the rate of emission of ultraviolet light must be due to some underlying cause to which sunspots themselves are directly related.

Carrington had noted that a moderate but very marked magnetic disturbance had occurred at the time of the bright flare which he had observed and that it had been followed some 17 hours later by a great magnetic storm. With true scientific caution, though he suspected that these phenomena were related, he remarked that "one swallow does not make a summer." This same sequence of events has, however, been found to follow many intense flares in recent years. Carrington's observation of a flare in integrated light is almost unique; it is extremely rare for a flare to be so intense that it can be seen by ordinary visual observation of the sun. The flares are best observed in the light

of the Hα line of hydrogen, either visually with the spectrohelioscope or photographically with the aid of a monochromatic filter or with the spectroheliograph.

A characteristic magnetic disturbance which is termed a crochet is found to be associated with each intense flare. The amplitude of this magnetic disturbance is comparable with the amplitude of the normal diurnal magnetic variation. These crochets are better observed at places near the magnetic equator than at places in higher magnetic latitudes; this is understandable, as the effect on the ionospheric current system tends to be greatest near the subsolar point. The emission of ultraviolet light from a very bright flare is thus comparable with the normal emission from the whole of the sun's disk. There is consequently a great enhancement of ultraviolet light radiation from the sun during a flare, which gives rise to greater ionization in the ionosphere. The crochet is the magnetic effect associated with this increased ionization, arising from a great enhancement in the strength of the electric-current system in the ionosphere.

It is found that when a bright flare occurs on the sun there is a practically simultaneous fadeout in short-wave radio transmissions on channels passing over the sunlit hemisphere of the earth. The transmissions over the dark hemisphere remain unaffected. The enhanced emission of ultraviolet light from the sun, which occurs while the flare is in progress, causes the photoionization to extend to a much lower level, where the atmospheric density is much greater. The radio waves are then absorbed instead of being reflected and the phenomenon of a radio fadeout occurs. The suddenness with which a fadeout develops is very striking: in the course of a few seconds the radio waves can fade from normal intensity to complete inaudibility. This is a consequence of the extreme rapidity with which the outburst develops.

A secondary effect associated with the flare outburst is an enhancement in the reflection of the very long waves reflected by the D-layer, which is a consequence of the increased ionization in this layer produced by the flare. The occurrence of a flare is thus accompanied by a sudden enhancement of the atmospherics which come to us mainly from the tropical regions where thunderstorms are most numerous. Thunderstorms are occurring throughout the 24 hours somewhere or other on the earth; a receiver which records the integrated intensity of the atmospherics will show a sharp increase in intensity when a flare occurs. Such receivers have been built and provide a simple means of recording and timing the occurrence of flares which may not be observed because of cloudy weather and, if the weather is not cloudy, of enabling observations of a flare to be secured during its progress, if the sun was not already under observation at the time.

Carrington remarked that a great magnetic storm commenced at an interval of about 17 hours after he had observed the flare. Many other instance of magnetic storms following flares after an interval of 16 to 30 hours have since been observed. But not every flare is followed by a magnetic storm; for a storm to develop the flare must occur in a region of the sun that is not at a great distance from the central meridian. The time interval between the two phenomena indicates that the storm is produced by an effect that travels from the sun with a speed of the order of 1,000 to 1,500 miles a second. This is now known to be corpuscular or particle emission from the sun. The stream of particles is emitted in a direction nearly normal to the surface and will not meet the earth unless the region from which it is emitted is near to the central meridian.

A magnetic storm usually begins suddenly and at the same time all over the earth. Its duration is normally between one and two days. The intensity of the magnetic disturbance during a magnetic storm increases with magnetic latitude. In sufficiently high latitudes a bright auroral display is invariably seen during a magnetic storm and the most brilliant periods of the display synchronize with the most rapid and violent movements of the magnetic needle. Aurorae occur most frequently in a belt with a radius of about 23°, centered at each magnetic pole, a further indication of their relationship with the earth's magnetism. The frequencies of both magnetic storms and of aurorae increase and decrease with the increase and decrease in the frequency of sunspots. The corpuscular stream emitted from the sun, though on the whole electrically neutral, contains charged particles. As these particles approach the earth, they are deflected by the earth's magnetic field toward the magnetic poles. When they enter the earth's atmosphere, the electrical effects produced are seen as an auroral display, while the magnetic effects give rise to the phenomenon of a magnetic storm. During the magnetic storm there is widespread interference with radio propagation, which, unlike the radio fadeouts associated with solar flares, is not limited to the sunlit half of the earth.

The magnetic storm disturbance is attributed to an intense electric-current system circulating mainly within the ionosphere, but possibly in part also outside the earth's atmosphere. This current system is about one thousand times more intense than that which produces the normal diurnal variation. The currents are intense across the polar cap and particularly so over the zones of maximum auroral frequency, and they do not show the marked difference of intensity between the sunlit and dark hemispheres that characterizes the current system responsible for the diurnal variation. There is also evidence of an intense current flow over the magnetic equator. The phenomena which

accompany a storm are of great complexity and although they can be accounted for in their broad outlines, there is not as yet any completely satisfactory theory of magnetic storms.

There are some significant differences between great magnetic storms and smaller storms. A great storm is almost always associated with a large sunspot and usually occurs within a day or two of the passage of the spot across the central meridian. It is often preceded about a day previously by a bright flare.

The smaller storms may be, but usually are not, associated with a sunspot. They may occur when no spot is to be seen on the disk. Like the great storms, the small storms must be produced by corpuscular emission from the sun; the emission must sometimes, therefore, take place from regions where there is no visible spot. The frequency of great storms correlates very closely with the sunspot frequency; the smaller storms, however, reach a maximum a year or two after sunspot maximum and show a pronounced lag, as compared with the sunspots, during the period of decreasing sunspot frequency. Small storms often occur within the two years preceding sunspot minimum, when sunspots are few.

Both magnetic storms and aurorae show a tendency to recur after 27 days, which is approximately the period of rotation of the sun relative to the earth. This is to be expected if the particle radiation from the sun is produced by a cause which persists for longer than 27 days. A great storm, however, is very rarely followed by appreciable disturbance after a 27-day interval, while a small storm may have several recurrences at 27-day intervals. The small storms are on the whole longer lived than the great storms. It seems then that the mechanism which gives rise to the small storms is essentially different from that which gives rise to the great storms. The small storms mostly come from areas of long-lived disturbance. A connection with filaments which, as we have seen, are also long-lived, has been suspected.

Another solar phenomenon which is intimately linked with large sunspots, solar flares, and radio fadeouts is the emission by the sun of radiation in the centimeter and meter wavelengths. During the solar maximum of 1937–38 many radio amateurs reported a troublesome hiss in their 10-meter receivers, which they found to be associated with periods of solar activity. At various times during the last war radar transmitting and receiving installations recorded strong sources of noise which were at first thought to arise from enemy interference but which, on further investigation, were found to occur only when the aerial was directed toward the sun. As the sun radiates approximately as a black body with a temperature of about 6,000° K., some radiation in radio wavelengths is to be expected. But the intensity of such radiation would be very far below that which could be detected with the most sensitive short-wave receivers available.

Since the end of the war the radiation from the sun on radio wavelengths has been extensively investigated. It proves to be complex in nature. There is radiation from the normal quiet sun, and much more intense radiation associated with various aspects of the active sun.

The radiation from the normal quiet sun is much more intense than can be attributed to a black body with a temperature of 6,000° K. The intensity of the radiation on wavelengths from one centimeter to several meters has been measured. It is usual to express the intensity at any wavelength in terms of the effective temperature of a black body that would emit radiation of the observed intensity at that wavelength. Expressed in this way it is found that the effective temperature required to generate the centimeter waves is about 10,000° K., and that with increase in wavelength the effective temperature rapidly increases, so that a temperature exceeding 1,000,000° K. is required to account for the observed intensity at wavelengths of several meters.

When a large sunspot appears on the disk of the sun the radiation in radio wavelengths is much enhanced; its greatest intensity occurs at about the time of central meridian transit of the spot. The radiation is found to be circularly polarized, which suggests that it is connected in some way with the magnetic field associated with the spot. Whenever a flare occurs an outburst of radiation on radio wavelengths is produced, which is of a temporary character, lasting for several minutes only. Such outbursts do not occur simultaneously with the peak intensity of the flare but follow it with a lag of several minutes. This lag is not the same at all wavelengths or frequencies but is greater on the lower frequencies. The outburst occurs first on the short waves of high frequency and then on the longer waves, with lags increasing progressively with the wavelength. This suggests that there is an effect that travels outward from the sun.

The key to the solution of many of the perplexing problems which the sun presents will ultimately be provided by the corona, the faint tenuous appendage to the sun which extends outward from the sun for more than two million miles. Until recent years the corona, because of its faintness, could be observed only on the rare occasions of a total eclipse of the sun. But Lyot has shown that by making observations under favorable conditions at a high altitude, when the scattering of sunlight by the atmosphere of the earth is much reduced, and by careful design and construction of apparatus, so as to eliminate instrumental scattering, it is possible to see the corona by producing an artificial eclipse. The shape and structure of the corona change through the sunspot cycle. At sunspot minimum, there are long equatorial streams and, in the polar regions, short plumes or tufts; at sunspot maximum the corona shows a more uniform distribution.

The great extension of the corona implies a rate of decrease of density outward about 500 times slower than that in the sun's photosphere. The only logical explanation of such a small density gradient is that the coronal temperature is extremely high. It may be inferred that it is at least one million degrees, as compared with the sun's effective temperature of about 6,000°. This conclusion may seem absurd at first sight, but there is ample corroborative evidence. The corona gives a continuous spectrum, on which are superposed a number of bright lines; none of these lines has ever been observed terrestrially, nor, until the last few years, had they ever been detected in the spectrum of any other celestial body. Their origin was one of the major unsolved problems of astronomy. In 1942 Edlen showed that the principal lines were due to atoms of iron, nickel, and calcium from which a large number of electrons—from 9 to 13—had been stripped. To produce such a high degree of ionization, a correspondingly large amount of energy is needed, and this in turn requires a high temperature of the order of one million degrees. This high temperature provides an explanation, moreover, of why the Fraunhofer lines of the solar spectrum are absent from the corona. The velocities of the electrons in the corona are, because of its high temperature, so large that the absorption lines are broadened through the Doppler effect to a width of about 100 angstroms and are, therefore, completely washed out. On the other hand, the velocities of the iron and nickel ions, because of their greater mass, are only of the order of 20 km. a second; the width of the coronal emission lines should therefore be about one angstrom, which agrees closely with observation.

The radiation from the sun itself has maximum intensity at a wavelength of about 5,000 A., whereas the radiation from the corona has maximum intensity at about 30 A. and thus consists largely of X-rays. In the visible region the radiation from the sun is about 10^8 times that from the corona, but at a wavelength of 600 A. the radiation from the corona is about 10^6 times that from the sun. It is the radiation of about this wavelength that is responsible for the ionization in the earth's atmosphere, so producing the ionosphere. Theoretical investigations have led to the conclusion that the observed degree of ionization in the E-layer of the ionosphere requires radiation whose intensity is of the order of 10^5 that of a black body of a temperature 6,000° K. This high intensity of radiation, which at first appeared puzzling, is readily accounted for by the high temperature of the corona. The radiation on radio wavelengths emitted by the normal quiet sun is also explained by the high coronal temperature; its source is in the corona and not in the sun itself.

There has been much speculation about the mechanism by which the high temperature of the corona is maintained. One theory attributes it to the infall of interstellar dust, the kinetic energy of the dust par-

ticles being distributed as heat throughout the coronal matter. Another view is that it is produced by magnetic processes, associated with magnetic fields on the sun and the emission of high-speed particles, the corona possibly being heated by electric currents flowing within it. A third suggestion is that sound waves are generated by the turbulent motion of gases in the sun's atmosphere and that as these waves move outward into more tenuous regions they develop into shock waves, which produce the high temperature of the corona. These alternative views are all very tentative; no completely satisfactory explanation of the high coronal temperature has yet been given.

The increase in effective temperature from centimeter to meter wavelengths that is required to account for the observed intensities of radiation on radio wavelengths from the quiet sun, can be explained on the assumption that the centimeter waves originate in the level just above the visible surface of the sun, while the meter waves originate at a much greater height, where the temperature is much higher. If these latter waves were generated near the surface of the sun they would be absorbed and would be unable to escape into space. There is in fact for each level above the surface an appropriate critical frequency of escape, which progressively increases as we penetrate deeper and deeper through the corona toward the visible surface of the sun.

The increase in the lag between the visible flash and the radio outburst accompanying a flare, as the frequency decreases and the wavelength increases, is an indication, as already mentioned, of some effect that travels outward from the sun. It is probable that a stream of particles is shot out with high velocity when the flare occurs and that as the stream passes outward through the corona the highly ionized gas is set into oscillation and radio waves are emitted of wavelengths which are appropriate to the electron density at the particular height reached by the stream. We should expect the radiations of very high frequency to be excited first, then, as the stream moves outward, radiations of progressively diminishing frequency to be excited. This is in agreement with what is actually observed.

There are many problems presented by the sun which are as yet unsolved. The corona probably holds the key to many of the hidden mysteries. Further observations, supplemented by theoretical investigations, are required before a complete and satisfactory explanation can be provided. Intensive observations of the sun will be made at many observatories during the International Geophysical Year, when the sun will be at or near its maximum sunspot activity; during the same period there will be worldwide observations of ionospheric, geomagnetic, auroral, and other phenomena. The coordination of the solar and terrestrial observations will lead, it is hoped, to a more complete understanding of phenomena occurring on the sun and of the manner in which the associated terrestrial effects are produced.

Forty Years of Aeronautical Research

By J. C. Hunsaker
Chairman, National Advisory Committee for Aeronautics
Regent, Smithsonian Institution

[With 10 plates]

Before the Wrights' airplane flew, all the elements of the airplane were known: wings, rudders, engine, and propeller. The Wrights showed how to combine a man's senses and reflexes with the controls of a flying machine to make the machine both controllable about its attitude of equilibrium and steerable as desired. The secret of flight was manual control, in a three-dimensional fluid medium, in accordance with visual signals (the pilot's view of the ground and observation of his attitude relative to it—fixed axes of reference), and monitored by visual observation of the response to his control actions (feedback). The Wrights' airplane was, however, like the Wrights' bicycles, inherently unstable and was controllable only when it had sufficient forward speed. Controlled by the sight, brain, nerves, and muscles of man, the Wrights' unstable vehicle was the first practical flying machine in the history of the world!

The Wright airplane was quick to respond to control action because it had no righting tendency if disturbed. The pilot was expected to act at once to recover from any disturbance of equilibrium. There was no fixed tail to push it into a safe glide if the engine stopped.

The early pioneers of flight worked with gliders and with self-propelled models. They strove for inherent stability and conceived the ideal to be an inherently stable flying platform on which the pilot need do no more than steer. Pénaud's model gliders of the 1870's, with long tails, were stable; Lanchester developed prior to 1908 a theory of dynamical stability for his model "aerodromes"; Langley flew stable steam-powered models in 1896, and Bryan in 1903 published the dynamical equations of motion for a glider, and criteria for inherent stability. In all cases, stability was found to require a tail and slightly elevated wing tips.

As might be expected from complete and constant dependence on one man's sometimes defective judgments and reactions, the Wright air-

plane could be tricky and even dangerous, especially in rough air. Furthermore, the gasoline engines of the day were notoriously unreliable. As a result of what later came to be known as the stall, Wright airplanes too often dived into the ground out of control. The press blamed it on an "air pocket" or "hole in the air."

European airplane builders were prompt to copy the Wrights' system of control but soon discovered the dangers of instability. They abandoned the Wrights' form of structure but retained their system of controls on airplanes shaped more like successful gliders.

The world was astonished in 1909 when Louis Bleriot flew across the English Channel in his little monoplane. It had a long tail, tractor propeller, and wheeled landing gear. It was, in fact, the prototype of the airplanes of the next 20 years.

After 1910, with the mounting tension of approaching war, aeronautical development in Britain, France, Germany, Austria, Russia, and Italy was intensively pushed. Scientists, engineers, and industrialists were encouraged by their governments to devote their skills and resources to the new art. European progress was rapid, and at times spectacular.

While development of the airplane in the United States was dependent largely upon the efforts of a host of amateur inventors, there was in Europe a quick recognition of the gains to be had from aeronautical laboratories staffed by competent engineers.

The French were among the first to utilize scientific techniques in aeronautics. The army's aeronautical laboratory at Chalais-Meudon and Gustav Eiffel's private wind tunnel clarified some of the principles of powered flight. As early as 1904 Riabouchinski had an aeronautical laboratory in Koutchino, Russia, and the same year Ludwig Prandtl began his classic aerodynamic research at Göttingen University, Germany. After 1908, German aeronautical work as rapidly expanded, first at Göttingen and later at the government establishment at Adlershof, near Berlin. Italy provided an aerodynamics laboratory for her Specialist Brigade of Engineers.

Great Britain was relatively late in undertaking a national program of aeronautical research. However, Great Britain could record a full century of experiment. In the first half of the nineteenth century, Sir George Cayley had made important contributions, and Stringfellow and Henson had succeeded, as early as 1848, in flying a steam-powered monoplane model a distance of 120 feet. In 1866 the Aeronautical Society of Great Britain was formed; it served to stimulate research and experiment by individuals, and to provide a forum for interchange of information. Wenham (the Society's first president) and Phillips were the first to devise and use wind tunnels.

After the public demonstration of practical human flight by Wilbur

Wright on his 1908 visit to France and Bleriot's 1909 cross-channel flight, the British Prime Minister was moved to appoint an Advisory Committee for Aeronautics with the great physicist Lord Rayleigh as chairman.

During this same period the United States made no special effort. The Army Signal Corps bought a few airplanes to train pilots and the Navy set up a flying school equipped with Glenn Curtiss seaplanes. When World War I erupted in 1914 it was reported that France had 1,400 airplanes, Germany 1,000, Russia 800, Great Britain 400, and the United States 23!

DRIVE FOR A NATIONAL LABORATORY

The backward position of the United States in the application of applied science to this new art was realized by a growing list of prominent Americans who believed the situation was not only a national disgrace, but a possible danger to our security. More Americans, including the leaders in Congress, were strong for neutrality, and felt that any special government concern with aeronautical development might imply belligerent intentions.

Capt. W. I. Chambers, USN, officer-in-charge of naval-aviation experiments, proposed in 1911 that a national aeronautical research laboratory be set up under the Smithsonian Institution. Along with objections by both the War and Navy Departments, the plan was referred to President Taft's Committee on Economy and Efficiency, from which it was never returned.

Two men who were more influential in the drive for a national aeronautical laboratory were Alexander Graham Bell and Charles Doolittle Walcott. The former, as a regent of the Smithsonian Institution, had been a supporter of Langley and had experimented with the lifting capabilities of kites. With Mrs. Bell he formed the Aerial Experiment Association in 1907 to support the airplane experiments of Glenn Curtiss, Lt. T. E. Selfridge, F. W. ("Casey") Baldwin, and J. A. D. McCurdy. Their efforts resulted in the development of the Curtiss biplanes and the use of ailerons to replace the Wrights' wing warping for lateral control.

Dr. Walcott was no aeronautical scientist; his field was geology. But Dr. Walcott, as successor to Professor Langley as Secretary of the Smithsonian, was determined that the Institution should resume its position as a leader of aeronautical science in America. How better than to have the new aeronautical laboratory attached to the Smithsonian!

The establishment of a national aeronautical laboratory was pressed by members of the National Academy of Sciences, notably by Bell and Walcott. The Academy had been created by Congress during

the Civil War and had the duty of giving advice to the Government, when asked. The Academy, as a body, was not asked for advice on this matter, but its members appear to have been influential in persuading President Taft to appoint on December 19, 1912, a 19-man commission to consider such a national laboratory and its scope, organization, and cost, and to make a recommendation to the Congress.

The President's Commission was headed by Dr. R. S. Woodward of the National Academy of Sciences and the Carnegie Institution of Washington and included Dr. Walcott. The Army, Navy, Weather Bureau, and Bureau of Standards were represented, as well as interested civilians. The Commission recommended that the laboratory be established in Washington and administered by the regents of the Smithsonian Institution. President Maclaurin of the Massachusetts Institute of Technology objected to the location at Washington, which the majority report favored as "conveniently accessible to statesmen of the National Government who may wish to witness aeroplane demonstrations."

Unfortunately, the President had appointed the Commission without "the advice and consent of the Senate." Authorizing legislation failed to get unanimous consent and the Commission's report was buried in the archives.

Probably as a result of his service with the President's Commission, President Maclaurin in May 1913 persuaded the Corporation of M. I. T. to authorize a graduate course in aeronautical engineering and a wind tunnel for aerodynamic research in the Department of Naval Architecture. He requested the Secretary of the Navy to detail an officer of the Construction Corps to take charge. The writer was so detailed for 3 years.

At about the same time, the Smithsonian regents decided to reopen Langley's old laboratory, with Dr. Albert F. Zahm in charge. It was arranged by Walcott and Maclaurin to send Zahm and Hunsaker abroad, armed with personal introductions to scientific friends. Their objective was to visit the principal aeronautical research laboratories and, as far as possible, to learn how to operate the special facilities and equipment in use there with a view to duplicating them in this country.

Visits were made to the Royal Aircraft Factory, the National Physical Laboratory, and Cambridge University in England; to the St. Cyr, Chalais-Meudon, and Eiffel Laboratories in France; and to the Deutsche Versuchsanstalt für Luftfahrt and Göttingen University in Germany. In 1913, security restrictions did not apply to scientific and engineering work and the visitors were cordially received. In fact, the Massachusetts Institute of Technology later built its wind tunnel from drawings supplied by Sir Richard Glazebrook of the N. P. L. and had the N. P. L. aerodynamic balances dupli-

cated by Sir Horace Darwin's Cambridge scientific instrument shops.

Dr. Zahm's report, published by the Smithsonian in 1914, made clear the width of the gap between European and American positions in aeronautical science. This report had an important influence on the decision of the Smithsonian regents in 1915 to memorialize the Congress once again on the subject of a national aeronautical laboratory.

Woodrow Wilson approved the Smithsonian plan of reopening Langley's laboratory with representatives of the War, Navy, Agriculture, and Commerce Departments serving on an Advisory Committee. However, the Comptroller ruled that, under an Act of 1909, such an Advisory Committee could not serve without the authority of the Congress.

On December 10, 1914, the Chancellor of the Smithsonian, Chief Justice White, appointed Dr. Alexander Graham Bell; Senator William J. Stone of Missouri; Representative Ernest W. Roberts of Massachusetts, and John B. Henderson, Jr., regents; and Dr. Walcott, Secretary, to consider once again "questions relative to the Langley Aerodynamical Laboratory." On February 1, 1915, a "memorial on the need for a National Advisory Committee for Aeronautics" was delivered to the Speaker of the House. Pertinent sentences from the memorial follow:

> This country led in the early development of heavier-than-air machines. Today it is far behind. . . . A National Advisory Committee for Aeronautics cannot fail to be of inestimable service in the development of the art of aviation in America. Such a committee, to be effective, should be permanent and attract to its membership the most highly trained men in the art of aviation. . . . Through the agency of subcommittees the main advisory committee could avail itself of the advice and suggestions of a large number of technical and practical men. . . . The aeronautical committee should advise in relation to the work of the Government in aeronautics and the coordination of the activities of governmental and private laboratories, in which questions concerned with the study of the problems of aeronautics can be experimentally investigated.

The Navy heartily endorsed the idea in a letter dated February 12 and signed by Franklin D. Roosevelt as Acting Secretary.

ESTABLISHMENT OF NACA

The Joint Resolution establishing the Advisory Committee and authorizing the President to appoint its 12 members was given final form in February. The people of the United States were at the time generally anxious to avoid involvement in what was then called the War in Europe. President Wilson is said to have felt that the establishment of a new aeronautical enterprise might reflect on American neutrality. Such reasoning may explain why the Resolution was attached to the Naval Appropriation Bill; perhaps a more likely reason was that in the rush to clear the legislative "log jam" by March 4, the

date for adjournment of the Congress, Representative Roberts, Smithsonian regent, had found it simpler to effect its adoption by introducing the measure, as a rider to the Naval Appropriation Bill, in the Committee on Naval Affairs, of which he was a member.

Following is the provision in the Naval Appropriations Act, approved March 3, 1915:

An Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed twelve members, to consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than five additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences: Provided, That the members of the Advisory Committee for Aeronautics, as such, shall serve without compensation: Provided further, That it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct *the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems*[1] which should be experimentally attacked, *and to discuss their solution and their application to practical questions.* In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories: And provided further, That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President.

That the sum of $5,000 a year, or so much thereof as may be necessary, for five years is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available, for experimental work and investigations undertaken by the committee, clerical expenses and supplies, and necessary expenses of members of the committee in going to, returning from, and while attending meetings of the committee: Provided, That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures.

This language establishing the NACA closely followed that used by the British Prime Minister when he announced the formation of a similar committee to the House of Commons on May 5, 1909, in the following words:

It is no part of the general duty of the Advisory Committee for Aeronautics either to construct or to invent. Its function is not to initiate but to consider what is initiated elsewhere, and is referred to it by the executive offices of the Navy and Army construction departments. The problems which are likely to arise in this way for solution are numerous, and it will be the work of the committee to advise on these problems and to seek their solution by the application of both theoretical and experimental methods of research.

The work desired thus falls into three sections: (1) *The scientific study of the problems of flight, with a view to their practical solution.* (2) Research and experiment into these subjects in a properly equipped laboratory with a

[1] Italics in this and the following quotation supplied by the author for emphasis.

trained staff. (3) The construction and use of dirigibles and aeroplanes, having regard mainly to their employment in war.

The Advisory Committee are to deal with the first section, and also *to determine the problems* which the experimental branch should attack, *and discuss their solutions and their application to practical questions.* The second section represents the work referred to the laboratory (the National Physical Laboratory), while the duties concerned with the third section remain with the Admiralty and the War Office.

On April 2, 1915, President Woodrow Wilson appointed to the new Committee: Prof. Joseph S. Ames, of the Physics Department of Johns Hopkins University; Capt. Mark L. Bristol, USN, Director of Naval Aeronautics, Navy Department; Prof. William F. Durand, of the Engineering Department of Leland Stanford University; Prof. John F. Hayford of the Engineering Department of Northwestern University; Dr. Charles F. Marvin, Chief of the U. S. Weather Bureau; Hon. Byron R. Newton, Assistant Secretary of the Treasury; Prof. Michael I. Pupin of the Physics Department of Columbia University; Lt. Col. Samuel Reber, USA, Officer-in-Charge, Aviation Section of the Signal Corps, War Department; Naval Constructor Holden C. Richardson, USN, Department of Construction and Repair, Washington Navy Yard; Brig. Gen. George P. Scriven, USA, Chief Signal Officer, War Department; Dr. Samuel W. Stratton, Director, National Bureau of Standards; and Dr. Charles D. Walcott, Secretary, Smithsonian Institution.

Of the initial 12 members, 6 were members of the National Academy of Sciences (within the period of their NACA membership). It is of interest to note that for 40 years all chairmen of the NACA except the first, General Scriven, have been members of the National Academy. In 1955, there are 5 Academy members out of 17 members of the NACA. This statistic is of significance in view of the increasing impact on aeronautics of advances in many fields of science: for example, physiology and psychology of pilots, chemistry of combustion, physics of metals, physics of the atmosphere, acoustics, communications, electronics. The Committee is strengthened by the special knowledge of its individual members.

By direction of the President, the Secretary of War called the first meeting. The date was April 23, 1915; the place, his office. Conforming with the designation in the call for the first meeting, the word "National" was prefixed to the title "Advisory Committee for Aeronautics." General Scriven was elected temporary chairman, and Naval Constructor Richardson temporary secretary. With formulation of rules and regulations, subsequently approved by the President, the temporary chairman and secretary were elected for one year.

Perhaps the most important regulation adopted was for an executive committee, composed of 7 of the 12 members of the Advisory

Committee. The full Committee was to meet only semiannually. The executive committee was set up to meet regularly throughout the year and was charged with the administration of the affairs of the Committee and "general supervision of all arrangements for research."

Dr. Walcott was the first chairman of the executive committee. The other members were Dr. Ames, Captain Bristol, Dr. Marvin, Dr. Pupin, Colonel Reber, and Dr. Stratton, with Naval Constructor Richardson, ex officio, as secretary. Improvised quarters in the Army's Aviation Section were used the first year.

In the beginning the executive committee was a working group; the NACA had no paid personnel. It was not until June 23 that the first employee was hired. He was John F. Victory; 41 years later he is continuing his faithful, effective service to the Committee. In 1917 he was named assistant secretary of the Committee; 10 years later he became secretary, and in 1945, executive secretary.

One of the first problems was to examine what aeronautical research was then in progress in the United States—both under Government auspices and by private organizations—and then to effect rational coordination to assure maximum value from the total effort. Congressman Roberts, reporting on the need for the NACA on February 19, 1915, had well stated the situation:

> Besides these governmental agencies [he named the Bureau of Standards, the Weather Bureau and the War and Navy Departments] for the development of aviation, individuals in civil life have devoted time and expense in the scientific study and practical development of aeronautics. At the present time all of these agencies, both governmental and private, work independently without any coordination of activities.

Ten years later Dr. Ames gave a prime reason for "the great success of the Committee, because the Committee is a success," the coordination, on a rational scale, of American aeronautical research. His comments were made before hearings of the President's Aircraft Board (often called the Morrow Board). He spoke as chairman of the executive committee, to which position he had been elected when Dr. Walcott became Committee chairman in 1919.

In part, Dr. Ames said:

> The organization has an Executive Committee which appoints a number of tchnical subcommittees whose function it is to coordinate the research work throughout the country . . . . The various problems which all the services of the Government and the people engaged in industry, so far as we know, have in mind are brought before these subcommittes. The importance of each problem is discussed, and a program is laid out . . . .
>
> Around our table meet . . . representatives from all the Government services involved . . . . We work for all the departments of the Government.
>
> Furthermore, there are discussions going on at our table between the Army and the Navy and all other people interested which otherwise would not take place. We are really a coordinating body and that function would be impossible

if our organization were to be transferred to any executive department as such, because if our Committee were to be a part of any department it would necessarily follow that the aeronautical needs of that department would be primarily served . . . .

We think, therefore, that in our independent existence we offer a wonderful opportunity for serving all the departments.

In 1915 one of the first projects undertaken by the executive committee was a survey of facilities available "for the carrying on of aeronautic investigations." It was determined that "a number of institutions have available mechanical laboratories and engineering courses capable of application to aeronautics, but only the Massachusetts Institute of Technology and the University of Michigan so far offer regular courses of instruction and experimentation." Note was made of the experiments with full-scale propellers mounted on a whirling table, being conducted at Worcester Polytechnic Institute.

"It appears that the interest of colleges is more one of curiosity than that of considering the problem as a true engineering one, requiring development of engineering resources and, therefore, as not yet of sufficient importance to engage their serious attention," the NACA commented in its first Annual Report. "Manufacturers are principally interested in the development of types which will meet Government requirements or popular demand, but which will not involve too radical or sudden changes from their assumed standard types."

The Committee recognized that "considerable work had already been accomplished with which the general public is not acquainted." The Annual Report said of this point: "This covers lines of development and investigation which if published would save money and effort on the part of individual investigators and inventors who are now duplicating investigations already made by others . . . . Some of this information is already embodied in reports which are only accessible to a few interested parties who know of its existence."

The Smithsonian Institution had published a bibliography of aeronautics, covering the period through the middle of 1909. Now the NACA undertook publication of later bibliographies compiled by Paul Brockett of the Smithsonian. The first such volume covered the period 1909–16; as soon as past years had been "caught up," the bibliography was published annually into the early thirties.

The Committee was fully aware that to fulfill its obligations would require not only a well-equipped, suitably staffed laboratory, but also a flight test center where engineers could determine "the forces acting on full-sized machines." It was felt, however, that "since the equipment of such a laboratory as could be laid down at this time might well prove unsuited to the needs of the early future, it is believed that such provision should be the result of gradual development."

In October 1916 the Committee recommended that the War Department (which alone had funds available) purchase land about 4 miles north of Hampton, Va., for use by the Army and Navy as an aircraft proving ground. Named Langley Field, this site became the home of NACA's first research center. The War Department used it for pilot training during World War I. Aircraft development work of both the Army and Navy was centered elsewhere.

Lacking its own facilities, the NACA took prompt steps to contract for research to be performed for it by others. The first annual report included seven reports, as follows:

No. 1. Report on behavior of aeroplanes in gusts, by the Massachusetts Institute of Technology.
- Part 1. Experimental analysis of inherent longitudinal stability for a typical biplane, by J. C. Hunsaker.
- Part 2. Theory of an aeroplane encountering gusts, by E. B. Wilson.

No. 2. Investigation of pitot tubes, by the United States Bureau of Standards.
- Part 1. The pitot tube and other anemometers for aeroplanes, by W. H. Herschel.
- Part 2. The theory of the pitot and venturi tubes, by E. Buckingham.

No. 3. Report on investigations of aviation wires and cables, their fastenings and terminal connections, by John A. Roebling's Sons Co.

No. 4. Preliminary report on the problem of the atmosphere in relation to aeronautics, by Prof. Charles F. Marvin.

No. 5. Relative worth of improvements on fabrics, by the Goodyear Tire & Rubber Co.

No. 6. Investigations of balloon and aeroplane fabrics, by the United States Rubber Co.
- Part 1. Balloon and aeroplane fabrics, by Willis A. Gibbons and Omar H. Smith.
- Part 2. Skin friction of various surfaces in air, by Willis A. Gibbons.

No. 7. Thermodynamic efficiency of present types of internal-combustion engines for aircraft, by Columbia University.
- Part 1. Review of the development of engines suitable for aeronautic service, by Charles E. Lucke.
- Part 2. Aero engines analyzed with reference to elements of process or function, by Charles E. Lucke.

"What has already been accomplished by the Committee has shown that although its members have devoted as much personal attention as practicable to its operations, yet in order to do all that should be done technical assistance should be provided which can be continuously employed," the Committee said in its first Annual Report.

For the fiscal year 1917 the NACA asked for and received $85,000. Of the funds available, $68,957.35 (all that was not spent otherwise) went toward construction of the new laboratory at Langley Field. Its total cost was estimated at $80,000, a figure that later was revised upward.

The war was over before the "Committee's field station" at Langley Field could be said to be in useful operation. The Annual Report for 1919 noted that the Committee's first wind tunnel, with a 5-foot test section, was completed but inoperative for lack of power. The Army's power plant at Langley Field was incomplete, with construction stopped for lack of money.

With the Army planning to keep its experimental work in aeronautics at McCook Field, Dayton, and with the Navy's experimental aviation work centered at Norfolk, the NACA in 1919 felt it had good reasons for moving its field station activities to Bolling Field, just across the Anacostia River from the Capital. It asked Congress to authorize the move:

> The Committee believes it uneconomical and unsatisfactory to remain at Langley Field. The same work can be carried on more efficiently, more promptly, and more economically at Bolling Field, where the work can be closely watched by all members of the Committee, and where the members of the engineering staff in charge of work can have ready access to the Committee, to large libraries, and other sources of information, constant communication with the Bureau of Standards, a more satisfactory market for labor and supplies and adequate power supply, and relief from the perplexing question of securing quarters at Langley Field or in Hampton or other nearby towns.

Congressional approval for the move to Bolling Field did not come. In April 1920, the Committee, perhaps with a collective sigh, took action that accepted as permanent the Langley Field site for the "field station." It sought Presidential approval of the name, "Langley Memorial Aeronautical Laboratory." President Wilson concurred, and dedicatory exercises were conducted on June 11. Attendance included guests, it was later reported, "of whom a number had flown to the field."

This date, June 11, 1920, may be considered the real beginning of NACA's own program of aeronautical research, conducted by its own staff in its own facilites. The previous year a start had been made in obtaining full-scale performance data from flight tests, but now the availability of a wind tunnel made possible systematic investigations of critical aerodynamic problems, such as: (1) Comparison between the stability of airplanes as determined from full-flight test and as determined from calculations based on wind-tunnel measurements; (2) comparison between the performance of full-scale airplanes and the calculations based on wind-tunnel experiments, and (3) airfoils, including control surfaces, with special attention to thick sections, plus combinations and modification of such sections.

THE COMMITTEE'S ADVISORY FUNCTIONS

This has been essentially a chronological account, first, of events preceding establishment of the NACA, and then its early steps to under-

take its responsibilities as the nation's aeronautical research establishment. At this point it is in order to glance briefly at some early activities of the Committee which were consonant with the "Advisory" in its name.

In 1916 the executive committee invited engine manufacturers to attend a meeting on June 18 in Dr. Walcott's office at the Smithsonian Institution to discuss the problem of obtaining more powerful and more reliable engines and to bring about a better understanding between builders and users. Representatives of the military services were in attendance, and although it is to be doubted that many problems were solved, unquestionable good was done by bringing them into sharp focus. Another benefit from the meeting was an arrangement whereby the Society of Automotive Engineers became active in providing assistance in the solution of aircraft powerplant problems.

Also in 1916 the Committee examined the problem of the carriage of mail by air. The Post Office Department had failed in efforts to establish a contract air-mail service in Alaska and from New Bedford to Nantucket Island. Air mail was then considered to be justified only over almost impossible terrain. "Conditions of both these routes were so severe as to deter responsible bidders from undertaking this service," the Committee decided. It felt, nonetheless, that because of the great progress made in aviation, the Post Office should set up one or more experimental routes, "with a view to determining the accuracy, frequency, and rapidity of transportation which may reasonably be expected under normal and favorable conditions, and therefrom to determine the desirability of extending this service wherever the conditions are such as to warrant its employment."

The above-stated opinion was transmitted to Congress in 1916 as a recommendation. In 1918, when $100,000 was appropriated for creation of an experimental air-mail service, the NACA invited the attention of the Secretary of War to the following facts: "Practically all aircraft manufacturing facilities in the United States were being utilized by the War and Navy Departments, and all capable aviators were in the military or naval air services . . . . . [and] it was exceedingly desirable that Army aviators be regularly and systematically trained in long-distance flying . . . . . [and that] it would appear to be to the advantage of the War Department and of the Government generally that military airplanes be used to render practical and effective service" in carrying mail between Washington, Philadelphia, and New York. In its 1918 Annual Report the NACA viewed with satisfaction the manner in which the experimental airmail service had been established along the lines recommended, and expressed the opinion it had already "been sufficiently well demonstrated since its inauguration to justify its extension generally."

In 1921, the Committee noted in a special report to the President that—

> There are several causes which are delaying the development of civil aviation, such as the lack of airways, landing fields, aerological service, and aircraft properly designed for commercial uses. The Air Mail Service stands out as a pioneer agency, overcoming these handicaps and blazing the way, so to speak, for the practical development of commercial aviation. As a permanent proposition, however, the Post Office Department, as its functions are now conceived, should no more operate directly a special air mail service than it should operate a special railroad mail service; but until such time as the necessary aids to commercial aviation have been established it will be next to impossible for any private corporation to operate under contract an air mail service in competition with the railroads.

In January 1917, the War and Navy Departments complained to the NACA about prohibitive prices for aircraft, said to be due to "the extra item of royalty added by each firm in anticipation of infringement suits by owners of alleged basic aeronautic patents who were then threatening all other airplane and seaplane manufacturers with such suits, and causing thereby a general demoralization of the entire industry."

The Committee held meetings with Government officials, owners of patents, and aircraft manufacturers. It then recommended organization of a Manufacturers Aircraft Association to effect the cross licensing of aeronautic patents and to make the use of all such patents available to any member firm at the relatively small cost of $200 per airplane. This happy solution was adopted, and resulted, in the Committee's opinion, in "the prevention of the virtual deadlock with danger of monopoly existing under the patent situation."

In many other ways the Committee gave advisory service on such varied matters as provision of insurance for aviators, naming of flying fields "in commemoration of individuals who had rendered conspicuous service," aerial mapping techniques, and selection of a site near Washington for a "landing field" to provide "accommodation of transient aviators."

A special subcommittee during World War I examined some 7,000 inventions and suggestions in the field of aeronautics. Of this work the NACA later said, "The great majority of the suggestions received are obviously of an impractical nature. Several, however, have seemed worthy of further consideration and have been referred to military or naval experts." In addition to this arduous task, the Committee served as arbitrator in the settlement of disputes involving technical questions between private parties and the military services.

Perhaps the most important of NACA's advisory services was the leadership which the Committee gave to the efforts for legislation necessary to the orderly development of civil aviation. With cessation of hostilities in 1918, the Committee promptly took up the basic ques-

tion of what should be done about the civil use of aircraft. Although it would be nearly 8 years before the required Federal legislation was adopted (the Air Commerce Act of 1926), the recommendations made by the Committee in 1918 encompassed what was needed: "Federal legislation . . . . . governing the navigation of aircraft in the United States and including the licensing of pilots, inspection of machines, uses of landing fields, etc. . . . . . designed to . . . . . encourage the development of aviation . . . . ., and at the same time to guide the development . . . . . along such lines as will render immediate and effective military service to the Nation in time of war."

On April 1, 1921, President Harding directed the Committee to meet with representatives of interested Government departments to determine what could be done to achieve Federal regulation of air navigation without legislative action, and what new legislation was needed. April 9, the recommendations were formulated. The Committee was brief: "Federal regulation of air navigation cannot be accomplished under existing laws . . . . . . It is recommended that a Bureau of Aeronautics be established in the Department of Commerce."

There were other NACA proposals in 1921: That the Post Office be authorized to extend its air-mail routes across the continent, and that naval aviation activities be centered in a Bureau of Aeronautics within the Navy Department.

In its Annual Report for 1921, the NACA noted the principal reason for delay in passing the recommended legislation:

> The Committee is not unmindful of the legal sentiment that a constitutional amendment should first be adopted before such legislation is enacted, on the ground that effective regulation of air navigation as proposed would otherwise be unconstitutional as violating the rights of property and encroaching upon the rights of States. To postpone such legislation until a constitutional amendment can be proposed and ratified would have the effect of greatly retarding the development of commercial aviation, with no assurance that sufficient popular interest would ever be aroused to accomplish such an amendment. The Committee is of the opinion that the most effective course to be followed for the development of aviation would be first to enact the legislation deemed necessary for the Federal regulation of air navigation and the encouragement of the development of civil aviation, and let the question of the constitutionality of such legislation be tested in due course. In the meantime, there would be development in civil and commercial aviation, and if eventually the legislation which made possible such development should be definitely determined to be unconstitutional there would then, in all probability, be sufficient public interest in the subject and popular demand to adopt an amendment to the Constitution.

Years of perseverance culminated, in April 1926, in a careful analysis by the Committee of fundamental differences of opinion respecting certain aspects of the basic legislation then before the Congress. The solutions then proposed by the NACA were accepted by the joint

Senate-House conferees, and the Air Commerce Act became law on May 20, 1926.

"This act provides the legislative cornerstone for the development of commercial aviation in America," the Committee said. It "gives an important measure of stability to commercial aviation as a business proposition and in its direct effects will go far toward encouraging the development of civil and commercial aviation."

AERONAUTICAL RESEARCH

The Air Commerce Act made the Secretary of Commerce responsible for the regulation of civil aviation, and for its encouragement. At the same time, this action freed the NACA from an "advisory" burden it had carried during its first 10 years. From now on, the Committee could concentrate upon its chief responsibility—the conduct of aeronautical research.

During the first 10 years of the Committee's existence, demands upon the time of NACA members were very heavy. From 1915 to 1919 the Committee had three chairmen: General Scriven, 1915; Dr. Durand, 1916–1918, and Dr. John R. Freeman, 1919. Dr. Freeman was sent on a mission to China and was succeeded as chairman in 1919 by Dr. Walcott, who had served as chairman of the executive committee since its formation in 1915.

Dr. Walcott was succeeded as chairman of the executive committee by Dr. Ames, who effectively supported Dr. Walcott until the latter's death in 1927. At that time Dr. Ames became chairman to serve until his retirement in 1939. The fact that he was located in Baltimore, where he headed the physics department of Johns Hopkins University until he became president of the University in 1929, proved no handicap. Dr. Ames was in Washington as often and as long as Committee business required.

With the development of laboratory facilities at Langley, the NACA began building a competent engineering staff. The Langley Laboratory attracted young men with good training, who could grow to do work of increasing importance. The independence of the NACA was one of the attractions, as was also the opportunity for the young engineer to sign the published report of his own research. So was the availability of superior research and test equipment.

In 1919 the Committee invited Dr. George W. Lewis, professor of mechanical engineering at Swarthmore College, to become its executive officer. In this capacity, he was called upon to guide the research programs and to plan and build the research tools needed. In 1924 Dr. Lewis' title was changed to one that more closely described his responsibilities, director of aeronautical research. From then until 1945, when his health failed under the tremendous burdens he insisted upon

carrying during World War II, George Lewis gave devoted and effective leadership to the staff of the Committee.

While the Committee was acquiring the equipment at Langley necessary for the research programs envisioned, use was made of facilities available elsewhere for certain investigations. Before the end of World War I Dr. Durand was conducting most valuable research on air propellers at Leland Stanford University, and at M. I. T. the availability of a wind tunnel and staff made possible fundamental aerodynamic research on stability and control and on the characteristics of wing sections.

The National Bureau of Standards worked on aeronautical problems at the request of the NACA and with its financial support. The Bureau developed apparatus for the study of combustion problems under simulated conditions of high altitude and later equipped itself with wind tunnels for fundamental research on turbulence and boundary-layer problems.

The aeronautical experimentation carried on at the Navy Yard in Washington and at McCook Field in Dayton was correlated with a comprehensive plan which the NACA formulated and which was kept up to date as military and industry needs changed. The pioneering work by Naval Constructor Richardson on seaplane hulls, and the later researches directed by Chief Constructor David W. Taylor, contributed significantly to the advancement of naval aviation. At McCook Field (later moved and enlarged to become Wright Field) the availability of a wind tunnel caused the NACA to detail one of its first technical employees, Dr. George de Bothezat (best known, perhaps, for his later work with helicopters) to Dayton to assist with aeronautical research there.

In 1920 the NACA's first wind tunnel was put to work. With relatively minor exceptions, this first major piece of equipment was patterned after one at the British National Physical Laboratory. The work that could be done with this tunnel was essentially no different from that which could be accomplished at the Navy Yard, McCook Field, M. I. T., or other locations where conventional wind tunnels were located.

In June 1921, the executive committee decided to build a new kind of wind tunnel. Utilizing compressed air, it would allow for "scale effects" in aerodynamic model experiments. This tunnel represented the first bold step by the NACA to provide its research personnel with the novel, often complicated, and usually expensive equipment necessary to press forward the frontiers of aeronautical science. It was designed by Dr. Max Munk, formerly of Göttingen.

The value of the new tunnel was explained in 1922 by Dr. Ames:

> When a new design of airplane . . . is made, it is customary to construct a model of it, one-twentieth the size or less, and to experiment upon this. The

method now in universal use is to suspend the model from suitable balances in a stream of air . . . at a velocity of 60 mph . . . The balances register the forces and moments acting on the model. From the results of such measurements one decides whether the original design is good or not. But is one justified in making such a decision? Why should the same laws apply to a little model inside the wind tunnel, as it is called, and to the actual airplane flying freely through the air? Evidently there is ground for grave uncertainty. The Committee has perfected a method for obviating this. It has been known from aerodynamic theory for some time that the change in scale, from airplane to its model, could be compensated by compressing the air from ordinary pressure to 20 or 25 atmospheres; as the structure moving through the air is reduced in size from 50 feet to 2 feet, the molecules of the air are brought, by comparison, closer and closer together until their distance apart is one twenty-fifth of what it was originally. The effect of scale is thus fully compensated and experiments upon a model in this compresed air have a real meaning. The Committee has constructed a large steel tank, 34 feet long and 15 feet in diameter, inside which is placed a wind tunnel with its balances, etc., and in which the air may be kept in a state of high compression. The information to be obtained from the apparatus will be the most important ever given airplane designers.

Experience with simple airplane models without propellers in the variable-density tunnel encouraged the NACA, in June 1925, to construct a wind tunnel large enough to test full-scale airplane propellers under conditions of flight. This was a costly decision, but the cost was repaid manyfold by improved airplane performance.

The propeller research tunnel was put into operation in 1927. It had a circular test section 20 feet in diameter and was powered by two Diesel engines rated at 1,000 hp. each. Its air speed was 110 mph. and, at the time, it was the largest wind tunnel in the world. Almost from the beginning of its use, the PRT provided information leading to design changes which resulted in dramatic improvements in airplane performance.

The first and most spectacular of these productive researches brought about the development of what became known as the NACA cowling for air-cooled radial engines. In its 1928 report, the Committee said that "by the application of the results of this study to a Curtiss AT–5A Army pursuit training plane, the maximum speed was increased from 118 to 137 mph. This is equivalent to providing approximately 83 additional horsepower without additional weight or cost of engine, fuel consumption, or weight of structure. This single contribution will repay the cost of the Propeller Research Tunnel many times."

The Collier Trophy, awarded annually "for the greatest achievement in aviation in America, the value of which has been thoroughly demonstrated by actual use during the preceding year," went to the NACA for the development of this form of cowling. President Hoover made the presentation on January 3, 1930 (for the year 1928), and after the reading of the citation Dr. Ames responded that "a scientist receives his reward from his own work in believing that he

has added to human knowledge; but he is always gratified when his work is recognized as good by those competent to judge."

A second important benefit accruing from work in the PRT was more positive information about the best location of engine nacelles. The engines of the Ford Tri-motor, and similar aircraft of the twenties, were hung below the wing. As a consequence of research reported confidentially in 1930, multiengine aircraft designed thereafter had their engines faired into the leading edge of the wing with an important gain in speed.

The systematic work accomplished in the PRT led to other practical design changes. For example, it was possible to obtain an accurate estimate of the drag caused by such apparently insignificant details as the location of a gasoline filler cap. Similarly, engineers studied the aerodynamic interference of wings and fuselage, and the use of fillets to reduce the interference was proposed. (In 1928 the NACA published its first Technical Note on this subject, by Melvin N. Gough.)

That the fixed landing gear represented a large amount of drag had long been appreciated, but it was not until the PRT became operative that the drag penalties of fixed landing gear could be determined precisely. The higher speeds made possible by use of the NACA cowling, the wing positioning of the engine nacelles, the filleting of wing-fuselage junctures, and other aerodynamic refinements now made attractive the investment of added cost and weight implicit in retractable landing gear.

In 1933, looking at the gains from the research at its Langley Laboratory, the Committee said: "No money estimate can be placed on the value of superior performance of aircraft in warfare . . . nor can a money estimate be placed on . . . improved safety. . . . The value in dollars and cents of improved efficiency in aircraft resulting from the Committee's work can, however, be fairly estimated. For example, the results of . . . researches completed by the Committee within the last few years, show that savings in money alone will be made possible in excess annually of the total appropriations for the Committee since its establishment in 1915."

The economic depression that began with the stock-market crash of 1929 was not an unmixed evil for the NACA. Although there were strong pressures to reduce operating expenditures, these were successfully resisted, in the main, by such impressive evidence of the money value of the Committee's work as that just cited. On the favorable side was the opportunity for the NACA to construct at depression costs new research equipment with funds already appropriated, and the availability of engineers, from whom many of its future leaders have developed.

The 30- by 60-foot, "full-scale" wind tunnel and the 2,000-foot towing tank (for study of hydrodynamic characteristics of water-based

aircraft) were completed in 1931. The designer of the $900,000 "full-scale" wind tunnel (then the world's largest) was Smith J. DeFrance, who became director of the Committee's second research center, at Moffett Field, Calif., when it was established in 1941.

A somewhat later "depression baby" was the 500-mph. 8-foot wind tunnel. For some time after its completion in 1936, it was known, somewhat optimistically, as the "full-speed wind tunnel." Other novel research equipment constructed at Langley in these years included a free-spinning wind tunnel and a refrigerated wind tunnel (for study of icing problems).

In this depression period NACA engineers first disclosed the ability to use air more than once. Soon after the variable-density tunnel was rebuilt following a fire in 1927, it was suggested that some use should be made of the air released each time the tunnel was returned to atmospheric pressure. Why not discharge the pressurized air through an appropriate nozzle and thus obtain a really high-speed air stream? The result was a blow-down device, with a 12-inch test section in which aerodynamic phenomena could be studied at speeds almost that of sound (about 760 mph. at 60° F.).

Thus far, the discussion of research by the NACA has been largely concerned with aerodynamics where the greatest effort was made. Nevertheless there was fruitful work on powerplants, loads, and structures, which will be noted later. In retrospect, one marvels that so much could be accomplished. At the beginning of 1930, for example, the total employment at the Langley Laboratory was only 181.

By the mid-thirties, the work of the NACA had become internationally known and respected. Somewhat earlier the British journal Aircraft Engineering had commented about the Committee: "They were the first to establish, and indeed to visualize, a variable-density tunnel; they have led again with the construction of the 20-foot propeller research tunnel; and . . . [with] a 'full-scale' tunnel in which complete aeroplanes up to 35-foot span can be tested. The present-day American position in all branches of aeronautical knowledge can, without doubt, be attributed mainly to this far-seeing policy and expenditure on up-to-date laboratory equipment."

Somewhat wryly, A. J. Sutton Pippard of the University of London observed in 1935 "that many of our most capable design staffs prefer to base their technical work upon the results of the American NACA."

An important effort of the NACA was to make its research findings fully available for use. First, there were Reports, comprehensive presentations expected to have lasting value. Then there were Technical Notes, preliminary or narrower in scope. Technical Memorandums were reprints, or translations, from the aeronautical literature of other nations. Aircraft Circulars reported information about foreign aircraft and engines. In later years Research Memorandums

were added; these were limited in distribution for reasons of military security or because they contained proprietary information.

Recognizing the importance of knowing what was available in the aeronautical literature of the world, Dr. Ames had been instrumental in the formation of an Office of Aeronautical Intelligence as an integral part of the Committee's program, and for years he served both as its director and as chairman of the NACA's subcommittee on publications and intelligence. Beginning soon after World War I and continuing (except for a break in World War II) until 1950, the Committee maintained a technical assistant in Europe. From 1921 the post was held by John Jay Ide, who faithfully and intelligently served the NACA both as European reporter and in a liaison capacity with foreign aeronautical research organizations. It was decided in 1950 to close the NACA's European office because the art and science of aeronautics had become too complex for reportage by a one-man bureau. International interchange of information is now handled by other means.

Beginning in 1926, the Committee sponsored an annual conference at the Langley Laboratory with representatives of the military services and the industry. In addition to the opportunity to see what the NACA was doing, guests had an occasion to criticize and to suggest new research on problems they felt were especially pressing. In the first years of the conference, "everyone" from the industry and the military services attended; even so, the guest list numbered little more than 200, and the journey to and from Langley, via Potomac River steamer, resulted in many unofficial but profitable sessions. After World War II, it became necessary to provide two types of meetings: (1) Technical conferences concerned with a specific subject, usually classified for security reasons, e. g., supersonic aerodynamics. (2) Inspections. Held annually, on a rotating basis at each laboratory, the NACA inspections seek to give the industry and military services a comprehensive view of technical progress. As many as 1,500 attend these meetings, which are not classified.

Also of importance from the standpoint of communication is a steady traffic of industry and military visitors to NACA research centers. Much is accomplished by discussion of matters of specific concern to those involved. No less important are the visits by NACA technical personnel to specific industry plants.

Beginning in the mid-thirties, the NACA reported annually to the Congress and to the President that certain European nations were making a determined effort to achieve technical and quantitative supremacy in aeronautics. Each year the Committee's comments on this subject were stronger. In 1937, for example, Dr. Ames reported: "The greatly increased interest of the major powers in fostering aeronautical research and their determined efforts to excel in this rapidly

expanding engineering science constitute a scientific challenge to America's present leadership." He explained:

> Up to 1932 the Committee had constructed at its laboratories at Langley Field . . . . . special equipment such as the variable-density tunnel, the propeller-research tunnel, the full-scale tunnel, and . . . . . a seaplane towing basin. They were at the time of construction the only such pieces of equipment in the world. The possession of such equipment was one of the chief factors in enabling the United States to become the recognized leader in the technical development of aircraft. Since 1932 this research equipment has been reproduced by foreign countries and in some cases special research equipment . . . . . abroad . . . . . is superior to the equipment existing at Langley Field.
>
> This condition has impressed the Committee with the advisability of providing additional facilities promptly as needed for the study of problems that are necessary to be solved, in order that American aircraft development, both military and commercial, will not fall behind.

EXPANSION OF FACILITIES

In 1938, the Committee reported that its laboratory employees at Langley Field were "working under high pressure." It warned that "the recent great expansion of research facilities by other nations will bring to an end the period of American leadership in the technical development of aircraft unless the United States also constructs additional research facilities." Dr. Ames, in October 1938, appointed a Special Committee on Future Research Facilities to make recommendations.

But even before the Special Committee met, the NACA was making a strong recommendation for special facilities for research on aircraft structures. "With the advance in size and speed of aircraft . . . . . the problems involved require the conduct of laboratory research on structures on an increasing scale," the Committee wrote Congress. "This is the greatest single need for additional research equipment and . . . . . in the interests of safety and of further progress in aeronautics, it should be provided at the earliest possible date."

On December 30, 1938, the Special Committee recommended immediate establishment of a second NACA research center, in California, to relieve what the late Maj. Gen. Oscar Westover (then Chief of the Army Air Corps and a member of the NACA) called "the congested bottleneck of Langley Field." Although the recommendations had been presented as emergency in character, it was not until midsummer—August 9, 1939—just before the start of World War II, that the second laboratory was authorized by Congress. Hardly a month later, September 14, ground was broken at Moffett Field, some 40 miles south of San Francisco, for what became the Ames Aeronautical Laboratory.

Earlier that year an expansion of Langley facilities was authorized by Congress. S. Paul Johnston (now managing head of the Institute of the Aeronautical Sciences) was named Coordinator of Research to

assist Dr. Lewis. Further intensification of research effort obviously was needed in the face of war in Europe, and a second Special Committee, headed by Charles A. Lindbergh, was appointed. This group recommended, October 19, 1939, that a powerplant research center be established at once.

"There is a serious lack of engine research facilities in the United States," Lindbergh's committee stated. "The reason for foreign leadership in certain important types of military aircraft is due in part to the superiority of foreign liquid-cooled engines. At the present time, American facilities for research on aircraft powerplants are inadequate and cannot be compared with the facilities for research in other fields of aviation." It was June 26, 1940—after Belgium and Holland had been overrun—that Congressional authorization for the new flight-propulsion laboratory was forthcoming.

A site was made available by the city of Cleveland adjacent to its municipal airport. Immediate steps were taken by Dr. Lewis to plan and construct a complex of laboratories equipped with facilities for the investigation of airplane engines, their parts and materials, fuels and lubricants, ignition and combustion, heat transfer and cooling, intake and exhaust aerodynamics, as well as for the fundamental physics, chemistry, and metallurgy of power generation. In addition, facilities were provided for flight testing in laboratory-instrumented airplanes—practical flying laboratories for propulsion research.

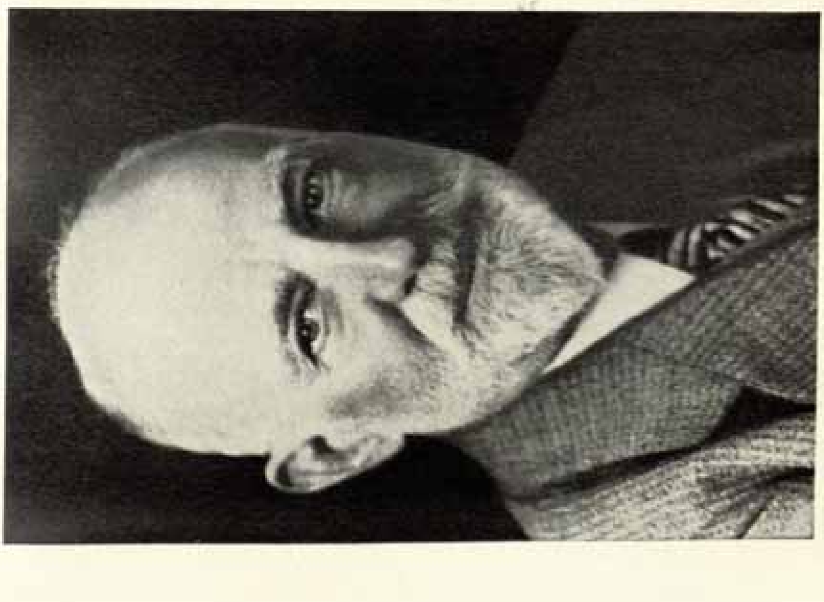
There is no doubt that this flight-propulsion center was a large step in advance of any comparable facility in the world. It has cost up to date about $110,000,000 and now employs about 2,800 people.

After the death of Dr. Lewis in 1948, the Committee decided on the name "Lewis Flight Propulsion Laboratory," as a memorial of that great engineer's crowning achievement.

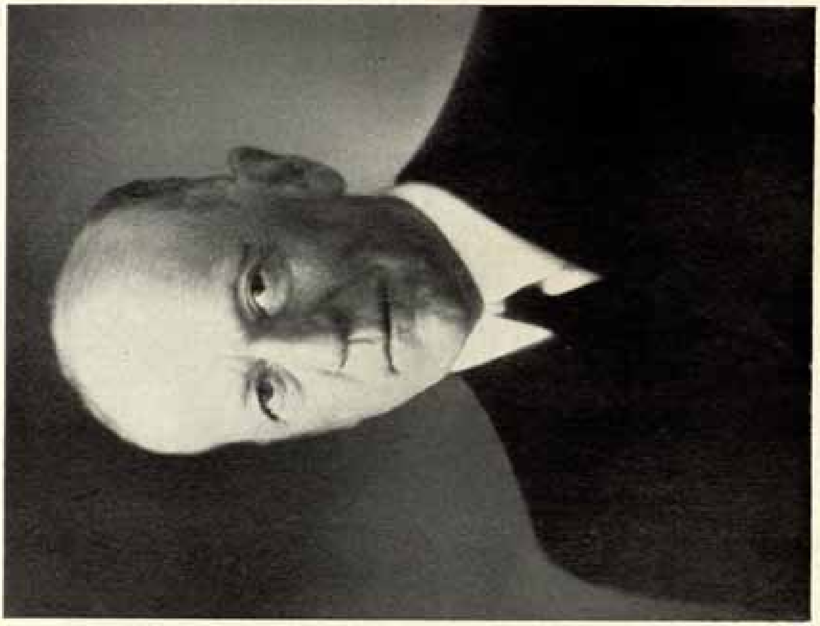
Here it may be proper to explain why the research effort on powerplants and on structures had been so much less than that devoted to aerodynamics. In the first place, it must be remembered that between World Wars I and II, the United States was an intensely peace-minded nation. In addition, the thousands of miles of ocean to our east and west gave a feeling of safety from attack, a complacent sense of detachment. The Congress was unwilling to expend really large sums for national defense or on research to improve it.

Until the eve of Pearl Harbor, the annual expenditure by the United States to support aeronautical research was indeed modest. Even as late as the summer of 1939, the NACA's total complement was 523, including only 278 technical people.

The major effort by the NACA over the years had been deliberately concentrated on aerodynamic problems. Here, for a given expenditure, the possible gains to be achieved were very large, particularly in view of the relatively few engineers who could be assigned to the work.



1. Dr. William F. Durand, member National Advisory Committee for Aeronautics 1915–1933, 1941–1945; Chairman, 1916–1918.



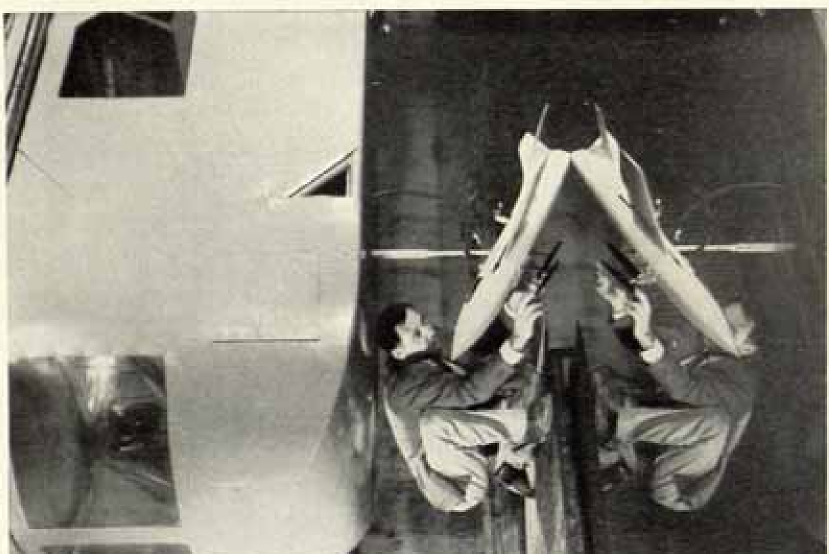
2. Dr. Charles Doolittle Walcott, Secretary Smithsonian Institution 1907–1927; member National Advisory Committee for Aeronautics 1915–1927; Chairman, 1919–1927.

1. Dr. Joseph S. Ames, member National Advisory Committee for Aeronautics 1915–1939; Chairman, 1927–1939.

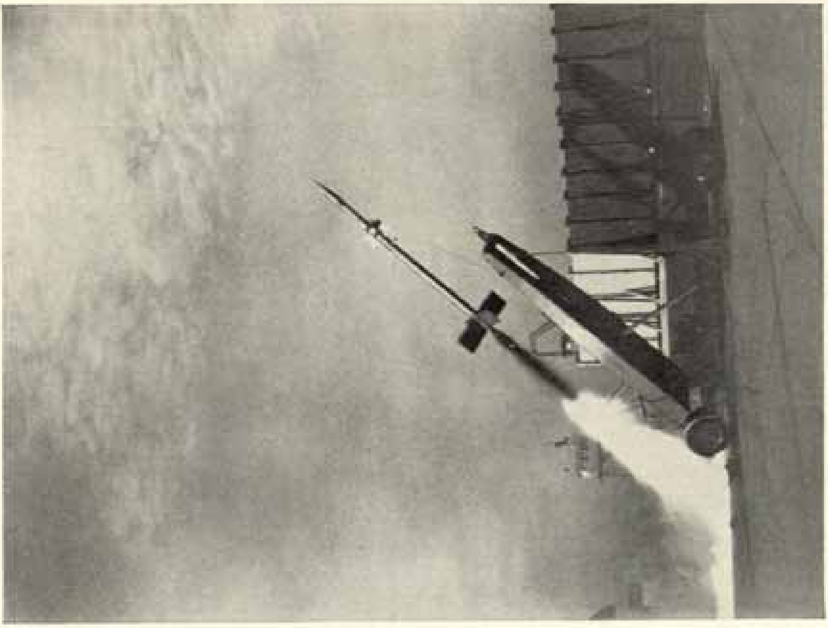
2. Dr. George W. Lewis, Director of Aeronautical Research, National Advisory Committee for Aeronautics, 1919–1947.

1. Application of NACA cowling on AT–5A Army pursuit training plane increased its speed from 118 to 137 mph. This was equivalent to providing 83 additional horsepower.

2. The NACA Langley Laboratory's low-drag wing was first used on the P–51 Mustang fighter, making it the fastest propeller-driven airplane of World War II.

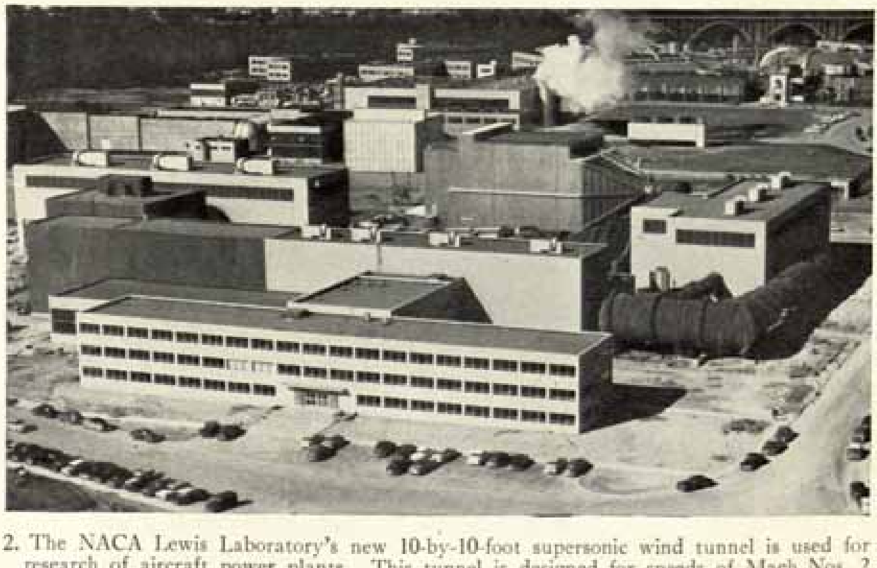


1. An engineer in NACA's towing tank at Langley Aeronautical Laboratory prepares a dynamic model equipped with hydro-skis for a test run.



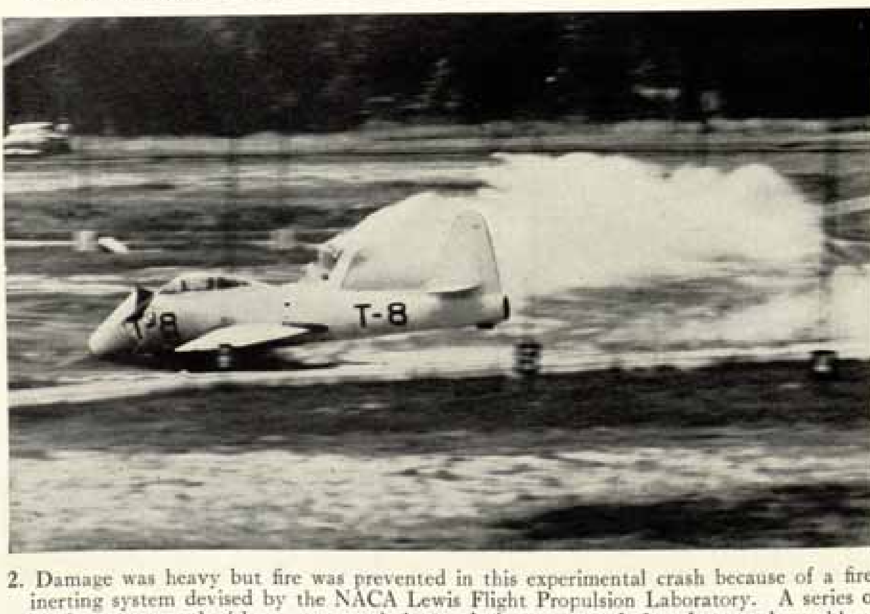
2. This rocket-powered model, one of a series tested by the NACA to investigate the flutter characteristics of low aspect ratio wings, shoots skyward toward the Atlantic Ocean from its launching ramp at the NACA Pilotless Aircraft Research Station, Wallops Island, Va.

1. The 14-foot test section of the Ames Unitary Plan wind tunnel. It is capable of operating smoothly from subsonic speeds through the speed of sound to low supersonic values, a region where conventional wind tunnels are not usable, owing to choking. The perforated or slotted walls of the tunnel permit flow disturbances to pass through the open parts while retaining sufficient solid area to guide the air uniformly past the model. Two other test sections operate at speeds up to Mach No. 3.5.

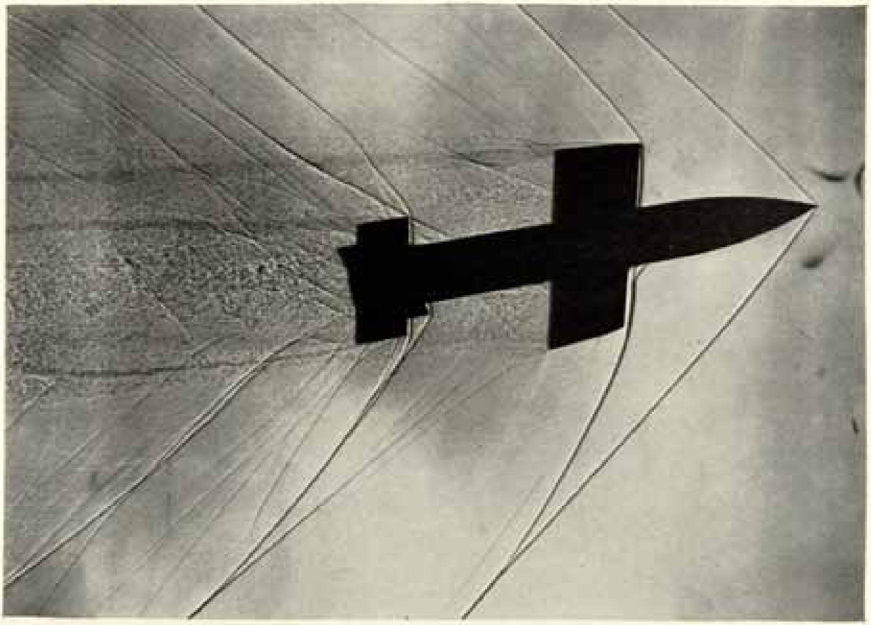


2. The NACA Lewis Laboratory's new 10-by-10-foot supersonic wind tunnel is used for research of aircraft power plants. This tunnel is designed for speeds of Mach Nos. 2 to 3.5.

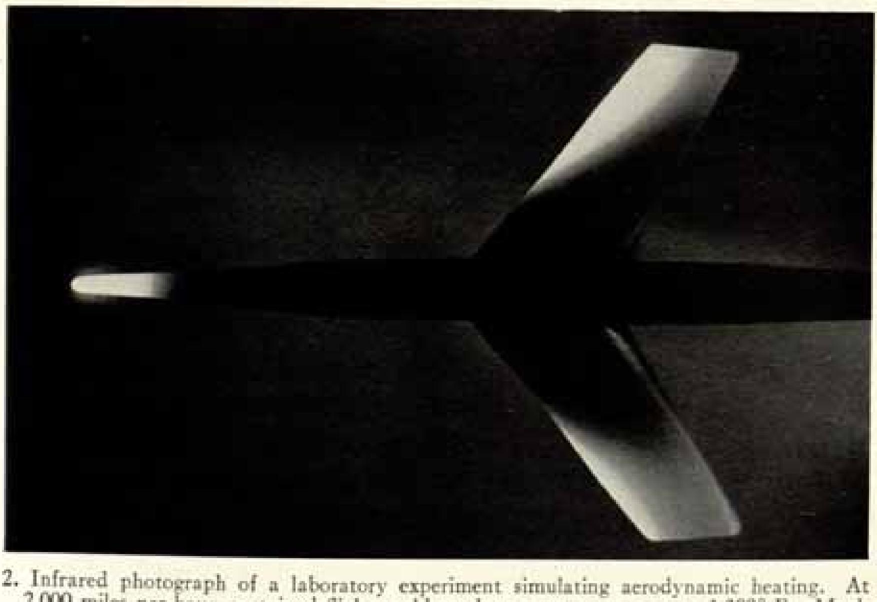
1. Six dummies, seated in various positions and in several types of seats, rode a service-weary Lodestar transport plane through a severe crash, one of a series staged by a research group of the NACA Lewis Flight Propulsion Laboratory. Objective of the crash program is to gather data on passenger and pilot survival problems in aircraft accidents.



2. Damage was heavy but fire was prevented in this experimental crash because of a fire-inerting system devised by the NACA Lewis Flight Propulsion Laboratory. A series of crashes was staged with worn-out turbojet- and piston-powered aircraft to study problems of fire and human survival in crash accidents. The white cloud in the picture is jet fuel issuing from the ripped tank in the right wing.



1. Caught in flight by shadowgraph technique, this free-flight research model shows the complicated pattern of shock waves and vortexes associated with high-speed flight. Vortexes are left in the wake of the model. The unsymmetrical shock-wave pattern shows that the model is turning. The model is 7 inches long and has just been fired from a 3-inch smooth-bore Naval gun into still air. Mach number at the instant of this photograph is 1.6.



2. Infrared photograph of a laboratory experiment simulating aerodynamic heating. At 2,000 miles per hour, sustained flight could produce temperatures up to 1,200° F. Much additional research is required to permit successful operation under such conditions.

Flying regularly at transonic and supersonic speeds, these research airplanes are exploring new fields for data needed to design the military and civil airplanes of the future. In center is the Douglas X–3; at lower left, the Bell X–1A flown late in 1953 at a record 1,650 mph. or 2.5 times the speed of sound. Continuing clockwise from the X–1A are the Douglas D–558–I "Skystreak"; Convair XF–92A; Bell X–5 with variable sweepback wings; Douglas D–558–II "Skyrocket," first piloted airplane to fly at twice the speed of sound; and the Northrop X–4. The National Advisory Committee for Aeronautics, the Air Force, the Navy, and the aircraft manufacturing industry are joined to design, build, and fly these and other advanced airplanes in a high-speed flight research program.

1. Grumman F11F-1. Use of the NACA-developed "area rule" concept for decreasing drag rise at transonic speeds gave this "Tiger" fighter plane supersonic performance. The "wasp-waisted" Navy carrier plane uses one-third less thrust than other airplanes of equivalent performance.

2. West Area, Langley Aeronautical Laboratory, Langley Field, Va.

1. Ames Aeronautical Laboratory, Moffett Field, Calif.

2. Lewis Flight Propulsion Laboratory, Cleveland, Ohio.

Powerplant research and structural research are expensive, and require extensive facilities for full-scale investigations. Small models are of limited utility in powerplant research. Furthermore, powerplants and structures are the immediate concern of strong and highly competitive industrial firms. The Committee evidently felt that under its fiscal restrictions, it would do better to concentrate on basic aerodynamic problems and might, hopefully, leave research and development of powerplants and structures to the industry and the military services.

However, the Lindbergh committee in 1939 said that this past policy was wrong, and the NACA agreed. It appeared that leaving fundamental research to the industry meant, in effect, that such research would be indefinitely postponed.

A competitive engine firm must concentrate on what its customers want. The firm improves its engine with small changes based on experience. It seeks the minimum risk of interruption of production. The military services, its principal customers, conduct competitive trials based on standard performance specifications. After quantity orders are placed, no major changes are possible. The services, of course, welcome small changes based on experience, if the risk of trouble be slight. As a result, engine development tends to adhere to a definite pattern and progresses slowly.

An engine manufacturer must make a relatively heavy investment in plant and tooling for production of a particular engine. The manufacturer is naturally inclined to concentrate on improvements in this engine to prolong its commercial life. These improvements are essentially proprietary in character.

Similar remarks apply to the airplane industry. Every effort is made to improve a particular airplane to prolong its vogue in production. This development effort is restricted to conservative changes in a basic design acceptable to the customer.

In this country, the Navy standardized on air-cooled radial engines that met Navy requirements, while the Army insisted on 12-cylinder liquid-cooled engines to power the fighters in their program.

However, there were important fundamental applications of science to engine design that needed investigation in 1940.

From the beginning, one of the principal technical committees of the NACA was concerned with powerplants. During World War I, a few research projects in the powerplant field were carried on under its auspices, notably in the altitude facility at the Bureau of Standards, where engines could be operated under conditions simulating those experienced by high-flying aircraft. A program of systematic tests was conducted there for the NACA, including supercharging with a Roots-type blower.

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At Langley the small but expert powerplant staff made some important contributions, in addition to their cooperation with the wind-tunnel people in developing the remarkable NACA cowling for air-cooled engines. One recalls improved finning for air-cooled engine cylinders, methods to decrease the octane requirements of high-compression engines, and work on such fundamental matters as the behavior of fuels—how they ignite, how they burn, and how this burning corrodes critical parts of the engine. A principal tool in the study of these latter questions was high-speed photography, and cameras capable of taking pictures at the rate of 400,000 per second were developed by the NACA.

In the field of jet propulsion the NACA exhibited an early awareness of its possible advent but did little about it. In 1923, in Report No. 159, "Jet Propulsion for Airplanes," Edgar Buckingham of the Bureau of Standards, reported that: "The relative fuel consumption and weight of machinery for the jet decrease as the flying speed increases; but at 250 mph. the jet would still take about four times as much fuel per thrust horsepower-hour as the air screw, and the power plant would be heavier and much more complicated. Propulsion by the reaction of a simple jet cannot compete, in any respect, with air screw propulsion at such flying speeds as are now in prospect." This conclusion was entirely rational on the basis of the technology at that time.

In the early thirties, the NACA was asked by a representative of the airframe industry to resurvey jet-propulsion prospects and, although airplane speeds by then had passed the 250-mph. mark which Buckingham considered a goal, the story was much the same. The inefficiency of the jet engine at the speeds contemplated ruled it out of consideration.

Near the end of the 1930's, some preliminary experimental work on jet propulsion was undertaken at the Langley Laboratory. These experiments indicated that jet engines would be so fuel-thirsty as to limit their useful application to very high-speed, very short-range aircraft. American thinking, perhaps because of geography, was focused on long-range performance where fuel economy was paramount. This idea served to discourage any real jet-development effort in the United States until intelligence of British and German experiments reached us.

In March 1941, Dr. Durand was recalled from retirement to head a special NACA Committee on Jet Propulsion. The fact that he was in his 82d year was only a matter of calendar counting. The vigor with which he and his committee launched a belated development effort would have done credit to a man less than half his age. Later in 1941, Gen. H. H. Arnold secured from the British one of the earliest

of the Whittle jet engines to aid the development program initiated by Dr. Durand. In this program, the Durand committee was handicapped by the fact that the country had just been plunged into a war for which it was ill prepared and the principal airplane-engine firms were overloaded. The decision came "from the summit" that we would fight with the weapons in hand. First priority was given their production in immense quantity. Consequently, the Durand committee had to arrange with nonaeronautical firms to undertake the development of turbojet engines for possible later use to power fighter airplanes.

Over some 20 years, aerodynamic and powerplant improvement, much of it based on application of research results, permitted the top speed of military airplanes and the cruising speed of commercial airplanes to be doubled; the air loads imposed on the faster airplanes were severely increased, especially in rough air and when maneuvering.

The loads research group at the Langley Laboratory consisted of but 20 men in 1939, but their contribution was considerable, notably the V-G recorder (V for velocity, G for gravity) by R. V. Rhode and H. J. E. Reid. It was devised to measure continuously the loads experienced by an airplane flying in rough air. This was but one of many novel instruments which NACA engineers have devised for precise measurements in flight.

The research problem directly related to loads deals with structures to carry the loads. Here again the manpower available at Langley prior to World War II was small; as late as October 1940, only 10 men were working on airplane structures. Their work was concerned, principally, with fundamental knowledge about structures from which a trustworthy theory could be developed for design application. Delicate experiments and mathematical analyses dealing with the behavior of thin-walled cylinders, stiffened panels, and other structural units produced useful conclusions that were used on our World War II aircraft.

On October 7, 1939, Dr. Ames resigned from the Committee because of failing health. His responsibilities as chairman of the Committee were given to Dr. Vannevar Bush, who had been serving both as vice chairman and as chairman of the executive committee.

Note has been made already of the manner in which Dr. Ames had provided leadership of the highest quality to the Committee for nearly a quarter-century. The letter President Roosevelt wrote upon the occasion of his retirement contained this statement:

> Our Republic would not be worthy of the devoted service you have rendered for over 24 years without compensation if it could not on this occasion pause to pay tribute where it is so justly due . . . . That the people generally have not known of your brilliant and patriotic service is because it has been overshadowed by your passion for accomplishment without publicity. But the fact remains, and I am

happy to give you credit, that the remarkable progress for many years in the improvement of the performance, efficiency, and safety of American aircraft, both military and commercial, has been due largely to your own inspiring leadership in the development of new research facilities and in the orderly prosecution of comprehensive research programs.

The Committee's resolution, tendered to Dr. Ames in Baltimore by a special delegation, said:

> When aeronautical science was struggling to discover its fundamentals, his was the vision that saw the need for novel research facilities and for organized and sustained prosecution of scientific laboratory research. His was the professional courage that led the Committee along scientific paths to important discoveries and contributions to progress that have placed the United States in the forefront of progressive nations in the development of aeronautics. His was the executive ability and far-sighted policy of public service that, without seeking credit for himself or for the Committee, developed a research organization that holds the confidence of the governmental and industrial agencies concerned, and commands the respect of the aeronautical world. Withal, Dr. Ames was an inspiring leader of men and a man beloved by all his colleagues because of his rare qualities.

In July 1941, the President appointed Dr. Bush director of the newly established Office of Scientific Research and Development, and he resigned as chairman of the NACA. The writer was elected chairman, an honor he has been privileged since to hold.

WORLD WAR II AND AFTER

The war years for the NACA were plagued by the necessity for rapid expansion of the civil-service staff from hardly 500 in 1939 to more than 6,800. Trained engineering personnel were unavailable. Consequently, it was mandatory that professionals be spread ever thinner, while loom fixers, toymakers, mechanics, blacksmiths, and women school teachers were recruited for jobs they could do or for which quick instruction could be given.

Especially in the matter of skilled management of research programs, the NACA might have been expected to be sorely weak. And yet, somehow, with each expansion of effort, new leaders were found from within the permanent NACA staff. No sooner did Henry J. E. Reid, director of the Langley Laboratory, see some of his best men on their way to build the new laboratory at Moffett Field—named in 1944 in honor of Dr. Ames—than the process of designating the leaders of the new engine laboratory—named in honor of Dr. Lewis in 1948—was begun. Smith J. DeFrance was named director of the Ames Aeronautical Laboratory, and later Edward R. Sharp became director of the Lewis Flight Propulsion Laboratory. Both of these men were senior members of the permanent staff at Langley.

NACA's war effort was of necessity devoted very largely to applied research, the business of finding "quick fixes" to make existing aircraft

better performers, and production engines more powerful. Fortunately, a considerable backlog of design data was available for application to such subjects as low-drag wings, high-speed propellers, stability and control, and improved systems for cowling and cooling engines. Between December 1941 and December 1944, the Committee's research centers worked on 115 different airplane types. In July 1944, 78 different models were under simultaneous investigation.

Perhaps the best comment on the value of NACA's World War II work is to quote from a statement by the late Frank Knox, made in 1943 when he was Secretary of the Navy:

> New ideas are weapons of immense significance. The United States Navy was the first to develop aircraft capable of vertical dive bombing; this was made possible by the prosecution of a program of scientific research by the NACA. The Navy's famous fighters—the Corsair, Wildcat, and Hellcat—are possible only because they were based on fundamentals developed by the NACA. All of them use NACA wing sections, NACA cooling methods, NACA high-lift devices. The great sea victories that have broken Japan's expanding grip in the Pacific would not have been possible without the contributions of the NACA.

The end of World War II marked the end of the development of the airplane as conceived by Wilbur and Orville Wright. The power available in the newly developed turbojet and rocket engines for the first time brought within man's reach flight through and beyond the speed of sound.

In the years following World War II there were changes, too, in the membership of the Committee. In 1948, the death of Orville Wright closed 28 years of his membership on the NACA. Though he was but one among many strong men who had given of time and talent to the work of the Committee, his passing sharpened the realization that in the working years of one man's life—between December 17, 1903, and January 30, 1948—the speed of the airplane had been increased from hardly 30 mph. to almost 1,000 mph.

In 1948 the membership of the Committee was increased to 17. This permitted the inclusion of a representative from the Department of Defense, presently the Assistant Secretary (Research and Development). Since the war the Committee has included one Presidentially appointed member from the airframe, the engine, and the air-transport industries, thus insuring awareness of the needs of those major segments of American airpower.

In 1948 Dr. Lewis died. In 1945, his health broken by the war effort, he had been forced to withdraw from active participation in the work of the Committee. For almost two years, John W. Crowley, Jr., served as acting director of aeronautical research. With the Committee since 1921, Crowley had been chief of research at Langley for a number of years. He provided vitally needed leadership during a critical period.

To succeed Dr. Lewis, the Committee in 1947 chose the Associate Director of the National Bureau of Standards, Dr. Hugh L. Dryden. He was no stranger to the NACA. Trained in physics and mathematics by Dr. Ames at Johns Hopkins University, he had gone to the Bureau of Standards in 1917, where he soon earned an international reputation by his aerodynamic researches in turbulence and boundary layer. His new task at the NACA was extremely difficult, yet it was vital to the Nation that a "new look" at the postwar situation be taken, and new objectives defined in terms of supersonic jet-propelled vehicles potentially available for the worldwide exercise of air power and, eventually, for civil air transportation.

At the end of World War II, the most urgently sought goal was attainment of practical flight at supersonic speed. It was realized that success in this effort required new knowledge which could be obtained only with new tools and new techniques. Even before the end of the war efforts were made to acquire needed data. Efforts to develop useful transonic aerodynamic theory had failed and it was necessary to resort to direct experimentation at velocities passing through the speed of sound. The fact that the principal tool of aerodynamic research, the wind tunnel, was subject to "choking" phenomena near the speed of sound forbade its use for the critical experimentation. Entirely new techniques had to be devised. The NACA's attack was broadened to include all approaches which offered promise.

The earliest attempt used especially instrumented aerodynamic bodies dropped from a high altitude, but it was not until late in 1943 that advances in radar and radiotelemetering equipment made it possible to obtain reliable data by this method. Even then, the velocity of a free-falling body seldom went much beyond a Mach number of 1 (M=1 equals the speed of sound).

Other attempts sought to use the acceleration of airflow above a curved surface. Small model wings were mounted near the leading edge of the wing of an airplane. In this way, lift, drag, and other aerodynamic characteristics of the model were measured. The method was employed also to study stability and trim of airplane shapes in the transonic speed range. The same principle of accelerating airflow was tried with small models positioned over a "hump" in the test section of a subsonic wind tunnel, but scale effects complicated the interpretation of test results for use in design.

Use of rocket-propelled models fired from the ground followed the first work with free-falling bodies by about a year. As instrumentation has been improved, this technique has become a valuable tool for transonic research. By the addition of powerful booster rockets, models of this kind are being used to study aerodynamic problems at speeds ranging up to a Mach number of 10 and higher. The fact that

very high speeds are reached at low altitude, where the air is dense, makes the aerodynamic data readily usable for plane and missile design. In 1945, the NACA established a Pilotless Aircraft Research Station at Wallops Island off the Virginia coast, to carry on this work. It is attached to the Langley Laboratory.

In 1943, the idea was advanced of using specially designed piloted airplanes to explore the transonic speed range. Propelled by powerful rocket engines and provided with elaborate data-recording equipment, the research airplane could be safely flown at high altitudes where the density of the air, and hence the loads imposed on the structure, would be low.

The spectacular accomplishments of the research airplanes—the supersonic flight of the Bell X–1, October 14, 1947; the twice-the-speed-of-sound flight of the Douglas D–558–II, November 20, 1953, and the even faster flights of the Bell X–1–A which followed soon after—have sometimes obscured the fact that these airplanes were tools for research. These flights are historic; all agreed as to the rightness of the Collier Trophy award to three men for the year 1947: John Stack, Langley Laboratory, for conception of the research airplane program; Lawrence D. Bell, for design and construction of the X–1, and Capt. Charles E. Yeager, USAF, for making the first supersonic flight.

But even more valuable than the dispelling of the myth about the sound barrier was the accumulation of information about the transonic speed region. The shape and the performance of tactical military aircraft which have been designed since reflect the use of data obtained by the research airplane program centered at the NACA's High-Speed Flight Station at Edwards Air Force Base, Calif.

Despite the success of this flight program, there remained the need for a technique whereby transonic experimentation could be carried on under the closely controlled conditions possible only in the laboratory. Actually, the data coming from the research airplanes accented this need, because they pointed up the fundamental problems of fluid mechanics that would have to be studied in great detail for the design of useful supersonic aircraft.

By late 1950, following intensive theoretical work, there was put into operation at the Langley Laboratory a new type of wind tunnel. Incorporating a "slotted throat" at the test section, it was free from choking near the speed of sound and truly could be described as a transonic wind tunnel. Again, the Collier Trophy was awarded to John Stack and his Langley associates for the conception, design, and construction of his most useful research tool.

One must appreciate the very great difference between airplane design in the past and today. In the past, the difference between the best design and the second best, assuming the same power, might be at most

only a few miles an hour. Now the difference may be measured in hundreds of miles an hour. The art is being extended so rapidly that no longer is there a comfortable time margin between the acquisition of research data and its application.

Hardly had the first of the NACA's transonic wind tunnels gone into full operation, in 1951, when Richard T. Whitcomb, a young engineer at the Langley Laboratory, began the experimental verification of what has since become known as the "area rule." In essence, Whitcomb worked out a rational way to balance the lengthwise distribution of volume of fuselage and wings to produce an airplane form with minimum drag at high speeds. Seemingly slight modifications to the shape of the airplane fuselage greatly improved performance.

As soon as the new design principle was verified in preliminary form, it was made available in confidence to the designers of military airplanes and the new information was promptly applied.

In one instance, the prototype of a new fighter aircraft was unable on test to attain supersonic speeds. With the deceptively subtle modifications dictated by the "area rule," the airplane enjoyed a performance gain in speed of as much as 25 percent.

At the velocities contemplated for our future missiles and airplanes, temperatures measured in thousands of degrees Fahrenheit will be encountered owing to aerodynamic heating—friction. The consequent structural problems are little short of fantastic and, with presently available materials of construction, the solution is not in sight. More research is needed.

The performance possible from the harnessing of nuclear energy for airplane propulsion would be nonstop flight over virtually unlimited range. Again, one is faced with problems of enormous complexity and difficulty, but national security requires that research and development be carried forward with imagination and vigor.

Millions of passengers are now carried by air. Air transportation also expedites the delivery of great volumes of mail and goods. Airliners regularly span oceans and continents, and smaller utility planes serve remote regions in the Arctic and tropical jungles. There is promise of helicopter service between nearby cities, with no need for large outlying airports.

The safety record of civil aeronautics is remarkably good, but it is never good enough. We still read, from time to time, of disasters from collision, fire, storm, human error, and, rarely, from structural or mechanical failure of the airplane itself. The human pilot is aided by wonderful instruments and by radio, radar, gyros, etc., but we still depend on his judgment and skill. He must be better protected against noise and fatigue—subjects for research.

Air transportation is fast and can be faster. But greater flight speed is illusory if it requires too long a climb to reach the high altitude

necessary for economy. Furthermore, higher-speed airplanes tend to require longer runways and bigger airports. This could mean a new program of airport building at colossal expense, with the new airports even farther from the passengers' ultimate destination. Getting to and from the airport could consume more time than is saved by faster flight. Research continues on improving landing and takeoff characteristics of airliners.

It may be that airliners of the future will be designed to the limitations of the airports they are to serve, just as transatlantic steamers are designed to enter only a few major seaports, where the channel and piers have adequate depth of water.

Civil aeronautics can make its greatest contribution to trade and commerce under a favorable international climate of free interchange of people, goods, and ideas. Greater economy, efficiency, and safety are prerequisites for its full utilization. Research can show the way to advance toward these goals.

Through the years the NACA has been provided by Congress with the most modern research equipment at a total cost of approximately 300 million dollars, and the present operating staff numbers about 7,600 persons of whom over 2,000 have professional degrees. These resources, in the present hostile and threatening international climate, are directed for the most part toward research helpful to national security. Research to improve military aircraft is ultimately applied to civil aviation, when proved to be thoroughly practical by experience, but there are differences in emphasis, because safety, comfort, and economy are relatively more important in civil airplanes. The Committee has numerous investigations in progress which are directed toward the immediate problems of civil aviation, as for example the work on noise, icing, fire prevention, atmospheric turbulence, and reduction of landing speed.

A more favorable international climate would permit greater emphasis on civil aviation, but it is likely that for some time to come the national security will require a great effort to penetrate more rapidly into the vast region of the unexplored and unknown. The Committee feels its responsibility for guidance of the over-all research effort in aeronautics, and it is hoped that through its work aeronautics may make the maximum possible contribution to human welfare.

A Transatlantic Telephone Cable[1]

By **H. A. Affel**

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In the fall of 1955 telephone communication was established for the first time across the Atlantic by means of a submarine cable. In the summer of 1956, when weather conditions permit, a second cable will be laid to provide the return transmission paths for the speech channels. The new cable system will then become a reliable addition to the global telephone network which links the continents.

In the summer of 1955, the British cable ship *Monarch*, with hundreds of miles of cable stored in its hold, set out from Newfoundland shores in the direction of Scotland to lay the first section of the new telephone cable. Somewhat less than a hundred years ago the old *Great Eastern* set forth from Ireland westward toward Newfoundland to lay the first successful transatlantic telegraph cable.

Superficially, the old telegraph cable and the new telephone cable would not look much different in the process of paying out over a large sheave on the bow or the stern of a ship, but at this point the similarity ends. In the case of the first crossing, the cable provided one very slow-speed telegraph channel—at the most a few words per minute. The new cable will provide 35 talking paths. If employed exclusively for telegraphy, it would yield more than 500 high-speed telegraph channels having a total capacity of 30,000 words per minute. This is considerably more than now derived from all existing transatlantic cables or, indeed, all the deep-sea submarine telegraph cables in the world.

The improvement in information-transmitting capacity is a rough measure of the advance in performance that the new cable represents. In detail, a century of technical progress lies between the two projects. This would be more evident if one opened up the cable to examine the insides, or if one waited until, in the course of paying out the cable, there appeared a bulge in the new structure for a distance of some 20 feet. But this is getting ahead of the story.

[1] This article is based largely on a detailed technical description of the same title by Mervin J. Kelly, Sir W. Gordon Radley, G. W. Gilman, and R. J. Halsey, which was delivered as a paper in the spring of 1955 before the British Institution of Electrical Engineers and the American Institute of Electrical Engineers, published in Electrical Engineering, vol. 74, No. 3, 1955.

SOME HISTORY

A transatlantic cable was envisioned not many years after the electric telegraph had been born. As early as 1840, telegraphy was being applied over land circuits, both underground and overhead.

The first transatlantic telegraph cable, laid in 1858, failed a few weeks after it had been put in service. It was 1866 before more scientific studies, chiefly under the direction of Sir William Thompson (later Lord Kelvin), inspired renewed faith in the project so that a new cable could be laid which continued to operate satisfactorily. The foresight, courage, and determination of Cyrus W. Field, an American, were also powerful factors in the ultimate success of the undertaking.

Decades after the first transatlantic telegraph cable there came radio telegraphy, then radio telephony. Transatlantic radio telegraphy started with the Marconi experiments in 1901. In 1927 commercial transatlantic radio telephony was inaugurated. This has grown over the years until now there are some 15 radio-telephone circuits in operation between the two continents.

Radio has the advantage of being comparatively inexpensive as compared with transatlantic cables, but radio, either telegraph or telephone, for the distances involved, has proved to have serious weaknesses. The wavelengths that are available and useful for the single-span operation across the Atlantic are greatly dependent on Nature's vagaries. Transmission is frequently interrupted for hours at a time, particularly in periods of unusual sunspot activity.

It was not until about 1928 that advances in the technique of constructing submarine cables, together with the science of electronics, had reached the point where serious consideration could be given to the design and laying of a transatlantic telephone cable. The American Telephone and Telegraph Co. made a good start on this project, but this was interrupted by economic considerations resulting from the depression of the thirties. Had it not been so interrupted, it is likely that such a cable would have been installed. It would have provided a single reliable talking path across the Atlantic. Its cost, however, would have been many times that of a single radio-telephone link.

As a technical achievement, it would have had something like 1,000 times the message-carrying capacity of the original transatlantic telegraph cable. In addition to taking advantage of improved materials and cable construction, it would have incorporated at the terminals vacuum-tube amplifiers capable of boosting the feeble voice power of a telephone transmitter manyfold to enable it to override the high attenuation of the cable for the voice currents.

The history of transatlantic communication is fascinating and has been well documented. In the Kelvin Lecture before the Institution

of Electrical Engineers in 1942, Dr. Oliver E. Buckley, then president of the Bell Telephone Laboratories, summarized the status of and prospects for transoceanic telephony. He commented on the fact that the interruption of the first telephone cable proposal may, indeed, have been fortunate because it offered an opportunity later for a new approach that led to the present project, which is not only technically sound but economically justified, because it provides not merely one, but a large number of telephone circuits.

SOME BASIC PROBLEMS

Consider briefly some of the problems that make long deep-sea communication difficult. Structurally, the cable is disarmingly simple. It generally consists of a sizable flexible copper wire, surrounded by a layer of flexible insulating material (in the early days guttapercha), which may be covered with some fabric. To give it physical strength to resist abrasion, and tension, it is further covered with a spiraled layer of heavy steel wires. Over-all, the structure may be from ¾ to 1½ inches in diameter.

Of course, the insulating material must not have any holes to permit the sea water to reach the inside conductor under pressures which, for an Atlantic crossing, may reach several thousand pounds per square inch. It must also withstand electrical pressures, resulting from the voltages necessary to signal over the cable.

In our present technical knowledge the electrical problems can be approached quite scientifically, but in the early days of transoceanic telegraphy things were not quite so simple. Experimenters with electricity fairly early became aware of the fact that any electrical conductor insulated from ground has the characteristic of acting to store or soak up electrical energy to a degree depending on the size of the conductor. This characteristic was termed "capacity."[2]

Long wire circuits naturally had greater capacity than short circuits. This capacity is not generally harmful in a circuit of established conditions in which the current flows from one end to the other, but it was not at first realized that an effort to vary the current in order to produce telegraph signals could be seriously frustrated by the capacity that exists in a long submarine cable circuit.

It acts as if the signaling path consisted of a long trough of water and the signals were received as changes in the level of the liquid—but the mass or volume of the water in the trough swamped out most of the level changes that were imparted at the sending end—particularly the fast changes involved in rapid signaling. There would also be considerable time delay as the wave passed from end to end.

[2] More recent terminology is "capacitance."

Apparently it was thought by some that the use of higher voltages would tend to overcome the capacity effect. This may have been part of the reason why very high voltages were applied to the first transatlantic cable. The insulation was seriously affected, making the cable unworkable and discouraging further efforts for several years. However, as noted, by a more complete understanding of the physics of the problem, under the leadership of Lord Kelvin, terminal equipment and operating techniques were devised which imposed lesser stresses on the cable insulation. Reliable transoceanic cable telegraphy then came into being (1866).

Even then the operating speeds were only of the order of three words per minute—very modest, but nevertheless an achievement, considered in the light of the fact that the alternative at the time was no direct communication, only a delay of days, if not weeks, in getting messages across the Atlantic via ship.

How far such a telegraph cable falls short of serving for telephony will be appreciated from the fact that the current fluctuations, or range of frequencies, required for a single speech path are roughly one thousand times as great as the slow-speed telegraph signals. It is not surprising therefore that it took many decades to achieve performance of this order.

In the meantime, the communication needs across the Atlantic were being augmented from time to time, until there are now some 20 telegraph cables, as well as numerous radio-telegraph and more than 15 radio-telephone circuits, between the two continents.

STEPS TOWARD THE ULTIMATE TELEPHONE CABLE

Beginning in 1919 a small development group was organized under Dr. Oliver E. Buckley at the Bell Telephone Laboratories to study the problem of increasing the transmission capacity of long deep-sea cables. These studies led to several important developments.

1.—Experiments were made and cables successfully laid using "loading" in order to improve their transmission capabilities. Loading is a process of adding "inductance" along the cable in order to offset the effect of the capacity effects which have been previously noted. Inductance may be added by inserting coils of wire at intervals in the cable, or by surrounding the conductor with tapes of some magnetic material. A special magnetic material called perminvar was devised for this purpose.

The addition of loading to cables greatly reduces the effect of capacity and makes it possible to use much longer cables for a given amount of distortion, or it may permit higher signaling speeds for a given cable. However, one difficulty with loading is that it imposes an upper limit on the speed of operation. In other words, it limits the

band of frequencies which can be transmitted. Loading was, however, a feature of the proposed single-channel telephone cable of the thirties.

2.—Incident to the other work, better materials were devised for use as insulators. These included a material termed paragutta, a mixture of guttapercha and rubber, which served effectively as a substitute for the guttapercha of the earlier cables. More recently, another material, which was originated by the Imperial Chemical Industries, called polyethylene (polythene), has been found to have greatly superior qualities as an insulating material for cables.

A very useful improvement in cable structure for long cables consisted in providing a definite path for the return currents by adding a thin coaxially located sheath of copper outside the insulation, instead of permitting the return currents to follow the ocean path. It also lowers the attenuation of the cable for high-frequency currents. An incidental advantage is that if there are spurious currents in the ocean which may get into the cable circuit, the coaxial return conductor effectively shuts them out and permits the application of higher amplification on the cable.

3.—But the most important advance in thinking leading to the final concept of a multichannel cable consisted in the application to undersea cables of the techniques that had grown up over the years for overland cables, namely, the introduction of amplifiers or repeaters in order to boost the feeble cable currents at intervals before they have a chance to become sufficiently attenuated to be lost in the background disturbing currents of a cable circuit.

The proposals of Dr. O. E. Buckley and his associates, in particular O. B. Jacobs, included certain fundamental features that led to the present successful telephone cable system:

1.—Relatively closely spaced, low-power repeaters, which favored the development and application of vacuum tubes having a long life.

2.—The use of separate cables for opposite directional transmission, which minimized the problem of two-way transmission.

3.—A flexible repeater structure incorporated under the cable armor to minimize laying difficulties and having necessary physical strength to function satisfactorily at depths up to several miles and with tensions of thousands of pounds often involved in normal cable-laying operations.

The details of this amplifier structure, how it retains its flexibility to pass over a sheave several feet in diameter, at the same time maintaining its integrity from the standpoint of water seepage, will be told in more detail later. These amplifiers are installed at intervals of some 40 nautical miles across the Atlantic, and the power necessary to actuate their vacuum tubes is fed over the cable conductor which also carries the communication currents.

For those who are unfamiliar with an amplifier of this sort, it may suffice to note that, in basic principle, it is not unlike that which forms part of any radio receiving set in order to amplify the speech waves from a minute amount to that which finally radiates from the loud-speaker. In the case of the cable, the amplifiers are designed to be effective over a very wide frequency band so that they have carrying capacity for many voice channels when used with terminal equipment of the proper type. The vacuum tubes involved must necessarily be very special and have lives many times that of conventional tubes.

In pursuing this problem of amplification in long cable circuits, British engineers later devised amplifiers that are housed in long tank-like structures. These are suitable for relatively shallow water conditions and are laid by somewhat different techniques.

In the new transatlantic cable, whose route is shown in figure 1, the major deep-sea portion of about 2,000 miles is equipped with the flexible amplifiers. The shallower section from Newfoundland to Nova Scotia — some 330 miles — is being equipped with tank-type amplifiers having somewhat greater channel-carrying capacity. This route is partly overland.

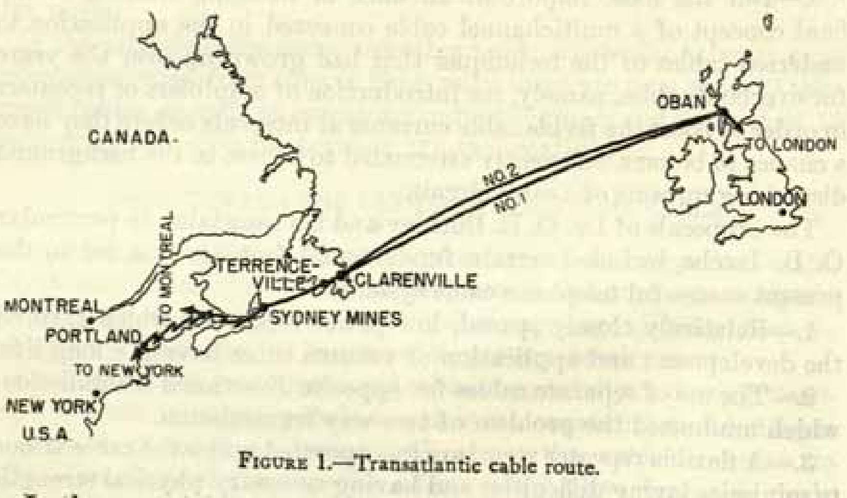

FIGURE 1.—Transatlantic cable route.

In the case of the long deep-sea portion, a separate cable is laid for each direction of transmission. In the shallow-end section a single cable suffices for both directions of transmission.

The whole transatlantic circuit, from working terminal to working terminal, is a splendid example of the adaptability of modern communication practices. For example, from Nova Scotia to New York, where most of the circuits will terminate, the circuits are largely over repeatered microwave radio links.

The cable techniques being used, particularly the deep-sea portion, have previously had a tryout in other installations. No apprehension

is felt about their continued success, although the previous experiences have been for shorter distances. In the case of the deep-sea section, the same technique was employed in 1950 for cables between Key West and Havana, some 120 nautical miles long, having three repeaters in each direction. This system has operated over 5 years with no noticeable deterioration.

The whole project has required great attention to detail and great precision in design and manufacture. Very small differences in the cable and in the amplifier performance would, if allowed to accumulate, have serious over-all results. At least 20 years' life has been the objective in designing the elements making up the cable system.

It is possible, of course, that in time certain parts of the cable or repeaters may become faulty and will have to be removed. This is done by grappling and raising them to the surface from a cable ship. Unfortunately, each time this is done in deep-sea section it is necessary to splice in a longer piece of cable than already existed. This is because, when the cable is first laid, it follows the bottom closely and, since it has very little stretch, it is almost impossible to pick it up by grappling in the deepest sea portions without first cutting it at the bottom. The two ends are then brought up separately and repairs are made. A new section of cable, perhaps as long as 5 or 10 miles, must then be spliced in to close the gap.

What follows gives more details of the new project and, as noted, is largely taken from the paper "A Transatlantic Telephone Cable," by Mervin J. Kelly, Sir W. Gordon Radley, G. W. Gilman, and R. J. Halsey, published in Electrical Engineering, vol. 74, No. 3, 1955 (see footnote 1, p. 273). That paper goes into more detail in historical and other aspects of the project. It should be referred to for a still more complete appreciation of the numerous technical problems that had to be solved to obtain assurance that a project representing an outlay of as many millions could be relied on without unreasonable maintenance.

BACKGROUND OF AMERICAN EXPERIENCE

As noted previously, when the proposal for a transatlantic telephone cable was first considered, electronic techniques were becoming established in land-cable practice, although they had not reached the point where serious proposals could be made to lay a submarine cable with submerged repeaters on the ocean bottom. To permit this, further improvements in technology were required, notably the use of amplifiers whose performance could be stabilized by features such as negative feedback and long-life vacuum tubes.

Negative feedback is a modification of an amplifier circuit which greatly improves its stability with time and power fluctuations. It tends to insure that the amplified currents are an exact replica of those

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that are applied to the input, with the exception, of course, that they are much larger in amplitude.

These developments contributed greatly to long-distance multichannel telephony in the early thirties. Until they were available, the only kind of repeatered transatlantic-cable system that could be imagined was one in which the repeaters could be mounted on moored platforms at sea or in submerged buoys fed with power from local batteries and visited at intervals for maintenance and repair—an arrangement considered impractical.

The advances made in the long-distance systems for land use by the early thirties involved not only vacuum-tube repeaters at frequent intervals on open wire lines and cables, but the use of carrier systems in order to obtain many talking channels through one set of conductors and repeaters. Carrier systems obtain their name by virtue of the fact that each talking channel is associated with its own "carrier" current, the different carrier currents having different frequencies. By the use of a number of carrier currents, the combined intelligence of several speech channels can be joined at the sending end of a circuit to pass over one set of conductors and through a single repeater. At the receiving end, the different carriers, with their intelligence content, can be separated by filters or tuned circuits responsive to the different frequencies, as they are in the process of selecting particular radio stations in the tuning-in process.

The design of vacuum tubes reached a point permitting consideration of tubes whose effective life would be extremely long. There grew, therefore, the broad concept of a transatlantic cable system using two nonloaded coaxial cables, one for each direction of transmission, into which the repeaters would be spliced at regular intervals. The term "coaxial" is here used to indicate a type of cable in which the return conductor consists, as previously noted, of a thin sheath of copper surrounding the insulating material.

The use of loading to improve the transmission characteristics of the cable was omitted since it was hoped that, by the use of a sufficient number of repeaters, i. e., a relatively short interval between them, a wide band of frequencies could be transmitted, providing many telephone channels, using a range of frequencies beyond which loading would no longer be effective.

Detailed discussion of the relative merit of two cables versus one is outside the scope of this paper. As a matter of present-day technical achievement, the twin cables, i. e., one-way operation in each, may be more economical on deep-water routes where traffic capacity is growing rapidly. In the practical case, the present choice was also influenced strongly by the need for a repeater of small size which would cause a minimum of physical irregularity in the cable structure and therefore permit more practical deep-sea handling.

The repeaters required for the deep-sea system had to be designed to withstand the shocks of laying and recovery and the pressure of water encountered at the greatest depth on the North Atlantic route—approximately 3 miles.

There are three vacuum tubes in each repeater. These had to be designed not only for long life but capable of operating with comparatively low power and potential to make it safe to supply power to all the 50-odd repeaters from the shore ends without exceeding a safe working potential. This potential, incidentally, is of the order of 2,000 volts direct current at each terminal.

DEEP-SEA REPEATER CONSTRUCTION

The desirability of a flexible type of housing has been referred to. The structure, as noted, is a flexible bulge in the cable, 10 feet long, and 2.8 inches in diameter, tapering, for a distance of about 28 feet at each end, down to the cable diameter. The armor of the cable itself is continued over the repeater housing but with extra armor wires added to get complete coverage. To prevent the twisting of the repeater in the laying operation, there is a second layer of wires with opposite lay.

The structure of the repeater container is shown in figure 2. It can pass readily around a cable drum several feet in diameter, and over the bow sheave of the cable ship without requiring that the ship be stopped. To attain this flexibility, the repeater elements within the container are mounted inside a series of plastic cylinders, successive units being held together by a spring assembly to form an articulated system. Surrounding this series of plastic cylinders is a series of butt-ended steel rings. There are two layers of rings, the joints between successive rings in the two layers being staggered. Over the rings and supported by them against collapse at sea-bottom pressure, there is an envelope in the form of a long tube of thin copper. Over the copper tube are certain protective coatings and armoring wires.

The repeater enclosure is terminated at each end with a series of seals, comprising, first, a glass-metal seal adjacent to the repeater elements, next, a plastic seal molded to the cable insulation, and, finally, at the extreme ends, a 7-foot-long seal formed within a copper tube which is an extension of the repeater housing. Sea water, in order to penetrate the housing, would therefore have to thread a long multibarriered path. All the seals are adapted for the sea-bottom pressures that they may have to withstand. A partially sectioned portion of the seal is shown in figure 3, together with further details of the repeater structure.

The 51 repeaters in each cable will be located at intervals of 37 nautical miles. They will be fed with direct-current power originating at each shore end, as described later.

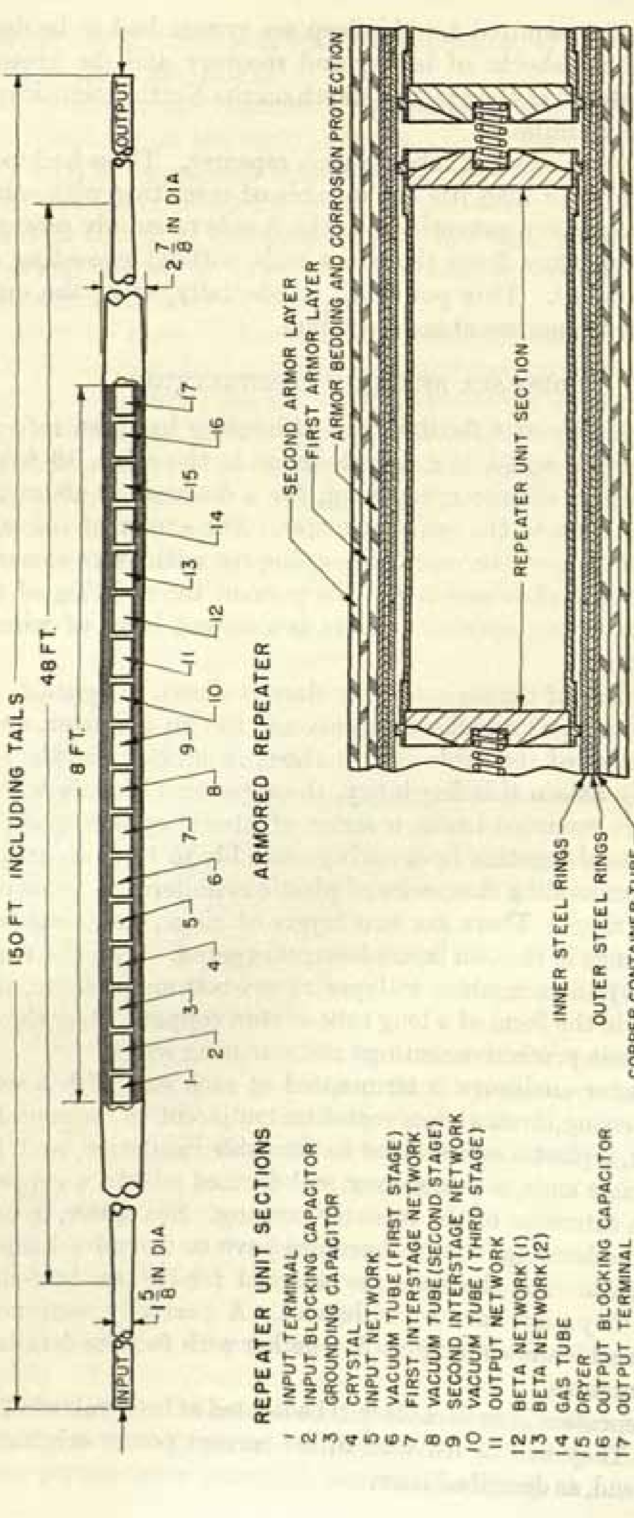

FIGURE 2.—Repeater structure, Clarenville-Oban section.

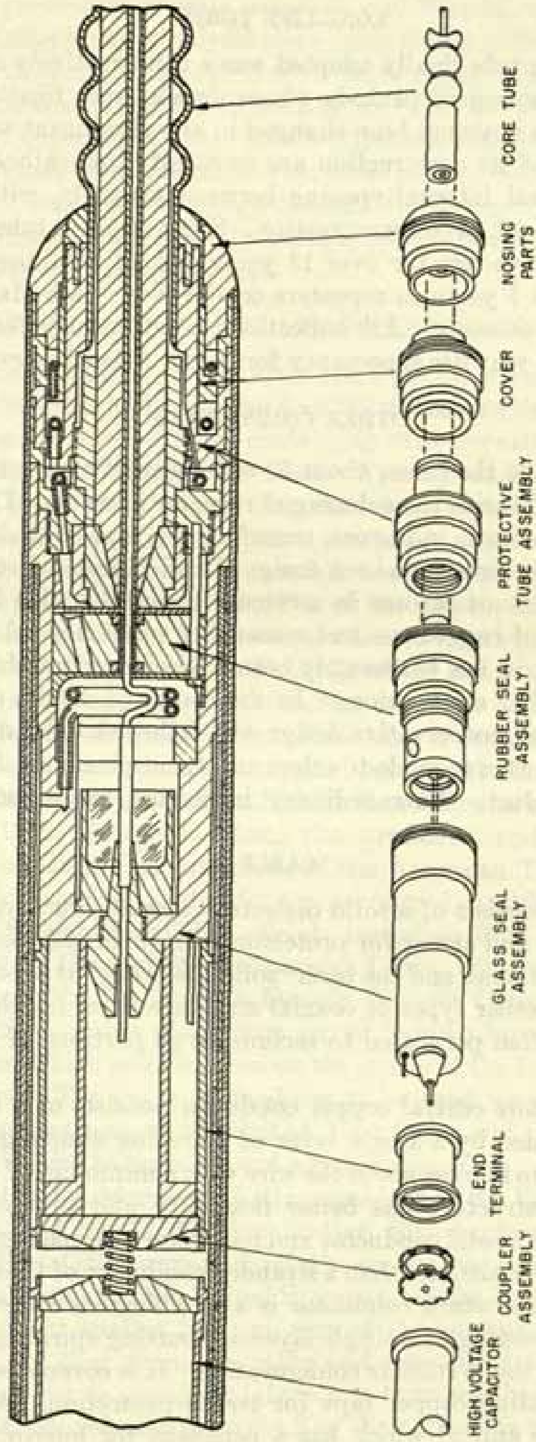

FIGURE 3.—Internal construction of repeater seals.

LONG-LIFE TUBES

The vacuum tube finally adopted was a conservatively designed so-called suppressor-grid pentode whose details were finalized in 1941 and which has not since been changed in any significant way. Essential features of its construction are unusually low cathode temperature and liberal internal spacing between elements, with generally rugged and shock-proof construction. Some of these tubes have been under continuous test for over 13 years and 18 have been in operation for about 5 years in repeaters on the Key West–Havana cables referred to previously. All indications are favorable for something better than 20-year life expectancy for North Atlantic service.

OTHER COMPONENTS

In addition to the tubes, about 60 other circuit elements have to be accommodated inside the submerged repeater housing. These include resistors, capacitors, inductors, transformers, and crystals. Like the tubes, these elements have been designed and fabricated so as to avoid all possible risk of failure in service. They have also had to meet requirements of ruggedness and reasonably small size. As in the case of the tubes, cost has fortunately been a less important factor than it is in many other applications. In the choice of details of design of the components, conservative design was followed. For manufacture, particular effort was made to select and train personnel for skill and pride in product. Extraordinary inspection techniques were employed.

CABLE

The cable consists of a solid dielectric coaxial structure covered by the usual jute and armor for protection. In its broader aspects this is not unconventional, and the term "solid dielectric" is used to differentiate it from other types of coaxial structure in which the insulating material is often permitted to include large portions of air or other gas.

The composite central copper conductor consists of a central solid wire surrounded by a single layer of spiraling abutting tapes, carefully formed to fit close about the wire with a minimum of voids. Such a composite structure has better flexibility and protection against breakage than a solid conductor and has better alternating-current and direct-current resistance than a stranded conductor of the same outside diameter. The return conductor is also a flexible composite copper structure consisting of a single layer of abutting spiraling tapes carefully formed into a tubular configuration. It is covered with an overlapping spiraling copper tape for teredo protection. A teredo is a small marine animal which has a penchant for burrowing into the insulation of submarine cables to create serious current leakages.

As noted previously, shortly before World War II, representatives of the Post Office brought polyethylene (polythene), a British development of the Imperial Chemical Industries, to the attention of the Bell Telephone Laboratories. On test, it has proved to have characteristics that make it superior to other insulating materials, including paragutta, which had been used earlier on some cables. It is particularly adapted for insulation where high frequencies are employed because of its low high-frequency losses. It is also more uniform in its characteristics and less pervious to sea water.

DECISION ON TRANSATLANTIC TELEPHONE CABLE PROJECT

In 1950 the American group, after some previous shorter deep-sea trials, completed the laying of two Key West–Havana cables (i. e., for going and return circuits), each containing three repeaters having the flexible structure previously discussed. These were laid in order to meet service needs for growing United States–Cuba telephone traffic, but, at the same time, the installation was made quite similar to that which would be employed in a possible transatlantic crossing. The maximum depth of water involved is of the order of 1 mile, rather than approaching 3 miles for the transatlantic crossing.

Early in 1952, President Cleo F. Craig of the American Telephone and Telegraph Co. appointed a committee to report on the feasibility of a transatlantic telephone cable. Following a favorable report by this committee, negotiations were opened between the American Telephone and Telegraph Co. and the British Post Office on such a project. In August 1952, George L. Best, vice president, and William G. Thompson, assistant vice president, of the American Telephone and Telegraph Co., went to London for a prearranged consideration of the matter with British Post Office officials, including Earl De La Warr, then Postmaster General; Sir Alexander Little, Director General of the Post Office; Sir Ben Barnett, Deputy Director General, and their associates. The ensuing discussions served to lay a broad foundation for the project which had also been on the minds of the British officials for some time. The types of facilities to be used were left for the technical organizations of the British Post Office and the Bell Telephone Laboratories to consider and agree upon.

Subsequently, Dr. Mervin J. Kelly, president of the Bell Telephone Laboratories, and Sir W. Gordon Radley, then engineer-in-chief of the British Post Office, reported jointly on the status of submerged repeater development in the United States and in the United Kingdom after independent studies by engineers of the company and of the Post Office. At that time, the cable and repeater designs had already been subject to stringent laboratory tests and had been given the practical trials referred to on the Key West–Havana route. It was recommended that these designs be used for the long link between

Newfoundland and Scotland because proved reliability is an essential requirement in a pioneering and costly venture such as the transatlantic telephone cable.

There had not been the opportunity to subject to comparable tests the elements in the British development using tank-type repeaters, particularly those which it was proposed to introduce as parts of a deep-water (as distinct from a shallow-water) system. Nevertheless, it was apparent that if a means for laying and recovering the large repeater housings in deep water without damage to the cable were later developed, the design would provide great flexibility in repeatered cable systems of the future. Kelly and Radley therefore recommended that the British design should be used for the link between Newfoundland and Nova Scotia where the water is of moderate depth, and offered the opportunity for observation of a design based on shallow-water techniques. The design permitted a lower cost per telephone circuit on this short link.

The Canadian Overseas Telecommunication Corporation was asked to join in the enterprise because of its interest in overseas communication and the desire to improve United Kingdom–Canada communication. Administrative and technical discussions took place on both sides of the Atlantic and agreements were arrived at and formalized in a contract signed on November 27, 1953. Ownership of the system will be vested in the American Telephone and Telegraph Co., the British Post Office, the Canadian Overseas Telecommunication Corporation, and the Eastern Telephone and Telegraph Co. The last is a subsidiary of the American Telephone and Telegraph Co. and will be concerned with the facilities within Canadian territorial limits.

GENERAL DESCRIPTION OF THE COMPLETE SYSTEM

A map of the complete system has already been referred to in figure 1, and the route in Newfoundland is shown in greater detail in figure 4. This route between Clarenville in Newfoundland and Oban in Scotland has been chosen in order to be well clear of existing telegraph cables lying to the southward, and also to avoid known "holes" in the sea bed. Selection of a landing site in Newfoundland was determined by other practical considerations involving icebergs, other cable crossings, and provisions for a staff to maintain these cables.

Both the cables between Clarenville and Oban will be approximately 1,950 nautical miles long; each will be equipped with 51 repeaters. The greatest depth at which a repeater will lie will be approximately 2,300 fathoms (2.6 statute miles); most will be at depths between 1,200 and 2,000 fathoms.

Several alternative routes connecting Clarenville with Nova Scotia were considered, none particularly attractive from an engineering

standpoint. On the route chosen the cable will be laid overland to Terrenceville at the head of Fortune Bay, thence, picking up the inshore route, in water of moderate depth to Sydney Mines. This part of the system thus falls into two sections: to the east about 62 statute miles overland and to the west about 274 nautical miles in coastal water in depths of about 250 fathoms.[3] The single cable will

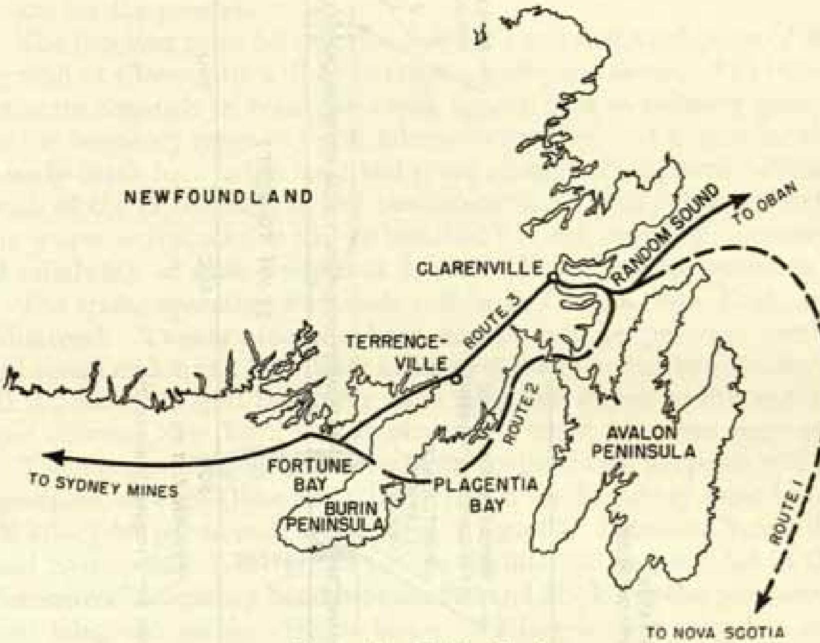

FIGURE 4.—Newfoundland.

be equipped with 16 repeaters; 2 of these will be on land. Each repeater consists of a combination of amplifiers and filters in order to separate the different frequency currents in the opposite directions so that, in effect, the two directions of speech can be independent even though they pass over the same cable structure.

CIRCUIT CAPACITY

Figure 5 shows the location of the various frequency bands used for transmission. The cables between Clarenville and Oban will have transmission frequency bands extending from 20 to 164 kilocycles per second (1 kilocycle equals 1,000 cycles). This, when used with the proper carrier-system equipment at the terminals, will provide capacity for 36 carrier telephone circuits at 4-kilocycle spacing.

The circuit capacity of the cable between Clarenville and Sydney Mines will be somewhat greater because it is planned to transmit the frequency band 20 to 260 kilocycles per second from Sydney Mines to

[3] 1 fathom=6 feet.

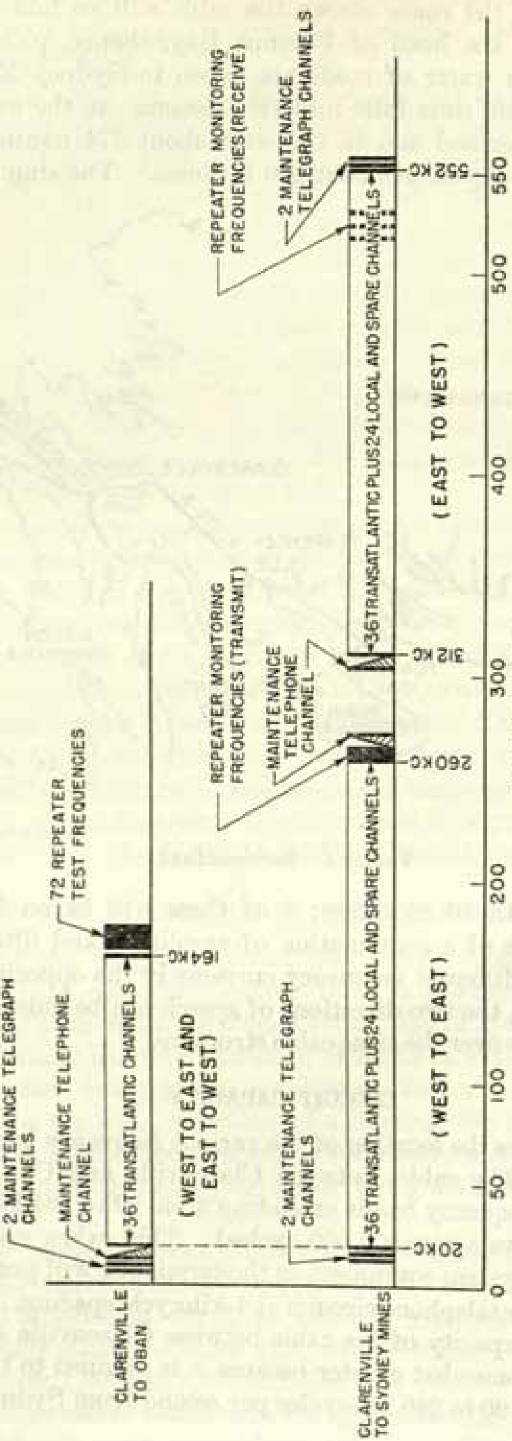

FIGURE 5.—Frequency allocation.

Clarenville and the frequency band 312 to 552 kilocycles per second in the reverse direction. The cable will therefore provide 60 carrier telephone circuits with channels spaced 4 kilocycles apart. One of two 12-channel groups in each direction not employed for transatlantic service will be used to provide 12 circuits for "local" telephone circuits between Newfoundland and the rest of Canada; the other will be held spare for the present.

The junction point between the eastward and westward parts of the system at Clarenville will be in effect a group connector. The transatlantic channels in both parts will appear here as primary groups in the frequency range 60 to 108 kilocycles per second. Connection will also be made here to the local and spare groups. Equipment to bring each of the 12 channels in any one transatlantic group down to ordinary speech frequencies will be installed but not normally connected. Availability of such equipment is desirable for testing purposes.

The traffic operating terminals will be in London, New York, and Montreal. Twenty-nine telephone circuits will be put into service between London and New York and six between London and Montreal. It is planned to split the thirty-sixth telephone circuit at the western end between New York and Montreal and use it for other purposes.

Telephone and telegraph circuits for maintenance purposes will be provided between Oban and Clarenville in the frequency band below 20 kilocycles per second, as indicated in figure 5. Between Clarenville and Sydney Mines, telephone service circuits will be provided in the "crossover" frequency band between 260 and 312 kilocycles per second and telegraph service circuits below 20 kilocycles per second in one direction and 552 kilocycles in the other direction.

TRANSMISSION OBJECTIVES

Since the transatlantic circuits will serve to connect two extensive telephone networks on opposite sides of the ocean, including connection to the European continent, which will be reached through London, they are being designed to cause as little extra loss and other forms of impairment as possible. For example, it has been agreed that the target for frequency characteristics of the channels between London and New York or London and Montreal should be as good as that specified by the C. C. I. T.[4] for a 2,500-kilometer international circuit.

Other objectives for the circuits compare favorably with those specified for long-distance circuits wholly on land.

CABLE DETAILS

As already indicated, two cables will be used between Newfoundland and Scotland, one for each direction of transmission. The cable used

[4] Comité Consultatif International Telephonique.

on the transatlantic route will have a somewhat greater thickness of insulation than that included in the makeup of the Key West–Havana cable. The core diameter before the addition of the return coaxial conductor will be 0.62 inch. Figure 6 illustrates the typical cross sections used in different parts of the over-all cable system. It will be noted that the interior structure, namely, the inside conductor, the insulation, and coaxial return conductor are the same in each case, the cables differing only in the degree to which external materials, including armoring, are applied, depending on the location of the cable.

Manufacture of the cable demands control of the dimensional tolerances to a greater degree of precision than has been attempted heretofore. This is because the large number of repeaters in the circuit make it of great importance to maintain a fine balance between repeater amplification and cable loss. Predetermination of the effects of temperature and pressure on cable attenuation assists in maintaining this balance when the cable is at sea-bottom temperature and pressure. Fortunately, the sea-bottom temperature is very constant. Electrical irregularities which would result from structural imperfections must also be avoided since they affect the gain-frequency characteristics of the repeaters.

As is customary in cable practice, special cable armoring will be used near the shore ends and the various types are shown in figure 6. Type A has an armoring consisting of 12 galvanized mild-steel wires, each 0.3 inch in diameter, and is laid in water not deeper than 300 fathoms; type AA, used for some landings, is similar but has an extra layer of armoring. Type B is laid in moderate depths and has 18 mild-steel wires, each 0.165 inch in diameter. Type D is laid in all depths greater than 700 fathoms. It is armored with 24 high-tensile steel wires, each 0.086 inch in diameter, each wire being taped; these enable it to be laid and lifted in the deepest water.

The structure and dimensions of the conductors and core of the submarine cable used between Clarenville and Sydney Mines will be identical with those of the cable used between Clarenville and Oban. The cable will have AA- or B-type armoring. It will, however, be tested to a specification appropriate to the higher frequencies to be transmitted.

The land cable will be basically the same as the submarine cable but, being more subject to electrical interference, will be shielded with layers of soft iron tape applied over the outer conductor. The tape in turn will be protected from corrosion by a polythene sheath over which will be applied jute bedding.

The cable will be laid in a trench at a depth of approximately 30 inches where the temperature is expected to have an annual variation of about 35° F. and a maximum daily variation of about 2° F. Guard wires, for the protection of the system against lightning, will be laid in

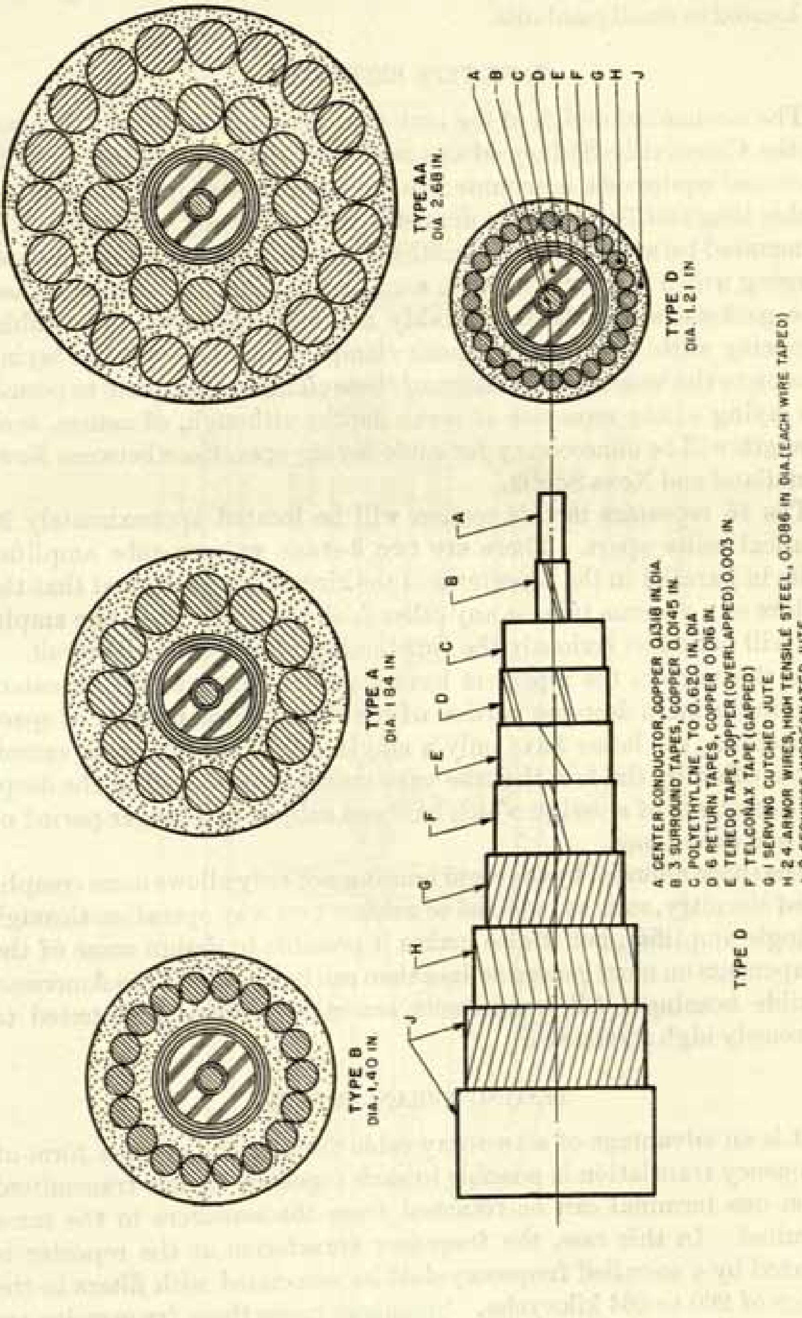

FIGURE 6.—Types of cables.

the trench above the cable. The two repeaters in the land section will be identical with those in the sea and, according to the terrain determined in the final survey, will be laid in ponds, buried in the ground, or located in small manholes.

TANK-TYPE REPEATERS

The mechanical design of the tank-type repeaters which will be used in the Clarenville–Sydney Mines section is shown in figure 7. The electrical equipment is mounted in an inner sealed cylinder 4 feet 2 inches long and 7¾ inches in diameter, filled with dry nitrogen. This is mounted between brazed-in bulkheads in the pressure-resisting outer housing which is 9 feet long with a maximum diameter of 10½ inches. The gaskets or glands are suitably molded polythene. The cable-armoring wires are fastened under clamps which transfer the laying tension to the housing; the design of these clamps is adequate to permit the laying of the repeaters at ocean depths although, of course, such strength will be unnecessary for cable-laying operations between Newfoundland and Nova Scotia.

The 16 repeaters in this section will be located approximately 20 nautical miles apart. There are two 3-stage vacuum-tube amplifier units in parallel in the repeater and the circuit is so designed that the failure of a vacuum tube or any other faulty component in one amplifier will not affect seriously the functioning of the over-all circuit.

In this respect the repeaters have some margin over the repeaters used in the main deep-sea portion of the circuit since, because of space limitations, the latter have only a single amplifier. To some extent, this is offset by the fact that the vacuum tubes employed in the deep-sea section are of a design which has been subject to a longer period of test and experience.

The space afforded by the rigid housing not only allows more complicated circuitry, such as required to achieve two-way operation through a single amplifier, but it also makes it possible to design some of the components on more generous lines than can be fitted into the American flexible housing. All components are manufactured and tested to extremely high standards.

TESTING ARRANGEMENTS

It is an advantage of a two-way cable that, provided some form of frequency translation is possible in each repeater, signals transmitted from one terminal can be returned from the repeaters to the same terminal. In this case, the frequency translation at the repeater is effected by a so-called frequency-doubler associated with filters in the range of 260 to 264 kilocycles. Signals at twice these frequencies are returned to the sending terminal and enable an accurate measurement

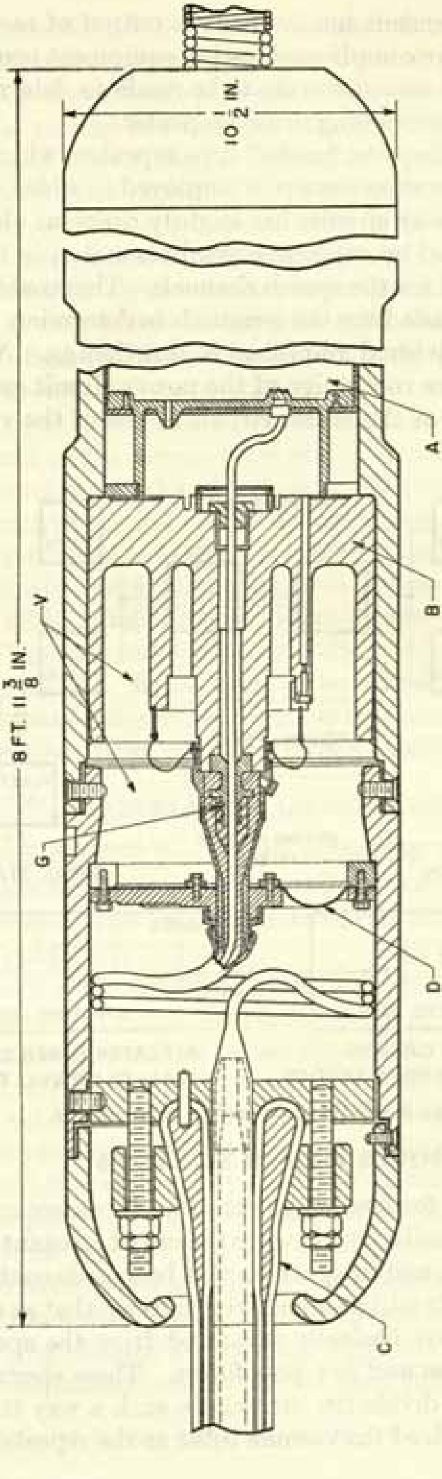

FIGURE 7.—Repeater housing, Clarenville-Sydney Mines section.

to be made of the transmission level at the output of each repeater at any time. Other more complicated testing equipment provided at each terminal will enable measurements to be made to determine whether both amplifiers are functioning in each repeater.

In the case of the deep-sea "snake"-type repeaters which transmit in only one direction, an arrangement is employed in which each repeater of the 51 in the one-way circuits has slightly different electrical characteristics, determined by a quartz-crystal resonator, in the frequency band above that used for the speech channels. This enables a selective measurement to be made from the terminals to determine, in effect, how well each of the individual amplifiers is functioning. Arrangements are provided to insure continuity of the power circuit even in case of the complete failure of the heater circuit in one of the vacuum tubes.

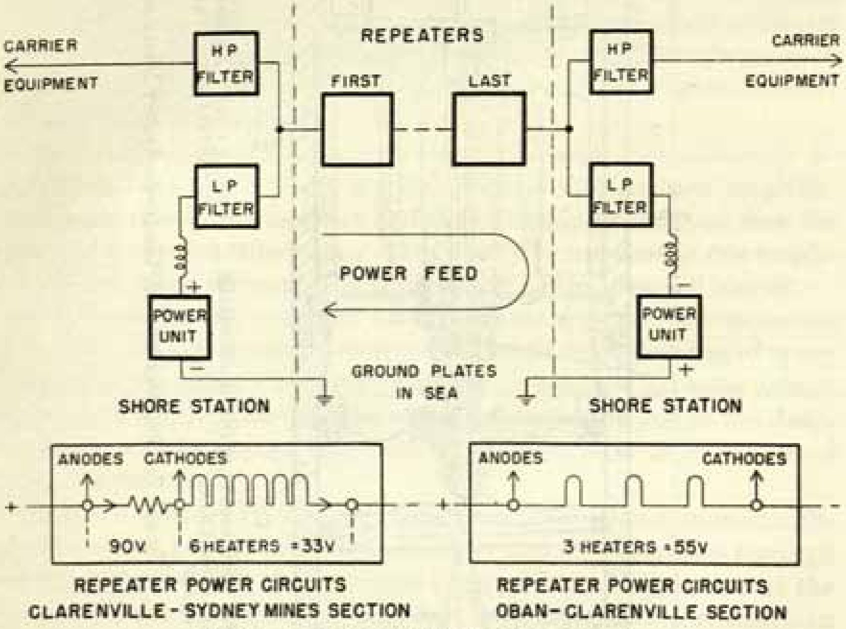

Figure 8.—Basic power-feeding arrangements.

POWER FEED TO REPEATERS

The arrangements for feeding power to the repeaters on the two sections are generally similar and involve the use of constant-current generators series-aiding, and designed so that both ends control the value of the line current. It will be noted from figure 8 that at the terminals the power currents are basically separated from the speech currents by so-called high-pass and low-pass filters. These electrical circuits, as the name implies, divide the currents in such a way that the direct current necessary to feed the vacuum tubes at the repeater points, and

the high frequencies of the speech channels find free access to their respective terminal equipments.

The repeatered cable on the Clarenville–Oban section will require initially a total voltage of about 3,700 volts, increasing with later years perhaps to about 4,450 volts, or even up to about 4,700 volts if it is necessary to introduce additional repeaters after repairs.

Since these voltages are divided between the two terminals, the maximum voltage on the cable is only half the above figures. For the repeaters on the Clarenville–Sydney Mines section, the necessary total driving voltage will be only about 2,300 volts and, if necessary, it will be possible to feed this from one end only since the cable and other circuit elements will withstand this voltage.

There are some differences in the makeup of the constant-current generators used on the two sections but these are incident to the particular problems involved and not generically important.

Every effort will be made to insure continuity of the direct-current power supply to each cable. In order to assist this, the alternating current supplied to each constant-circuit power-feed unit will be derived via alternating-current—direct-current—alternating-current machines. These machines will normally be driven from commercial power-supply means. In the event of power-supply failure, a storage battery continues to drive the direct-current machine. If the failure is of long duration, diesel engines will be started up.

CABLE-LAYING ARRANGEMENTS

All the cable is being laid by the cable ship *Monarch*. This ship, which was built for the British Post Office in 1945, has a gross tonnage of some 8,000 and, with full oil bunkers, can carry between 5,000 and 6,000 tons of cable.[5]

The *Monarch* is the only ship afloat capable of laying the whole of the deep-water part (about 1,600 nautical miles) of each cable between Newfoundland and Scotland in one operation. It is obviously desirable to avoid any sequence of operations which will make it necessary to pick up a cable end and make a splice in deep water. Such operations will have to be carried out if repairs are necessary after the cable has been laid, but inevitably at some risk of the cable's kinking. All repeaters are joined into the cable before it is loaded into the ship.

A period of 12 days during which continuously good weather conditions may be anticipated is necessary in order to carry out the main operation without undue hazard to the repeatered cable. In the North Atlantic such conditions are unlikely except during the period mid-May to mid-September, and it has not been practical to lay both the

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[5] The tons referred to here and elsewhere in the paper are long tons of 2,240 pounds.

cables on the main crossing in one summer. As noted, one of these cables was laid during the summer of 1955 and the reverse-direction cable will be laid during the summer of 1956.

The essential parts of conventional paying-out, or picking-up, machinery are shown in figure 9. Although the flexible, built-in repeaters are designed to be handled as part of the cable, it is, of course, desirable not to bend them to a small radius. New cable drums of approximately 7-foot diameter have been fitted on the *Monarch*. Bow and stern cable sheaves have also been made this diameter. Various other minor structural changes, some based on successful laying of the Key

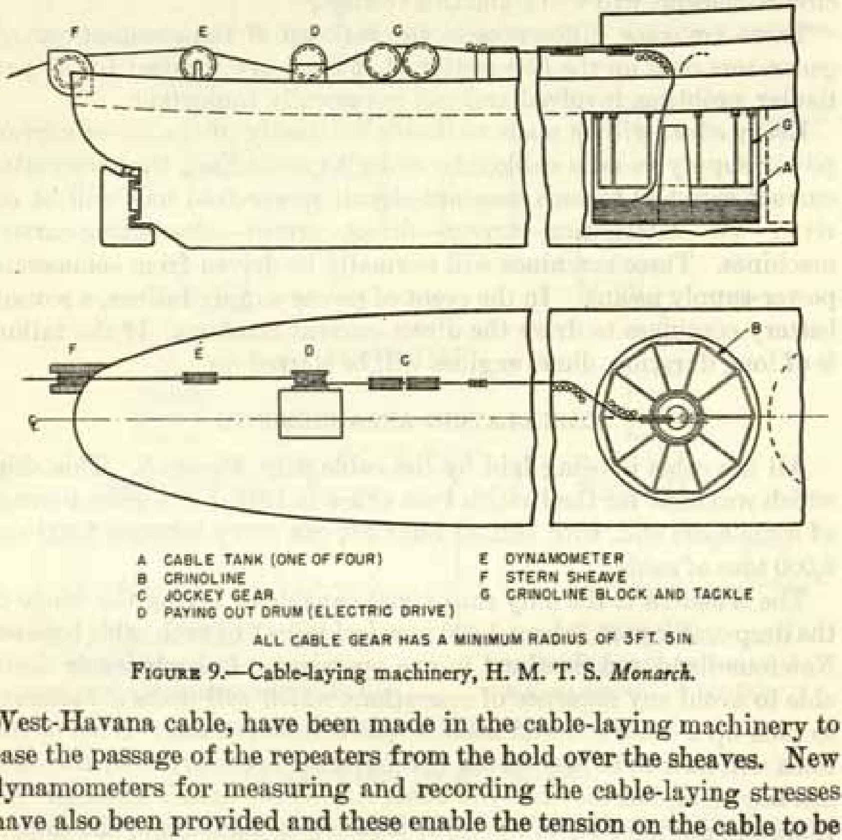

FIGURE 9.—Cable-laying machinery, H. M. T. S. *Monarch*.

West-Havana cable, have been made in the cable-laying machinery to ease the passage of the repeaters from the hold over the sheaves. New dynamometers for measuring and recording the cable-laying stresses have also been provided and these enable the tension on the cable to be closely controlled as it is paid out.

The laying of the cable between Newfoundland and Nova Scotia presents no special problems, but an electrically driven hoist has been fitted over the ship's bows to facilitate handling the rigid tank-type repeaters.

CONCLUSION AND SPECULATION

Barring unforeseen and unexpected delays, the latter part of 1956 should see the completion of the first transatlantic telephone connec-

tion by submarine cable. With the completion of this project, telephone service between the two continents should enter a new era marked by improved quality of service and reliability. Capacity for growth will no longer be restricted by the limited capacity of the radio spectrum.

Certain advantages of the radio will remain, however: flexibility, the speed with which communications can be established and switched from route to route, direct access to one country from another, relatively lower cost, etc. These are not inconsiderable advantages and they augur for the continued importance of shortwave radio-telephone services.

On the other hand, the new transatlantic cable will by no means represent all that could be done if full advantage could be taken of contemporary techniques. The submarine cable art is a conservative one. As Dr. Buckley observed, the laying of a deep-water submarine cable, like any other activity on the high seas, must be planned with its unavoidable hazards in mind, and experience over 100 years has shown that in such a project it is better to be safe than sorry.

But the consequences of this doctrine of caution are equally plain. The submerged repeaters in the 1956 deep-water cable section incorporate tubes whose proven design dates back to 1941. On the other hand, more recently designed tubes provide superior performance and these are the types that will be used in the system between Newfoundland and Nova Scotia, where the consequences of tube failure will be minimized. The integrity of such postwar tubes, under the severe and highly specialized conditions of installation and use, remains to be established. However, with such new types of tubes, it is certain that cable systems with still greater communication capacity can be realized.

Looking still farther ahead, the transistor looms as a development which has the potentialities of making possible long, deep-water submarine cables with much greater communication capacity than can be realized with repeaters employing vacuum tubes. The voltage required by the tubes sets an upper limit on the number of them that can be operated in tandem before the power supply results in voltages on the cable that are beyond the limits of safety. The much lower power drain of the transistor would overcome this obstacle and permit more repeaters to be used and wider frequency bands to be accommodated. Ruggedness, long life, and small size are added attractive features of the transistor which are of not inconsiderable importance to the future development of submarine cables.

A transatlantic submarine television cable is a long-range goal worthy of serious study and by no means to be dismissed as impractical of attainment.

The concept of a transatlantic telephone cable, as noted, owes its origin to the inspiration of Dr. Buckley's early work. He laid the firm technical foundation for such a project. Subsequent developments which have been described have been the work of many engineers and physicists on both sides of the Atlantic; on the American side, in the Bell Telephone Laboratories, the Western Electric Co., and the Simplex Wire and Cable Co.; on the British side, in the Post Office Research Laboratories, Standard Telephones and Cables, Limited, and Submarine Cables, Limited. Without this development work, the particular project would be impossible.

In carrying out the complete project, individuals possessed of a variety of skills, representing many organizations, have worked in close cooperation. In addition to the scientists, engineers, and technicians, the office staffs, lawyers, financial specialists, and administrators of the British Post Office and other organizations previously mentioned and, in particular, the general departments and long-lines department of the American Telephone and Telegraph Company, have played an important part. Not to be neglected are the capable staff and crew of H. M. T. S. *Monarch*.

Genetics in the Service of Man[1]

By Bentley Glass
Professor of Biology
The Johns Hopkins University

Human power, which mounted slowly indeed through the eons of prehistory and somewhat more rapidly after the advent of the sword and pen, has gathered momentum with logarithmic sweep since the dawn of modern science. Today it seems to be rocketing into outer space with the incredible energy of atomic fission.

I would be the last to imply that the principal value in the pursuit of scientific knowledge is the utilitarian one—that society should nurture science only because of its fruits. Yet the fruits are of undeniable importance, and before we eat, it might be well for us to see upon which side of the tree of good and evil they are borne. Power, especially unlimited power, can be more danger than blessing, and what foresight and intelligence we do possess ought to be exercised in safeguarding and channeling it into wise uses. Mankind was not prepared to use and control nuclear power. Today we stand on the verge of biological discoveries of an equally revolutionary and potentially devastating kind, which it will require all our wisdom to control. It is these eventualities which I wish to discuss.

A century ago, when my grandfather was born, the life expectancy of the average male infant was 40 years. At the turn of the century, it was still only 48 years; but by 1930 it has jumped to 59 years, and today stands at the amazing average of 69 years. Whatever we may think about the wise use made of those extra 29 years of life by the average American man, surely this achievement of medicine and biology has been spectacular.

Without recounting here the several steps in the advancement of health and longevity, I wish merely to point out that genetics has contributed its share to this progress. You are certainly aware of the tremendous role of penicillin in virtually wiping out many infectious diseases. In the course of the enormous wartime effort that went into

[1] Reprinted by permission from The Johns Hopkins Magazine, vol. 6, No. 5, February 1955.

the attempt to produce penicillin on a large scale, one serious difficulty was met. The highest-yielding strains of the mold *Penicillium* would grow only on the surface of the culture medium in the great vats, and strains that grew well when submerged were poor penicillin producers. Applying the methods of inducing mutations already known to geneticists at the time, Milislav Demerec and his coworkers at the Cold Spring Harbor Laboratory of the Carnegie Institution of Washington undertook to irradiate with high doses of X-rays some *Penicillium* strains that grew well when submerged, and to look for mutations that would permanently affect the yield of penicillin. Among 504 selected products, one was found that doubled the production of penicillin over that in the original strain. This high-yielding strain became the basis of the enormous production of penicillin that within the last 10 years has contributed so much to our national health.

Even more significant than the production of this strain, however valuable, was the insight gained in the studies by Demerec and others into the fluctuating relations between virulent, disease-causing bacteria and viruses and those agents that may be used to combat them. It was discovered that the infectious agents have powers of mutation too; and among the mutations that can be induced by X-rays or by chemical compounds, or among those that are always arising spontaneously in any large population of organisms, there are some mutations that confer resistance to the sulfonamide drugs, to penicillin, to streptomycin, in fact, to the killing effects of radiation itself. Learning this, geneticists at once made dire predictions about the consequences of an overenthusiastic use of the wonder drugs and the antibiotics. But it seems that their medical colleagues failed to understand the danger, while the clamor of those who were ill led to the widespread use of such agents even for the common cold. Millions of doses were given to soldiers as mere prophylaxis, in the hope of warding off some possible infection. The result, now well known, was a near-disaster. People began to say, "The miracle drugs don't work any more. Penicillin has lost its punch. Streptomycin is no good." What had happened was exactly what the geneticists had predicted. Mutant strains of infectious germs had arisen that were now resistant to our drugs and antibiotics, just like the now all-too-common houseflies that seem to thrive on DDT. As a matter of fact, there is in existence at least one bacterial strain that actually *requires* a supply of streptomycin in order to grow.

New kinds of antibiotics had then to be discovered and put into mass production. Yet the race was a losing one, for the mutational powers of the infectious organisms seem virtually unlimited and permit change far more rapidly than scientists can discover and produce new agents.

Here again the geneticist may interpose a prediction. The simultaneous coincidence of two mutations, say to penicillin resistance and to streptomycin resistance, is of an order of probability so low (about 10^{-16}) as to be truly negligible. Start out with two antibiotics to which the infectious agents have never been exposed, and use them together; and use a high enough initial dose to leave no survivors—except, of course, your patient. In this way the antibiotics may continue to serve mankind in the future. But meanwhile, penicillin and streptomycin must be given a rest.

In recent decades the shade of Malthus has once again risen to trouble us. Clearly, if the general life expectancy doubles, then even without any increase in births at all there are twice as many mouths to feed at any one time as there were before. But there are also more than twice as many adults with unmodified (or but slightly moderated) yearning to have children and rear families. The world population has soared, in spite of wars and famines, from one and a half billions of people, a century ago, to two and a half billions today. Fertile land is almost fully occupied. How can we feed another billion people, whom we may expect inevitably to arrive before the slowly dropping birth rate overtakes the still declining death rate? The immediate answer, if there be one, lies in the almost unheralded achievements of geneticists in increasing the food supply.

On September 28, 1954, there died in Princeton, N. J., a geneticist who never received a Nobel prize or made a fortune. To most Americans George H. Shull remains completely unknown. Yet this man, together with a few others who made his theoretical achievement a practical possibility, has brought about a two-thirds increase in the United States yield-per-acre of the corn crop with no further requirement for labor, and has added literally billions of dollars to the income of our nation.

In fact, a true agricultural revolution, though scarcely recognized, has resulted from the discovery of hybrid corn. During the war years 1942–44, in the face of acute shortages of labor and of bad weather, and at a time when the corn acreage of the United States was still only about one-half planted with hybrid corn, the increased yield amounted to approximately 50 percent—a total of 1,800,000,000 bushels worth two billion dollars. Hybrid corn thus in a sense paid for the entire development of the atomic bomb. Even more important, it was a large factor in preventing this time the aftermath of hunger that followed the end of the first World War; for the amount of food we were able to ship to the desolated countries of Europe in 1946–47 was more than equaled by the increase in the corn crop attributable to the planting of hybrid corn. The hunger and chaos of eastern Europe in 1918 and 1919 furnished communism with the seedbed in which it first rose to politi-

cal domination in Russia. The curbing of the spread of communism in western Europe after the more recent World War may in a very considerable measure have been due to the boon of hybrid corn, as Paul Mangelsdorf of Harvard University has claimed.

It is of some interest, therefore, to see just what G. H. Shull did with his corn plants. He started out with the intention of studying the inheritance of quantitative characters, such as yield, in order to see whether these followed the laws of Mendelian inheritance; and he began by inbreeding his lines. He found that this inbreeding brought out a number of hidden, deleterious hereditary characteristics, and that the inbred strains showed a marked loss of both vigor and productiveness. Eventually he obtained very pure strains of great uniformity, though for the farmer totally worthless, runty, and weak, with small ears bearing few seeds, and of course very low in yield. When, however, two of these inbred lines were crossed together, there was a phenomenal improvement in the hybrids. The ears were large and full, and the production equaled or bettered that of the best strains of the time.

In 1917 Donald F. Jones, at the Connecticut Agricultural Experiment Station, invented the so-called "double cross," with quite the opposite effect from that of the usual connotation. By crossing together the two hybrids produced from the single crosses of four different inbred lines, A, B, C, and D, Jones obtained seed that, when planted, considerably exceeded in vigor and yield even the hybrids of the first crosses, of A with B, and of C with D. Seed produced by Jones' method is the present-day hybrid corn, and later efforts have been devoted simply to finding the best inbred lines to combine for a particular purpose or area, and to producing the hybrid seed in a quantity great enough to plant some 60 million acres.

The same hybrid corn that is best suited for growth in Iowa is not adapted to Texas, and assuredly not to Mexico. Hence the extension of the benefits of hybrid corn to the entire Nation, and then to foreign countries, requires a repetition of the process while utilizing native strains of maize. This takes time, but requires no essential modification of theory or method. Already in Mexico hybrid corn suited to the country has been produced and is revolutionizing the agriculture of that country, and with it the level of well-being and the culture of the people, which from pre-Conquest days has been based on maize. When we realize that today two-thirds of the world's population are chronically malnourished, and that larger and larger populations are inevitable before the world population can be stabilized, the importance of hybrid corn and similar products of the geneticist's plant breeding becomes fully evident.

Eventually we may have to subsist on great quantities of yeast or some microscopic alga like *Chlorella* that can be raised by the ton in

tanks of nutrient solution, but these answers to the world's hunger are not yet ready. Meanwhile the geneticist must continue to breed drought-resistant sorghums, new wheat varieties that are resistant to the latest mutant forms of wheat rust, and more productive fruits, vegetables, and field crops like hybrid corn. Even when the day of mass-produced yeast and algae does arrive, the geneticist will have had to make an essential contribution in finding palatable, productive, and disease-resistant strains, as the British learned during World War II. For after many millions of dollars had been spent in producing a great yeast plant in Trinidad, which was to run on waste molasses and feed cheaply the teeming populations of the Caribbean, it was found that the natives didn't like it and wouldn't eat it, regardless of how nutritious it was said to be.

The geneticist faces such responsibilities with modest confidence, for within the past 50 years his knowledge of reproductive processes and hereditary mechanisms, of the nature of genetic changes within populations, and of evolutionary processes on a still larger scale has so increased as to enable him at will to alter the hereditary nature of any plant or animal in an astonishing variety of directions. He can even create new species—in fact, he has already done so. He can, in short, control the course of evolution.

The evolutionary process is conceived today in somewhat different terms from those of Charles Darwin, although his ideas have been supplemented rather than superseded. In a population that is breeding quite at random with respect to certain alternative characteristics, the gene frequencies underlying those characteristics will remain in equilibrium, unchanging from generation to generation. In other words, the hereditary nature of the species, the makeup of the population, will change only if some factor upsets the equilibrium and favors one gene over another.

Four major factors contribute to evolutionary change. Only these four, and no others, can be shown to be effective in altering the frequency of particular genes in populations. The first of these factors is mutation, the rare but permanent change of individual genes or chromosomes. This is the process fundamental to all the others, for it provides the variety of hereditary material upon which the other factors can act. The second factor is natural selection, which is today regarded simply as the differential reproduction of genetic types rather than as that ruthless competition embodied in the classic phrase, "the survival of the fittest." The third factor is genetic intermixture, brought about by means of the migration and interbreeding of individuals from populations that have been to some degree isolated in the past and have become genetically differentiated, like the several races of mankind. The fourth factor is chance itself, which in populations of very small size may result in statistical fluctuations about

the expected composition of the population. These deviations may sometimes chance to occur in the same direction, like a run of luck, until the hereditary composition of the population is quite altered.

Human control over the mutation process began in 1927 and 1928 when my former teacher H. J. Muller and my later friend and mentor L. J. Stadler, working quite independently, the one with fruit flies and the other with maize and barley, succeeded in demonstrating that exposure to X-rays enormously increases the frequency of all kinds of mutations. Other kinds of potent radiations, and even ultraviolet rays, were found to do the same. During the course of World War II, as a byproduct of the scientific study of poison gases, chemical compounds were discovered that likewise enhance the frequency of mutation. Dozens of workers are now actively studying the conditions that limit or enhance the action of physical and chemical mutagens. From all this exploration there is arising the ability—not yet to direct the course of mutation so as to produce just the mutation desired, or even a particular type of mutation, for that is still impossible—to increase the over-all frequency of mutation so that once-rare hereditary changes become common.

Most of the mutations produced are harmful to their carriers, as might be expected from a blind interference with the delicately balanced mechanisms of life. Most mutants have a lower viability and a poorer fecundity than the types they are derived from. Yet this is not always so. Sometimes a new mutant type may be poorer than the original type under the existing conditions of life, but may prove itself superior when these are altered. Flies dependent on garbage pails do better in the city of Baltimore if they have wings, but on the storm-swept island of Kerguelen in the southern Indian Ocean the only flies to be found creep about without wings, or with little stubby vestiges of wings. Natural selection, as Darwin pointed out, determines the differential survival of various hereditary types, and natural selection is but a name for the complex combination of conditions under which each population lives and reproduces, and which is different, at least somewhat different, in every other time and place.

For a long time now mankind has substituted for the selection of nature his own artificial selection of whatever chance mutations appeared in his domestic animals and cultivated plants and which seemed to him to be desirable. It is thus that all the progress in plant and animal breeding has been made, from the day the first animal was tamed and the first seed planted to the beginning of our own century. What geneticists are now enabled to do is merely to speed up this process a thousandfold and to control and direct it more effectively. Thus, for example, it was discovered about five years ago that certain inbred strains of field corn have as high a sugar content in the stalk as sugarcane itself. The genetics has been worked out, selection has

been used to obtain strains with a constant high sugar content in the stalk, and now hybrid corn with sweet stalks is ready to be used, either for the human sweet tooth or as silage for our horses and cattle, which need sugar too. A shorter corn plant that would stop growing at less than 6 feet in height would clearly be invaluable to the seed growers of hybrid corn, who find some difficulty in detasseling, by hand, corn plants that grow 12 feet tall. The desired mutation was found, and now hybrid corn that is just as productive as formerly, but grows to only 6 feet, is available.

The third evolutionary factor is genetic intermixture, certain possibilities of which have already been indicated in what has been said about hybrid corn. Intermixture may, however, be extended to wider limits, to encompass crosses between different geographic races or even different species. The latter have evolved to a point where the hybrids between them are commonly highly sterile—witness the mule. Yet just here, by an odd chance, there emerges the very mechanism that has enabled the geneticist to create his first true new species. For if in some way the chromosomes of a sterile hybrid can be doubled, its self-fertility is often completely restored, although it remains infertile when crosses are made with either of the parent species. If, for example, one could double the chromosomes of the mule, the latter would have two sets of horse chromosomes and two sets of ass chromosomes. Hybrid sterility is often due to the inability of the chromosomes of different species to pair with one another during the formation of the sex cells; but after doubling, one set of horse chromosomes could pair with the other and likewise for the ass chromosomes, so that each egg cell or each sperm cell would possess when mature a full set for both kinds. No one has yet succeeded in doing this to a mule, or in breeding two mules together afterward, but exactly this feat has been accomplished a number of times in the plant world.

The first and most famous instance was performed by a Russian geneticist, G. D. Karpechenko, in 1927. Karpechenko crossed two different genera, the radish (*Raphanus*) with the cabbage (*Brassica*), and obtained a sterile hybrid. He then succeeded, with some difficulty, in getting the chromosomes to double, following which he could self-pollinate the hybrid and obtain in the next generation a perfectly fertile form which he named *Raphanobrassica* and which, according to the same etymological principle, should in English be called by the common name of "rabbage." Since it could be crossed with the original radish or cabbage parent species only with a resultant almost-complete breakdown of fertility, Karpechenko rightly regarded this as a new species, the first man-made one in history.

But unfortunately for Karpechenko, the new rabbage species combined the prickly inedible leaves of the radish with the miserable root of a cabbage. Although he received worldwide fame among geneti-

cists for his feat, it was scarcely an achievement to impress the makers of agricultural 5-year plans. Karpechenko was later liquidated. The method is nonetheless one of great promise, for in some instances the valuable characteristics of two species may thus be combined in a single new one; and today, by means of the drug colchicine, it has become easy to double the chromosomes of a hybrid, just the step where Karpechenko met his greatest difficulty.

There is, at any rate, no difficulty in controlling the amount of genetic intermixture by performing, on the one hand, the desired crosses, and on the other by isolating and otherwise preventing intermixture, just as man in the past has controlled the interbreeding between different breeds of dogs or cats. As to the fourth factor, this too is under human control because it depends particularly on the size of population, which may be readily regulated.

At this point one might feel like singing, with Swinburne, "Glory to Man in the highest, for Man is the Master of things." But one had better be wary. Problems aplenty remain just as soon as one begins to consider the application of this newfound genetic power to man himself.

Eugenics, the term Francis Galton applied to this endeavor, was envisioned by him as the safeguarding and improvement of our human heritage. The late Professor W. E. Kellicott of Baltimore defined it as "the social direction of human evolution." This seems to be a very good definition, for it focuses attention on the process as well as the power to control it, on the choice of goals as well as the ultimate chooser. The basis of effective eugenics must include not only an understanding of evolutionary processes and the power to control them; it must include also a far wider knowledge of human genetics than now exists, and the ultimate consideration by society of many questions of human values.

The idea of the social direction of human evolution is not new. Many people have practiced infanticide in order to rid their society of abnormal or defective individuals. The ancient Spartans not only did this, but also, in order to maintain ascendancy over the helots, they practiced most of the eugenic measures advocated in recent times. Their emigration was restricted, and marriage within their own order was encouraged. Special taxes were levied on celibates, and the production of offspring was rewarded by the state. A severe regimen was maintained to promote fitness and to eliminate the weak or deformed. Also, periodically, the helots were massacred, so as to keep that supposedly inferior element of the population down. Plato's proposals for a eugenic society are likewise famous.

There are many misconceptions about heredity. For example, in the strict sense, there are no hereditary *characteristics* at all. The ferti-

lized egg from which each of us starts out in life must *develop* those characteristics common to all members of its species, race, and family, besides those peculiar to itself. One inherits only what is in the fertilized egg: that is, in the physical sense, only the chromosomes and the genes they contain; in the developmental sense, only the potentialities and capacities inherent in those genes. Those potentialities can be realized only within the limitations of the environment.

Heredity is biparental; for each gene inherited from one's mother, a corresponding gene is inherited from one's father. These corresponding genes are not always identical, because mutations give rise to varieties of the same gene within the population. Should the two genes of a pair happen to be different (a condition called "heterozygous"), then one gene, known as the dominant, commonly determines the specific trait concerned; and the other gene, the recessive, is masked, although it will still be transmitted to succeeding generations without alteration. Thus a person who has a pair of genes, one for brown hair and the other for red, will have brown hair, and the presence of the gene for red hair may be quite unsuspected. One can have red hair only by inheriting two genes for red hair, one from each parent; one would then be "homozygous." A good many of each person's genes are probably recessive, and most of these will be heterozygous and as a consequence unobservable.

The significance of this for eugenics is unmistakable: a considerable proportion of the genes in any person, and therefore in the entire population, is hidden, and to that extent the measures of eugenics must be applied blindly.

Many characteristics are determined or affected by more than one pair of genes—intelligence, for example. In such a case it is a particular combination of dominant genes, perhaps together with some homozygous recessive genes, that determines the nature of the character. These combinations are very rarely inherited *in toto*, the reason being that no one inherits all his parents' genes, but only half of the genes of each. Pure chance determines which gene of the two making up each pair in the father and the mother will be transmitted to the child. Hence, the more genes there are in a given combination, the lower the chance that that combination will be transmitted intact. Nearly all combinations are broken up as the germ cells mature, and new combinations of a biparental origin are formed. Inasmuch as most of the human characteristics which are of social significance depend upon multiple genes, the combinations of which cannot be preserved, whether good or bad, the importance of this reassortment and recombination of genes in heredity to the success of eugenics can scarcely be overemphasized. Moreover, a particular gene which in most combinations has an adverse effect may, in just the right combina-

tion, produce a desirable effect; and conversely, a particular gene that in most combinations has a favorable effect may get into a bad combination. The geneticist can scarcely appraise the absolute, over-all effect of a gene; it must be judged by the company it keeps.

Galton was the first person to try to assess the relative power of heredity and environment in determining a person's characteristics. From his studies of the familial occurrence of genius and special talents, and from comparisons of one-egg and two-egg twins, he was convinced that "the power of nature was far stronger than the power of nurture, when the nurtures of the persons being compared were not exceedingly different." There is no reason to alter this judgment today, although one may amplify it. Thus, in general, physical traits are most rigorously determined by heredity, mental traits are more modifiable by environment, and social traits and personality, although still clearly affected by heredity, are most readily suppressed, diminished, or enhanced by past experience and present environment. A similar hereditary nature, as seen in "identical" twins, generally leads through similar development to similar characteristics, provided the individuals are not subjected to radical differences in their environment.

It is clearly necessary to clarify the meaning of that term "radical" in the present context. A pair of blond one-egg twins may be temporarily separated, one kept indoors, the other sent for a vacation at a beach. In a few weeks one is sunburned and very much darker than his twin. This does not mean that environment determines complexion and that heredity has nothing to do with it. It means that for blonds the amount of sunlight can constitute a "radical" difference of environment. Yet not all characteristics are affected by this particular "radical" difference of environment. It requires careful observation to determine whether a specific difference in environment can affect a characteristic or not, and it must be determined separately for each characteristic. The effects of environment are inextricably interwoven with the effects of the genes in the formation of a person's characteristics.

Only by mutation do new sorts of genes come into existence, and without it there could be no long-continued process of evolutionary change, eugenic or otherwise. The mutation rates for several human genes have been estimated. Their average is about 1 in 50,000 per generation; that is, to take a specific example, in a population of 50,000 persons 1 person has a gene for hemophilia which was not inherited from either parent, but instead arose by mutation from a corresponding gene for normal blood clotting. Hence, unless one could somehow prevent mutation to it from occurring, no measures can be successful in eradicating an undesirable gene from the population. At best, its frequency can be reduced to the level of the rate of mutation to it.

Hemophilia cannot be eliminated; its lowest limit is set by mutation at a gene frequency of 1 in 50,000.

For eugenics, the induction of mutations by X-rays or chemicals is too potent a tool, since the vast majority of all mutations produce harmful consequences. Hardly 1 in 500 or a thousand improve its possessor's fitness in the local environment. Although most mutations are recessive, and consequently do not show up for many generations, until in the course of time they become homozygous, nevertheless it is clearly undesirable to fill the human germplasm with an overload of harmful genes. It is likely, according to several methods of estimation, that even now everyone possesses at least one lethal gene that in a double dose would destroy us. Other detrimental genes are probably about three times as numerous as the lethal genes. These genes persist in the population because they are hidden, each kind being prevented from becoming more common because of natural selection. In the elimination of detrimental genes by natural selection a lot of desirable genes are also lost each time, for selection can act only on individuals; that is to say, on entire combinations of genes. It cannot pick out the solitary gene that is chief offender. The reassortment and recombination of genes that is the chief outcome of sexual reproduction represent salvation here, since they render it unlikely that the same unoffending genes will be lost each time a particular kind of detrimental gene is eliminated.

The rapidity with which the frequency of a harmful gene can be reduced by selection depends upon the percentage of carriers who manifest the effects of that gene. A full dominant, for example, with a fitness of only half normal, would in 20 generations, or about 550 years, be reduced to one-millionth of its original frequency. It would almost certainly before that time reach the level where it would be maintained by fresh mutation. Consequently, any particular harmful dominant trait is already, because of natural selection, very rare. It is of no eugenic consequence to try to deal with them. Only special circumstances, like the failure to manifest themselves until late in life, bring a few dominant traits, such as Huntington's chorea, a very unfortunate nervous affliction that is a form of St. Vitus' Dance, within the scope of eugenic measures.

On the other hand, a recessive with a fitness of one-half normal would in 20 generations be reduced by only 40 percent. What is more, the amount of reduction declines in each successive generation, as the proportion of heterozygous, concealed genes becomes larger and larger. The frequency of a *common* recessive gene, like those for blue eyes or red hair, might therefore be reduced by special measures very quickly; but the reduction in frequency of a gene that is already rare is almost imperceptible. Since natural selection has already been at work for

ages past, no gene very detrimental to viability or fertility can have become common. Each sort of harmful gene is already rare in frequency and is maintained in equilibrium between mutation and selection. The combinations of genes which determine complex traits such as intelligence are even more slowly affected by selection.

Chance changes in gene frequencies are not of as great eugenic significance in modern times as formerly, for they occur significantly only in small populations, such as the hunting groups of prehistoric man or the isolated rural communities of medieval times. In a study my colleagues Milton Sacks, Elsa Jahn, and Charles Hess and I recently made of a Dunker community in Franklin County, Pa., we found clear evidence that the genetic composition of such a group can deviate radically and within a span of three generations from its original makeup as well as from that of the surrounding population. In such communities even harmful genes might become established by chance; or even a beneficial gene might be eliminated. Furthermore, in a small population there is of necessity a closer degree of relationship between those who marry. This inbreeding does not of itself change gene frequencies, but it brings the recessive genes out into the open and allows selection to be exercised upon them. If a line is free of harmful recessive genes, this inbreeding will do no harm. (Cleopatra herself came of a number of generations of brother-and-sister marriages.) But I have already pointed out that most individuals do carry harmful genes. Hence the effect of inbreeding is in general to increase the number of afflicted persons in the population. Actually, since medieval times, the trend has been in quite the opposite direction. This brings us to genetic intermixture.

Obviously the trend of the modern world is away from the isolating effects of religion, race, and geography, even though not so obviously from those of politics. Little populations have been merging to make large ones, and migrations of tremendous magnitude have produced human melting pots the world around. This has had the effect of making a greater proportion of the recessive genes disappear from view and from exposure to selection. They can now increase under cover to a much higher frequency, until such time as by random mating homozygous persons are produced and selection again becomes active upon these genes. The action of the melting pot and the slowness of assimilation are clearly evident in a study of the present-day American Negro made by C. C. Li and myself. On the basis of the frequencies of certain blood groups and other genetic traits in the West African Negroes, the North American Negroes, and the North American whites, it was possible to conclude that the genes of the American Negro are now just over 30 percent derived from the white population, and that at the average rate of past gene flow from the white into the

Negro population, it will take approximately 2,000 years before assimilation becomes complete. Of course, the process will undoubtedly accelerate as the two populations become less distinguishable, and the gene flow from the Negro into the white population, till now negligible in amount, will some day become appreciable. Meanwhile, it is important to realize what a disastrous increase in the proportion of hereditarily afflicted persons would result if our present populations were for any reason—say, as the aftermath of another world war—to be broken up again into small units.

By surrounding himself with a social environment, mankind has unwittingly modified the rigor of natural selection in many ways. The price we must pay, in the end, for the mercies of medical care and surgical aid is the dysgenic increase in the frequencies of certain detrimental genes whose effects we have learned to ameliorate. Thousands upon thousands of diabetics who in a former day would have died early in life are now saved by insulin to live relatively normal lives, and, of course, to pass on the gene responsible for their diabetes to their descendants. Myopia is no longer a grave handicap in life; hearing aids alleviate certain types of deafness. Probably no one would have it otherwise. Yet to contemplate a future population composed largely of persons who must wear both glasses and hearing aids, and must start the day by inserting their false teeth and taking first an insulin injection in one arm and then allergy shots in the other, is none too pleasant. To say the least, medical science is steadily increasing the load it must carry.

Another instance of the unconscious direction of human evolution lies in the differential reproduction of economic and cultural groups. The differential reproduction of the several races may be passed over, since there is no valid evidence that any known hereditary differences between races alter viability or fertility, or affect any eugenic desideratum, such as intelligence. But there is little doubt that there is some positive correlation between intelligence and economic and cultural level, in such countries as the United States and Great Britain. In these countries the reproductive rate varies inversely with income. Theoretically, this should result in a decrease of those genes contributing to high intelligence, although the decrease may be slow. Yet the only extensive study on the subject, that of the I. Q.'s of virtually all Scottish school children over a 15-year period, 1932 and again in 1947, has revealed no decline whatsoever.

The various measures of positive and negative eugenics may now be considered. The former comprises four methods, all in use in certain States or countries.

The method most widely used is that of segregating males and females in separate institutions, such as prisons, mental hospitals, or

"homes." This type of measure is quite effective in preventing the propagation of the inmates. However, most social institutions of these kinds are today regarded as having a curative function rather than one of permanent incarceration or care, and eventually a large proportion of the inmates are released and are again at liberty to reproduce. To take care of the feebleminded alone in such institutions would require an enormous increase in the number of institutions and the amount of care beyond what is at present available, since it is estimated that 1 to 3 percent of the entire population, or some 5 million persons, in the United States, are feebleminded.

A second method is that of sterilization. This is also highly effective for the purpose. The surgical methods now used consist of ligating or cutting the sexual ducts, a method which prevents reproduction without interfering with the hormonal secretions of the ovaries or testes and thereby causing changes in the sexual characteristics and emotions, as castration does. In the United States, 27 States have laws for the sterilization of the hopelessly insane or the feebleminded, but application varies greatly. The total of sterilized persons now amounts to more than 50,000, of whom about half were insane and half feebleminded. By the most rigorous program of sterilization and segregation, mental defect and disease could be reduced perhaps 15 percent; that is, from 2 percent of the population to 1.7 percent. This may well be worth doing, but it is certainly far from elimination, which is apparently the expectation of many uninformed eugenists.

A third method consists of the universal encouragement of birth control by providing free birth-control clinics and supplies. Since birth control at present obtains largely in the higher social and economic groups, the extension of birth control to all classes of the population would, it is argued, tend to restore the balance between the differential reproductive rates of the more intelligent and the less intelligent. Probably to some extent this is true, and in Sweden, where this measure has been carried out, it seems indeed to have brought the reproductive rates of all economic classes of the population into line. However, even to use the present methods of birth control requires considerable intelligence, so that only too probably this measure will lower the reproductive rate of the intelligent persons of *all* economic and social classes, but will affect that of the morons and feebleminded much less. Note also that most methods of birth control are vigorously condemned by certain religious groups, although in India the objections appear to be weakening.

The final negative measure is one which does not actually change gene frequency but only diminishes the proportion of individuals who manifest certain traits. This measure is the prohibition of consanguineous and assortative marriages. In nearly all societies, taboos or legal

restrictions have long existed against the closest degrees of in-marriage. Perhaps these grew up because it was commonly observed that such marriages often yielded abnormal or defective children. At any rate, the only practicable extension of this method would be to prohibit marriages of first cousins, wherever now allowed. This would stop only about 56 percent of all consanguineous mating, according to J. B. S. Haldane, and in Baltimore, according to my own data from the Baltimore Rh Laboratory, would prohibit only 5 marriages in 10,000. By prohibiting assortative mating between defectives, the frequency of such defects as are recessive might more readily be reduced. Thus, assortative mating is strongest among the deaf, and at least two kinds of deafness are inherited as simple recessives. A ban on marriage between deaf persons would considerably reduce hereditary deafness in the population. Against this social advantage would have to be weighed the counteradvantage of permitting a happy social adjustment among the married deaf.

Positive eugenic measures might be of two types. The more extreme is the extensive use of carefully selected sires by artificial insemination, as in animal breeding. It is already possible not only to transport selected semen from one continent to another by air, and to inseminate large numbers of females with it, but also to quick-freeze semen, hold it indefinitely at low temperatures, and thaw it out without depriving it of fertilizing power. The use that thus might be made of the semen of a select male is not only worldwide but might conceivably extend over several centuries of time.

Apart from whatever social repugnance such a method would encounter, it involves a biological outcome that invites disaster. The gene-sharing it promotes in the breed leads to uniformity. In animal breeding this may be obviated by developing a number of individually uniform, but distinct, breeds. For mankind, it is at least arguable that general genetic diversity is better than uniformity. In particular, because of the high frequency of lethal and other harmful recessive genes in the population, there is a grave danger that any widely used sire might spread a detrimental gene throughout the population before it was detected. This has actually happened in cattle breeding.

The other way to promote a higher reproductive rate of the bearers of desirable genes is to offer inducements and rewards for parenthood, and to remove impediments to it. Such measures already have been tried by many countries concerned about their decline in population, rather than for any eugenic reason. Obviously, the low reproductive rate of the more intelligent people is mainly a result of choice. Too clearly they see that each added child is an economic burden that diminishes the standard of living of the entire family and the opportunities open to the other children. As H. J. Muller once said: "It is

undeniable that the profit system leaves little place for children. In general, they are not profitable investments: their cost is excessive, the dividends from them are uncertain, they are likely to depreciate in value, are practically non-transferable, and they do not mature soon enough."

What should be done? Direct subsidies to parents have not worked very well in those countries that have tried them. Taxation more steeply graduated in inverse ratio to family size, and the multiplicity of social services rendered directly to children, or to expectant or nursing mothers, seem to provide one answer.

Eugenics, although based on the science of genetics, is not itself a science, for it must above all concern itself with social values, with the question, Whither mankind? Perhaps general agreement could be reached that freedom from gross physical or mental defects, sound health, high intelligence, general adaptability, integrity of character, and nobility of spirit are the major goals toward which eugenics should aim; perhaps, too, that diversity of nature is better than uniformity of type. But how far ought selective reproduction to interfere with human freedom? Genetically, as in other respects, "there is so much bad in the best of us and so much good in the worst of us" that it is hard to assess the worth of the manifest hereditary characteristics of a person; and the numerous hidden genes make it quite impossible.

Nor can anyone determine to what extent a person's manifest characteristics are the product of environment, particularly as to those qualities that are eugenics' major concern—sound health, high intelligence, and the like. The Jukes and Kallikaks were horrible examples of degenerate humanity, but what might they have been in a better world? Was their alcoholism, their crime, their vice an inescapable product of their genes? It seems very doubtful. Only the experiment of putting them from earliest infancy into an optimum environment could possibly yield an answer.

It will be easier to define the essentials of an optimum environment—not forgetting that it need not be alike for everyone—than to modify gene frequencies by wise selection. Once mankind has produced an approximation of that optimum environment, the eugenic task will be simpler. In fact, the natural selection exerted by such an environment may make other eugenics quite unnecessary.

The moral is very plain. Today man, in the shape of the geneticist as well as in the shape of the physicist, possesses more power than wisdom. He could, as I have said elsewhere, "crystallize human society into a changeless rigidity dominated by reason armed with infinite scientific knowledge." He might even breed "a ruling caste of a relatively few individuals, evolving higher and higher levels of intelligence, and a helot or robot caste of workers, chained by their instincts

and minimal intelligence to the performance of simple, mechanical tasks." But can the geneticist breed wisdom, or integrity, or even simple humanity? As a former instructor in this university once wrote, in an inimitable essay on the same subject, "If we are to make a better world, we must breed people like Palamedes; the danger is that we shall breed people like Odysseus instead."

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Cultural Status of the South African Man-Apes

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[With 4 plates]

DARWIN'S AFRICAN HYPOTHESIS

Eighty-five years ago, in "The Descent of Man," Darwin (1871, pp. 240–242) noted that in each great region of the world the living mammals are closely related to the extinct species of the same region. As the chimpanzee and gorilla are man's nearest living mammalian relatives, he announced his belief that our early progenitors lived on the African Continent.

At that time one fossil ape, called *Dryopithecus* and believed to be akin to the living gibbon, was known from the Miocene epoch (10 to 35 million years ago) in Europe. A very early human skull with a thick vault, jutting upper jaw, and large bony ridges over the eyes had also been blasted out of a cave at Gibraltar in 1848. As this event had occurred 11 years before the theory of evolution was put forward by Darwin in "The Origin of Species," nobody had taken any serious notice of this skull except Lieutenant Flint; he saved the specimen and entered it in the catalog of the Gibraltar Scientific Society. Twelve years later events had occurred that caused Dr. Busk to take it to England, when he found it lying neglected in Gibraltar.

Even when a second fossil human skull of the same type, called the Neanderthal skull, was discovered in 1857 in a limestone cave near Düsseldorf, the great German pathologist Virchow declared that it was merely the cranium of an idiot. Today the proofs of evolution are known to all educated people; and many examples of this same fundamental Neanderthal type of fossil mankind or its near relations are known from Belgium, France, Spain, Italy, Russia, Palestine, Iran, Java, Tanganyika, Rhodesia, and Cape Town. Collectively they typify the neanderthaline phase of human evolution.

Darwin was not distressed by the apparent gap between living apes and mankind caused by the contemporary lack of illustrative fossils. He knew that the persistence of the anthropoid apes themselves into modern times was accidental; he realized it would only be a matter of time before they and all the great game, and even the races of mankind, which could not adapt themselves to human civilization, would be exterminated. Once man had succeeded in his self-imposed task of obliterating from the earth all animals not serviceable to him, the break, the gap between man and his nearest mammalian relatives, would be much greater still. However broad the gap was or might become, its width could not affect the geological and biological fact of man's having passed through an apelike phase in order to become man! Man's ruthless destruction of living things could only serve to demonstrate more vividly his essentially brutal nature.

Nor was Darwin perturbed by the absence of anthropoid and human fossil remains connecting man with his apelike progenitors. First, as he said, the discovery of fossils was a very slow and utterly fortuitous process; and second, the regions of the earth he thought most likely to contain remains linking man with extinct apelike creatures had not then even been searched. Livingstone had discovered the Victoria Falls only four years before "The Origin of Species" was published! Not until 1870, the year before "The Descent of Man" first appeared, did Schweinfurth succeed in reaching the area between the Nile and the Congo watersheds and in finding that the central African Pygmies really existed. So Darwin and his contemporaries were ignorant of many of the facts that have assisted since his time in vindicating his belief and confirming his optimism.

Darwin and his scientific supporters were not perturbed about this apparent gap between ape and man, but anthropologists have struggled ever since to fill it in with fossils. Some enthusiasts have even succeeded, at least temporarily, in thrusting a forgery like Piltdown man, the notorious *Eoanthropus*, into the gap. Others, like Eugene Dubois, have deliberately set out for the tropical regions where the great apes live to search for an early ancestor of mankind, a "missing link" such as Darwin's theory postulated. Dubois found an ancestral type near the homeland of the orang-utan in Java in 1890–91, i. e., *Pithecanthropus*, the Java ape-man. With equivalent dedication Von Koenigswald also went to Java in 1927 and survived imprisonment there during the second World War. He found two different varieties of *Pithecanthropus* in Java! Davidson Black, almost simultaneously, was recovering the closely related *Sinanthropus* type from Choukoutien, not far from Pekin in China. In this manner an earlier or pithecanthropine phase of human evolution preceding the neanderthaline phase was demonstrated to have been passed through by man.

These important Asiatic discoveries of very early man had been made possible by the great expedition of the American Museum of Natural History into Mongolia and the Gobi Desert and by Rockefeller Foundation funds. The public interest they aroused, along with Darwin's ideas (that when man first lost his hairy covering he probably inhabited a hot country and subsisted on a frugivorous diet) and the finding of fossil ape teeth in the Siwalik hills of India, had the effect of consolidating the general expectation that any important human ancestors could come only from the tropical or more northern regions of Asia. They could not conceivably come from the other end of the Old World, southern Africa, a temperate region on the fringe of the Kalahari Desert, where there were no tropical forests and no luscious groves of fruit-laden trees for man's supposedly frugivorous apelike progenitors to eat.

Times have changed in Africa in the 80 years since Darwin wrote. People nowadays rush across the continent from north to south and from east to west in airplanes, trucks, and cars, or on motorcycles and scooters. Every serious tropical scourge has been vanquished. Staggered by the stupendous mineral wealth and agricultural potentiality of central Africa, some, like Felice Bellotti (1954, p. 21), claim that "the Congo is the America of tomorrow." Certainly Americans are, and have good reason to be, deeply interested in central Africa. America's Negro population came mainly from central Africa; it was an American medical missionary, Dr. Thomas N. Savage, who shipped the first gorilla from the Congo to Boston and enabled an American anatomist, Dr. Jeffries Wyman, of Harvard University, to identify the gorilla as a separate race of manlike apes for the first time in 1847. It was also an American, Carl Akeley, who was instrumental in the further study of the great apes and in insuring their perpetual protection in the Parc National Albert between Lake Kivu and Lake Edward. Recently, too, it has been chiefly American aid from the Wenner-Gren and Wilkie Foundations that has been enabling us in South Africa to bring to light the australopithecine fossils. They have fulfilled Darwin's prophecy by connecting man with his apelike progenitors, and have thus closed the gap between living apes and mankind to such an extent that it is no longer apparent.

FACTS FROM SOUTH AFRICA

This South African "missing link" story goes back to 1924 when the late Miss Josephine Salmons, then a young science student in anatomy, brought me a fossil baboon skull that she had found on the mantelpiece of E. A. Izod, a friend she had visited the previous Sunday evening. It had come from the Northern Lime Company's works at Buxton, near Taungs in Bechuanaland, of which Mr. Izod was a direc-

tor, and was the first intimation that any fossil primate had been found in Africa south of Egypt. So we became very excited, and after interviewing the professor of geology, Dr. R. B. Young, learned to our satisfaction that he was going to Thoming nearby the following week.

Arrived at Buxton, Professor Young learned that in the previous week a miner, M. de Bruyn, had brought in a number of fossil-laden rocks blasted out the previous week. When they came to Johannesburg, I found the virtually complete cast of the interior of a skull among them. This brain cast was as big as that of a large gorilla; and fortunately it fitted at the front end onto another rock, from which in due course there emerged the complete facial skeleton of an infant only about 5 or 6 years old, which looked amazingly human. It was the first time that anyone had been privileged to see the complete face and to reconstruct accurately the entire head of one of man's extinct apelike relatives (see plates 2 and 3). The brain was so large and the face was so human that I was confident that here indeed was one of our early progenitors that had lived on the African Continent; and as it had chosen the southern part of Africa for its homeland I called it *Australopithecus africanus*, i. e., the South African ape.

Today, largely through the labors of the late Dr. Robert Broom and J. T. Robinson, the remains of about a hundred different infantile, adolescent, adult, middle-aged, and senescent specimens of these australopithecine progenitors of mankind are known from Taungs, 80 miles north of Kimberley; from three different sites in the Sterkfontein Valley, about 30 miles from Johannesburg; and from Makapansgat, somewhat less than 200 miles to the north in the central Transvaal. In some respects australopithecine anatomy is better known than that of living apes or even the living races of mankind. After the passing of a generation of scepticism and of repeated discoveries and debates, the Australopithecinae are generally accepted today for what they were originally claimed to be—a group or family of advancing creatures midway between ape and mankind. Their brains were about the size of, and in some cases even a little larger than, those of the largest of large gorillas, but their posture and body carriage were not apelike; they were erect like living human races, such as the African Pygmies and Bushmen. The South African man-apes varied in stature and body size from types as small as, or even smaller than, the little Pygmies of central Africa, to types as massively constructed as the biggest and bulkiest Negroes. There is good reason for believing that some fossilized pieces of teeth and jaws, found as far north as Kenya and as far east as Java, and generally called *Meganthropus*, are also the remains of genuine Australopithecinae! Unfortunately we do not know what the brains, stature, and posture of these wide-ranging *Meganthropus* members of the *Australopithecus* group were like; but

these northern and far-eastern discoveries indicate that, even at the earliest or australopithecine stage, protohumanity, like Cain, was a willful wanderer over the face of the earth.

Thus the apparent gap between living apes and living sapient men has been completely bridged by overlapping australopithecine, pithecanthropine, and neanderthaline phases of human development. Nothing illustrates this overlap better than brain volume. Although living men generally have fairly large brains, they vary in volume from 790 cc. to 2,350 cc. In other words, a person can still be called a sapient man even when his brain is only one-third the size of his fellows. The living apes' brains, however, vary in volume to a relatively far greater degree: from 87 cc. to 685 cc. So the gibbon can still be called an anthropoid ape even when his brain is only one-eighth the size of a gorilla's. Indeed, the gap in brain volume between the smallest brained gibbons and the largest brained gorillas is nearly 600 cc., while the gap between the biggest gorilla's brain and the smallest known sapient man's brain is only 105 cc. The gorilla should therefore be more insulted to have his brain compared with that of a gibbon than we should be to have the human brain compared with that of a gorilla. The australopithecine skull capacity varies, according to Broom and Robinson, from 400 cc. to 1,000 cc.; the pithecanthropine-sinanthropine skull capacity, according to Weidenreich and Keith, varies from 750 cc. to 1,250 cc.; and the neanderthaline skull capacity, according to various authors, from 1,250 cc. to 1,600 cc. Therefore, the range of skull capacity in living man overlaps not only that of the extinct neanderthaline and pithecanthropine races of man but even that of some members of the australopithecine race.

We know that *Pithecanthropus* was a primitive man, although his brain volume in some cases was 750 cc., i. e., only 65 cc. bigger than a gorilla's; also that a living man can still be a normal *Homo sapiens* when his brain is only 105 cc. larger than a gorilla's. We know, of course, that there are today and always have been some people in every human race, whether European, Mongolian, or Negro, who are *Homo sapiens* even though their skulls fail to exceed 500 cc. in volume. Nowadays we hide such individuals in asylums and call them abnormal or microcephalic idiots; but that does not change their sapient human ancestry; nor does it prevent them from living and speaking or acting like the sapient human beings they are; or learning to do anything that a very primitive man with a similar brain content, like *Australopithecus*, is likely to have been able to do.

On the anatomical side, therefore, nothing of importance remains for the anatomist to do in the way of finding further physical links to bridge the gap that was apparent between ape and man in Darwin's day. Such a gap no longer exists, even in brain size. We have at last

come face to face with the dilemma that Darwin (1871, p. 279) boldly visualized 85 years ago: He realized that when such creatures as the Australopithecinae were found we would not know whether to call them men or apes. He actually wrote on this very matter: "Whether primeval man, when he possessed few arts, and those of the rudest kind, and when his power of speech was extremely imperfect, would have deserved to be called man, *must depend on the definition we employ.* In a series of forms graduating insensibly from some ape-like creature to man as he now exists, it would be impossible to fix on any definite point where the term 'man' ought to be used. *But this is a matter of very little importance.*" (Italics are mine.)

Ever since the discovery of the South African manlike apes, this business of trying to determine the boundary between ape and man or, expressed otherwise, to define what is and what is not a man has become increasingly difficult. It will always remain difficult until we realize with Darwin that this question, like each of those other more ancient philosophical posers (such as "how many angels can balance on a pin-head" or "which came first, the hen or the egg"), *is a matter of little importance.*

AUSTRALOPITHECINE ACHIEVEMENTS AT MAKAPANSGAT

The thinking power of the australopithecine brain can be assessed to some extent by the form it takes inside the skull, by the differences between its form and that of the chimpanzee and the gorilla; but it can be gaged by the average person more conveniently through what these manlike apes did. Upon this very matter of what they did and were able to do, investigations in the Makapansgat Valley have been throwing much light in the past few years. (See pl. 1, figs. 1 and 2.)

This remarkable little valley, less than 200 miles north of Johannesburg, has been riddled for the last million years with limestone caves that have served as the dwellings of primitive mankind from australopithecine times right down to the European Voortrekkers and their northward intrusion into the Transvaal from the Cape of Good Hope.

Barely a mile separates the first from the last of eight known and partially explored caves along this valley; fossil-bone deposits show that all of them were occupied by recent man or his predecessors. One cavern, known as the Limeworks site, was occupied by the manlike apes called *Australopithecus prometheus* and no less than three other caves by prehistoric men in the various phases of their development from the Old Stone Age onward.

The most thoroughly excavated human site, known as the "Cave of Hearths," has revealed a virtually unbroken record of habitation from Old Stone Age times down to the present day, of probably 100,000 years duration. At the Limeworks site, nearly a mile farther down

the valley, just as at all other known man-ape sites, nothing in the nature of a stone implement had ever been discovered before October 1954. That month C. K. Brain was sampling the main sections of the Limeworks deposit for mineralogical analysis when he found a number of stone pebbles that appeared to have been artificially fractured. They lay in an 18-foot gravel stratum 15 feet above the stratum of gray bone-breccia material, from which the australopithecine remains had previously been recovered. The 129 trimmed stones submitted by Mr. Brain to Prof. C. van Riet Lowe for examination included 10 flake artifacts, 4 artifacts on water-worn pebbles, 2 artifacts on thin slabs of dolomite, and 1 split pebble, which he "assigned to the Developed Kafuan Culture as this occurs in Uganda and . . . in the 200 ft. terrace of the Vaal River at Klipdam."

Even implements of the Old Stone Age are rarely found in cavern deposits. To find in such a site pebble stone tools, that must have preceded Old Stone Age tools by hundreds of thousands of years and had only been found previously in the oldest known Pleistocene river gravels of Africa, was utterly unprecedented. As Prof. van Riet Lowe (Brain, van Riet Lowe, and Dart, 1955) pointed out, this discovery of Kafuan-type artifacts in a terraced river gravel in an undisturbed stratified sequence of deposits immediately overlying australopithecine-bearing breccias in a cave is *unique;* and as he stated later in a broadcast talk: "It narrows the gap between ape and man as it has never been narrowed before: it reduces the geological horizons between which missing links are to be sought in a manner that anthropologists could not previously have visualized."

Yet still more was to come from the Limeworks. The generous financial assistance afforded to Professor van Riet Lowe and to myself by the Wenner-Gren Foundation of New York for our previously separate programs (his at the Cave of Hearths, mine at the Limeworks) enabled us early in 1955 to make a joint onslaught on the Limeworks pebble stratum. Revil Mason and Alun R. Hughes undertook the fieldwork with the assistance of Dr. Edouard E. L. Boné of the University of Louvain and Mlle. Suzanne Jean of the Musée de l'Homme, Paris, during part of the time.

They recovered several thousand pebbles, and in the material coming from the same gravel stratum, which had previously furnished no fossils and was regarded as sterile, Mr. Mason first discovered various fragments of bone, including the enamel plate of an elephant tooth. Most important of all, on April 30 Mr. Hughes found a small fragment of the right side of the upper jaw of an *Australopithecus.* The piece was too small to enable us to determine whether or not it was actually *A. prometheus;* but if not, it is certainly a very closely related type. Small as the fragment is, it showed that australopithecines, identical

with or closely akin to *A. prometheus*, were contemporaneous with, and may have manufactured, the stone pebble artifacts found alongside these few fossil bones. At one stroke the supposed cultural gap between ape and man had also been so narrowed as virtually to vanish. The only alternative to the deduction that these australopithecines, whether man or ape, had made the stone artifacts, is to find one day some other and rather more advanced primitive human type in the same stratum, which might then be regarded as responsible for the implements and for destroying the australopithecines.

This latter, of course, is a possibility; but, from what we know about the intelligence of living anthropoids on the one side and the structure and habits of *A. prometheus* on the other side, it seems vastly more probable that protohumanity, at the australopithecine phase of development, had developed all the intelligence necessary for making whatever intellectual leap may have been involved in the cultural feat of utilizing stones as tools and even of shaping them to that end.

Kohler, Yerkes, and other students of chimpanzee behavior have shown, as Leslie A. White (1932, pp. 69–70) put it, that—

> apes can build according to plans which are formulated to fit the situation of the moment. Thus an ape can build a structure of boxes and, with a tool which he has made by joining two sticks, knock a banana from the roof of his cage. . . .
>
> The ape has the capacity to conceive of configurations and then to project them into materials, tools and objectives. He has the capacity to execute a series of acts implicitly before he commences them overtly. Figuratively speaking he rehearses in his mind the series of steps necessary to attain an objective before he makes a move. Then he proceeds to re-arrange his environment according to his plan. Thus the ape is a sub-lingual architect, or, even a dramatist.

These extinct australopithecines had brains about twice as big as those of chimpanzees; more important, they were not semierect creatures that built nests of broken branches in the tops of trees like chimpanzees, where they chattered and munched shoots of leaves and fruit. Australopithecines greatly exceeded chimpanzees and gorillas in the use of tools because, along with bigger brains, they had hip bones and a pelvis, thighs, legs, and feet that were in no sense apelike. Their trunk and lower limb bones and muscles were just as human as those in the torso and hips, buttocks and thighs, legs, and feet of Pygmies or Bushmen. They did not spend their lives clambering in trees or swinging from branches, nor did they scamper over the rocks on all fours like baboons; they strode and raced across the veld like men. They did not lollop along supporting a great part of their body weight on their knuckles like chimpanzees and gorillas, when they are on the ground; they marched on their heels and their arms swung free, and customarily they carried in their hands weapons, just as all human beings have carried them since they became upright. Their weapons were not fashioned of stones—they were crude, unshapen

clubs, such as were borne by Hercules. They flourished the jawbones of prehistoric buffaloes, antelopes, zebras, and giraffes, just as Sampson is reputed to have wielded the jawbone of an ass to slay the Philistines in thousands. They seized the back ends of antelope skulls as handles and employed their double-pronged horns as picks. Such were the axes, mattocks, and daggers used by these protomen. They slashed their opponents with antelope hip bones and shoulder blades; they struck them down with tibiae, thigh bones, and upper arm bones. These long bones made excellent bludgeons until their heads were smashed to smithereens by use or their shafts were broken. Then their sword-sharp shattered ends were as formidable as stilettos. Thus, armed with implements of bone and horn for striking and thrusting, and tusks of giraffes, baboons, wild bears, hyenas, or saber-toothed tigers for slashing down or slitting open—weapons torn from the carcasses of beasts slain by themselves or other carnivores—they were just as competent hunters as human beings—probably more competent, because they had fewer inhibitions.

How do we know all this? From analyzing the gray bone breccia in the basal layers of the bone breccia at Makapansgat Limeworks. There, no stone tool, not even a pebble stone tool, has been found hitherto. The Limeworks gray breccia is significant not so much for the number and variety of man-apes found in it (only 19 fragments had been found before 1955), but for the number and variety of huge wild animals found alongside the man-apes; and chiefly for the relative numbers of their bones, teeth, and horns (i. e., their *osteodontokeratic*—if we wish to say "bone, tooth, and horn" in one word—remains). The Limeworks site has now become even more significant: it is the only known site in the world which holds out the prospect of tracing the transition from bone to stone.

AUSTRALOPITHECINE BLUDGEON TECHNIQUE

The fossil animals slain by the man-apes at Makapansgat were so big that in 1925 I was misled into believing that only human beings of advanced intelligence could have been responsible for such manlike hunting work as the bones revealed. The bones accompanying *Australopithecus africanus* at Taungs have been those of little antelopes, tortoises, hares, and rodents—small creatures, not great game of huge bulk such as the kudu, giraffe, buffalo, rhinoceros, and hippopotamus. These Makapansgat protomen, like Nimrod long after them, were mighty hunters.

They were also callous and brutal. The most shocking specimen there was the fractured lower jaw of a 12-year-old son of a manlike ape. The lad had been killed by a violent blow delivered with calculated accuracy on the point of the chin either by a smashing fist

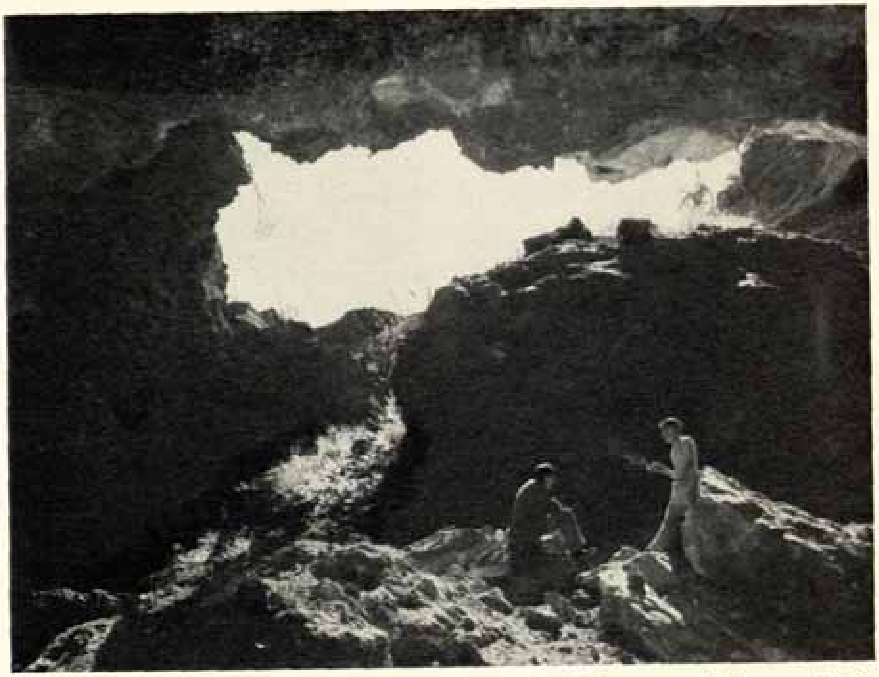
or a club. The bludgeon blow was so vicious that it had shattered the jaw on both sides of the face and knocked out all the front teeth. That dramatic specimen impelled me in 1948 and the 7 years following to study further their murderous and cannibalistic way of life.

Twenty years before that—the year after *Australopitheous africanus* had been discovered—it had been shown (Dart, 1926) that the Taungs cavern breccia was a midden heap; and that its contents consisted of comminuted bones of turtles, birds, insectivores, rodents, baboons, and small bucks, as well as bird-egg shells. Later, crabs and rock rabbits were added to the known diet; and when describing the dentition (Dart, 1934) I pointed out that the baboons, which constituted the best-known dietary objects at Taungs, had been killed by dexterous force. Some skulls showed radiating fractures due to the impact of picks or projectiles, probably stones, in the right parietotemporal region of the skull. Others exhibited rounded openings in the top or at the base, suggesting that the brains had been forcibly removed for food.

The 58 baboon skulls and jaws that had been found in the interim at Taungs, Sterkfontein, and Makapansgat (Dart, 1949) enabled me later to compare the identical kinds of violence to which they had been subjected at these three different sites removed geographically from one another by hundreds of miles and separated from one another in time by scores and possibly hundreds of thousands of years. Studying each specimen with the assistance of Prof. R. H. Macintosh, head of the Department of Forensic Medicine, and other medical men competent through their professional experience to express an opinion about lethal injuries, it became obvious that these cranial fractures were of too local and specific a character to be explained by rock falls or earth collapses, such as some people might have been led to suggest; they had been caused by implements of some sort wielded by hands.

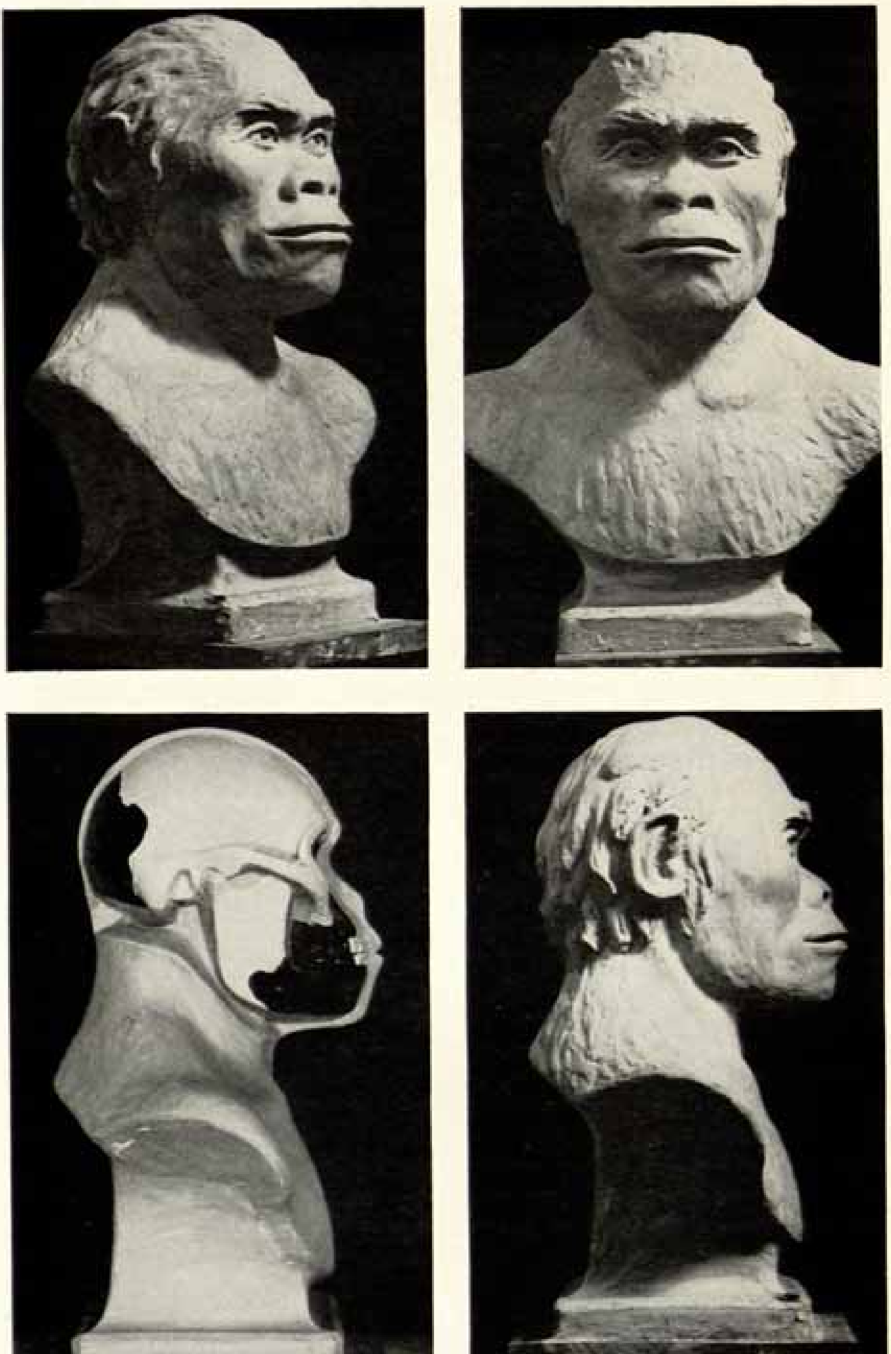
Sixty-four percent of these baboon skull and jaw specimens had been fractured by right-handed blows apparently delivered from the front; 17 percent were unmistakably right-handed because they had smashed in the left side; only 5 percent could be regarded as left-handed; and 14 percent had apparently been delivered from the rear by stealth and once again with the right hand. Out of six australopithecine skulls, four, i. e., two-thirds, had received vertical shocks from in front, while two had succumbed to blows in the left lateral region of the skull, also apparently wielded by the right hand. These diagnoses had been made before the adolescent mandible with its graphic chin blow came into my hands.

An utterly unexpected outcome of that careful analysis of baboon and australopithecine skull fractures was the further light the fractures threw on the technique employed in killing and eating. Small

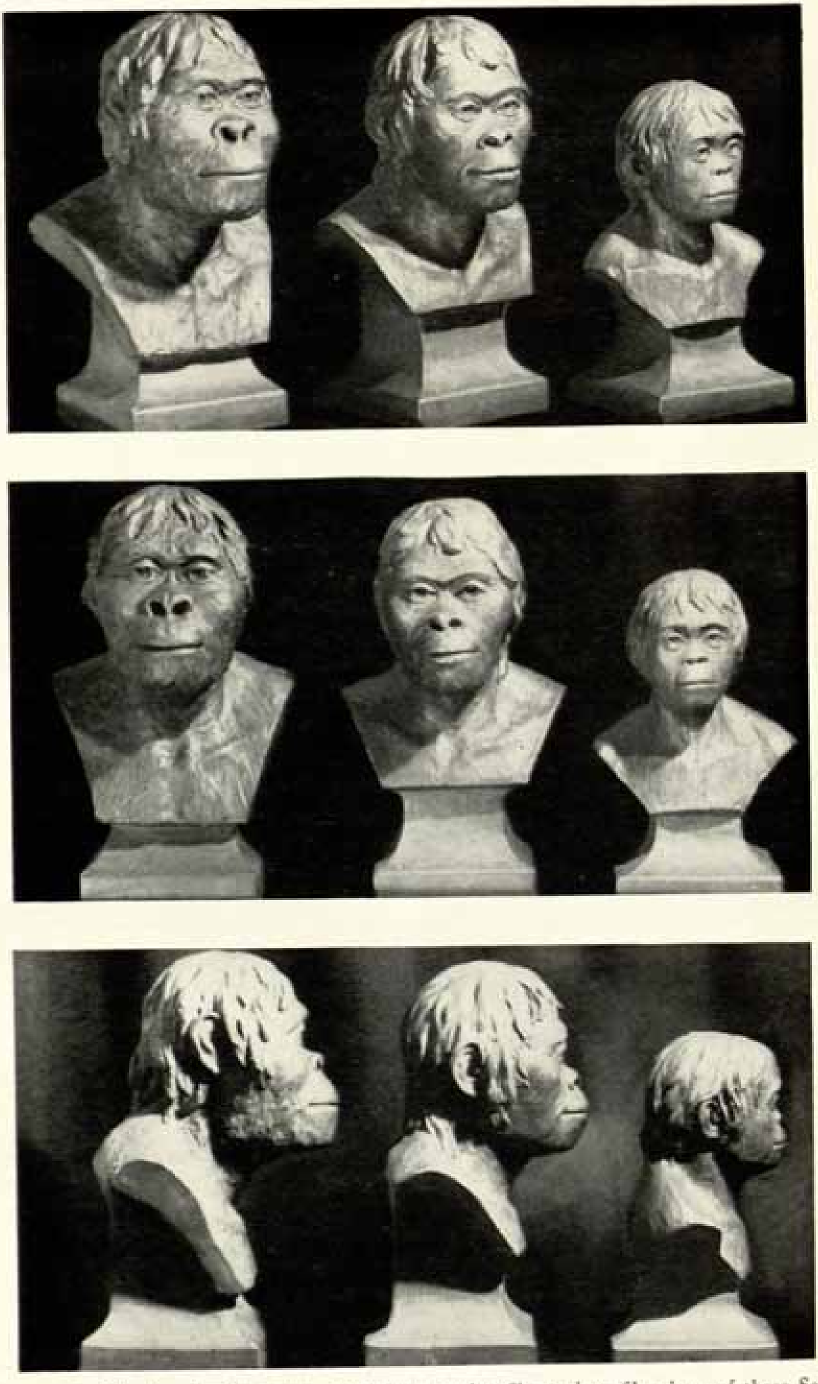


1. The interior of the main cavern of the Limeworks site in Makapansgat Valley near Potgietersrust in the Central Transvaal has been stripped of its stalagmites and stalactites by the limeworkers. From the dumps deposited on the hill slope outside and from strata remaining inside this cavern have been recovered most of the evidence discussed in this paper about the transition from ape to man. (Photo by J. P. Vorster.)

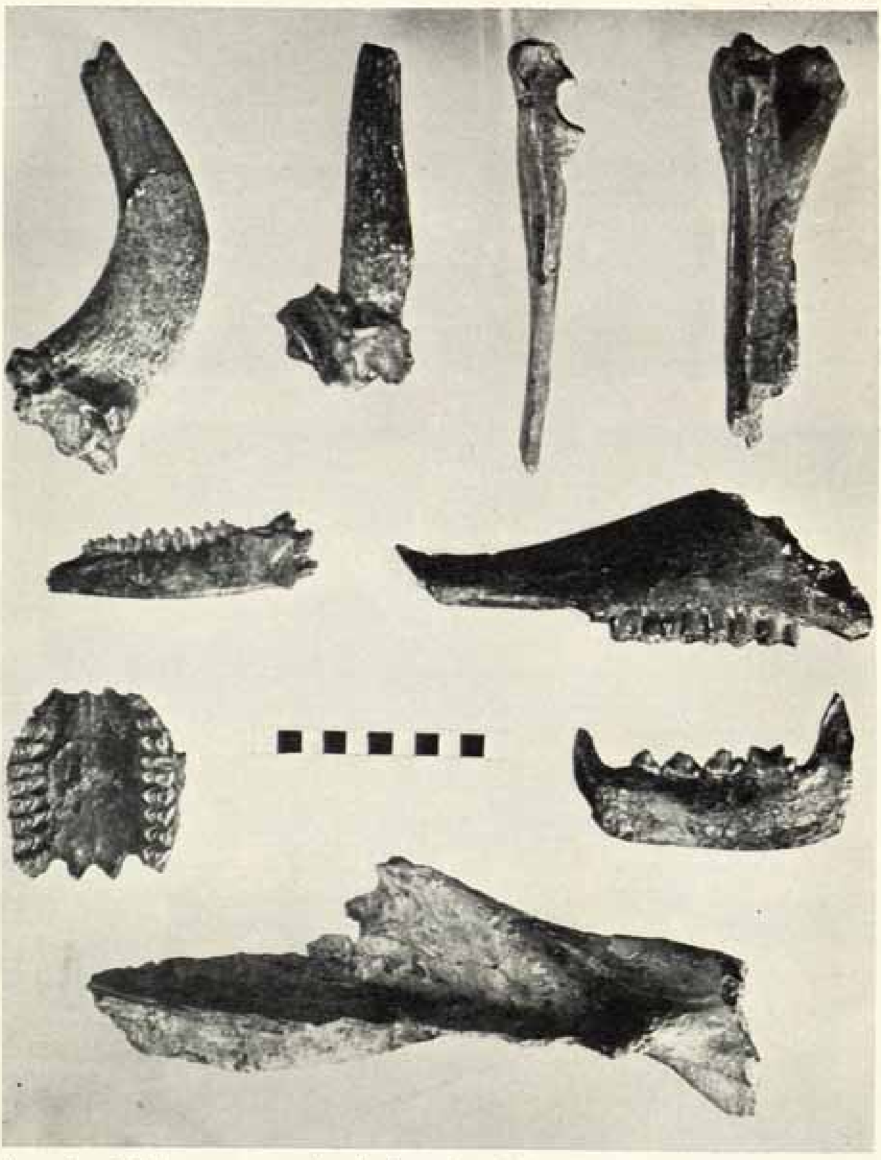
2. Part of the Limeworks dump on the hill slope outside the main cavern, from which the remains of the South African manlike ape *Australopithecus prometheus* and the accompanying types of extinct creatures have been recovered since 1947. (Photo by Alun R. Hughes.)



Semireconstruction (lower left) and complete reconstruction of the bust of an adult female *Australopithecus prometheus* based on the first three australopithecine cranial fragments recovered from the Limeworks dump. The reconstruction was carried out by the author and his technical assistant, B. J. Grobbelaar; its artistic investment was devised by Dr. Ismond Rosen.



An australopithecine family group. Full face, semiprofile, and profile views of three South African manlike apes, as reconstructed by J. F. Heim under the supervision of the author. From left to right they are: *Paranthropus robustus* (adult male) from Kromdraai; *Australopithecus prometheus* (adult female) from Makapansgat; *Australopithecus africanus* (infant male) from Taungs. (Photo by Dr. Paul Keen.)



Bones from Makapansgat gray breccia illustrating their adaptability as tools. All except the lower jaw of a hyena (second row from bottom, right side) came from antelopes. The size is indicated by the centimeter scale. Upper row, two horns of gazelle types, curved and straight (useful as picks or digging tools), an ulna (natural dagger form), and the distal or lower end of an upper arm bone or humerus (club or pounding tool). Second row, two lower jaws with serrated teeth that served as cutting tools (saws and knives). Third row (left), the natural scraper formed by the upper jaw, and (right) the ripping tool formed by the hyena lower jaw. Bottom, shoulder blade or scapula whose broad blade forms an ax or a shovel according to its manner of use. (Photo by Alun R. Hughes.)

triradiate or almost circular holes in skulls indicated thrusts with pointed objects such as the shafts of broken bones or horn tips; triangular depressions seemed as though caused by stones or other missiles; openings in the skull where the outer table had been wrenched away demonstrated tearing off by finger and thumb or by a levering bone or horn; depressed margins of openings and partially crushed infantile skull boxes exhibited the work of squeezing palms and poking fingers.

Most important and very puzzling until the explanation came to light were those skulls from all three sites, both baboon and australopithecine, where the fractures were in the form of a double furrow with a hillock formed by the broken bone in between the two furrows. Clearly the same sort of tool had been used at all three sites. The only objects in the breccia that fitted into these double depressions were the double epicondylar ridges on the distal ends of the antelope upper arm bones. Then it was seen that very rarely were humeri, or upper arm bones, of any ungulate beast found in the bone deposit, whose epicondylar ridges had not suffered extensive damage prior to fossilization. Patently the thug technique of bashing heads in with any handy bone or brick had a heritage of at least a million years.

HYENA FANCIES AND FACTS

Despite these convincing proofs concerning the systematized predaceous, carnivorous, and cannibalistic habit of Australopithecinae and these specific evidences of their ability to seize upon the limb bones and horns of wild beasts and to employ them in the chase and internecine strife as well as in the procurements of their food, various individuals (Oakley, 1953; Von Koenigswald, 1953) still insisted on resurrecting the notion, put forward in a conjectural fashion by Dean William Buckland (1822) 130-odd years ago, that cavern bone accumulations are the work of hyenas.

This myth of the bone-accumulating hyena has been discussed at length in an article in the American Anthropologist (Dart, in press), so it would be repetitious to deal with all its absurdities here. Buckland embroidered an Oriental fable to account for deposits of broken bones in caves (that were both contemporaneously and subsequently being shown to be the work of prediluvial man) which he could not attribute to the supposed Universal Deluge. Buckland's fanciful assumption was adopted uncritically in that pre-Darwinian era by his most brilliant pupil, Charles Lyell. First published in 1838, Lyell's Students' Elements of Geology ran through six editions and entrenched Buckland's bone-accumulating hyena theory in geological and archeological faith, despite the subsequent overthrow of the Mosaic chronology it was originally invented to support.

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Realizing the firm grip this preposterous theory had secured on geological and anthropological interpretation of bone deposits in caves, we decided in 1948 to sort the whole Limeworks dump systematically, to retain every fragment of bone isolated from the bone-bearing breccia, and thus to secure a body of material capable of statistical comparison with any samples of bones that might be taken from hyena or other carnivore dens. In this fashion, during the past 10 years, first by 3 years of casual sorting and during the subsequent 7 years by systematic extraction and development of all the breccia encountered, 7,159 bone fragments had been isolated up to July 1955. A statistical report was then presented at the Third Pan-African Congress of Prehistory at Livingstone analyzing their distribution.

Meantime hyena lairs had been examined, first in 1953 on the farm Mala Mala on the western boundary of the Kruger National Park, and then about 800 miles to the west in the Gemsbok National Park in the Southern Kalahari in the vicinity of the river-bed junction of the Auob and Nosob Rivers. Two low rocky recesses in the river banks within the Gemsbok National Park that had been occupied by porcupines yielded, in 1954, to Alun R. Hughes and C. F. Brand 146 bones and horns (89 from one and 57 from the other) of which 110 bore the marks of porcupine gnawing. The local game warden, J. D. le Riche, born on the farm Twee Rivieren before it was absorbed into the reserve, attributed the scattered bones littering the floors of these 2- to 3-foot-high calcrete recesses to the porcupines (many of whose quills corroborated his evidence), which had obtained them from hyena "kills" in the vicinity.

A similar symbiosis of hyena and porcupine on the hill Platberg, 15 miles north of Klerksdorp in the Transvaal, gave a surface total of 168 bones scattered about on doleritic blocks and the sloping ground below. Hyenas, two of which have been shot on the property in the last two years, have probably played some part in aggregating these bones, because their droppings occur nearby and 27 of the fragments are relatively fresh. The chief animal agents operating on the bones, however, are porcupines, for only 29 of the 168 have escaped their attention. The presence of a human temporal bone and femur together with nearby deserted stone circles also complicates the picture.

At Mala Mala two hyena lairs had been investigated by Alun R. Hughes and H. F. N. Harington in 1953, and one of them—an old antbear warren—was completely excavated; the only skeletal remains extracted from both of these lairs was the intact carapace of a tortoise that had apparently fallen into the warren and failed to find its way out. (Hughes, 1954a, b).

Hyenas, therefore, under the pressure of human proximity, may collect at a single locality (but not in a den) from the kills they make

as many as 200± bone fragments; and there the bones may attract the attention of porcupines. Porcupines, living in low recesses, also take advantage of the proximity of hyena (or possibly other carnivore) kills to drag these bones and horns into or near their occupation sites. At Makapansgat, however, we are dealing with bone, tooth, and horn-core fragments reckoned not by scores but by thousands. Hyenas are not cannibals and they cannot prey upon porcupines; in consequence at hyena or hyena–porcupine sites no hyena or porcupine skulls have been found; at Makapansgat, on the other hand, the skulls of both hyenas and porcupines, even giant porcupines, are found in relative frequency and also in a very damaged state.

The bones and shells of water turtles at Makapansgat, like the crabs at Taungs, show that the Australopithecinae hunted in streams and knew how to break open with a club or stone a turtle- or tortoise-shell case: this a hyena does not and cannot do. From eggshells and the skulls of birds such as the shrike, vulture, and marabou stork, we see that these Australopithecinae delighted, like baboons, gibbons, and all naughty boys, in bird nesting; and also in driving carrion birds away from their prey, or clubbing them when they were so gluttonously full that they could not fly away. So, too, in disputes over prey they probably clubbed the hyenas and the wild dog, jackal, leopard, saber-toothed tiger, and other carnivores, both medium and small, whose broken skulls are found in the deposit at Makapansgat. The giant rodent moles and spring hares found at Taungs could only be captured by digging them out of their burrows. The two hares at Makapansgat indicate their manlike speed; the eight porcupines, including two giant specimens, reveal their capacity to deal with prickly problems.

Clearly the australopithecines, like all primitive human beings, took fleshy food wherever they found it; they hunted small game and large game alike. We have the remains of at least 39 large bucks of kudu and roan antelope size, 126 medium of wildebeeste proportions, 100 small ones of the gazelle order, and 28 of the tiny duiker type represented at Makapansgat. In that bone breccia are also remnants of 4 fossil horses, 6 chalicotheres (an extinct type of tree-browsing creature with split toes like bear's claws for dragging down tree branches), 6 fossil giraffes, 5 rhinoceroses, a hippopotamus, no less than 20 wart hogs, and 45 baboons. No creature except man was so wide-ranging a hunter in stream or tree; above earth or underground; catching reptile, bird, rodent, carnivore, primate, or ungulate. The animals they caught were generally the young or the old, those most easily overtaken and overpowered; but it would be an error to underrate the manlike skill implied by the versatility displayed by the animals they hunted.

THE PRIMARY ARMAMENT OF AUSTRALOPITHECUS

(Plate 4)

The creatures that made this great heap of bones at Makapansgat lived chiefly on antelopes, which formed 92 percent of their diet; but they also destroyed hyenas and porcupines. Just as the hyena was their most popular carnivorous prey, so among the rodents they specialized in porcupines despite their quills (perhaps because they needed their quills as well as their flesh). Among the primates they concentrated on baboons; of the ungulates (other than antelopes) they liked wart hogs best of all.

The principal part of the body that recommended these non-antelope creatures to the midden-making australopithecines was the skull, as evidenced by the fact that 82.5 percent of the fragments are cranial! The parts of the skull they treasured were, first, the lower jaw, and second, the upper jaw. Obviously, too, the australopithecines were head hunters, as *only one vertebra* (a baboon atlas) of these 140 non-antelope creatures has been found. The heads were apparently cut off sharp at the junction of skull and neck; the bodies were probably left to rot in the veld.

The anatomical feature that the upper and lower jaws of hyenas, baboons, wart hogs, and porcupines have in common is long, sharp teeth (lacerating canines or chisellike incisors) such as will rip open a belly or tear out the eyes of an enemy. These ancient hunters were after the tusks and the teeth for cutting tools.

Darwin (1871, p. 106) tells the story of a female baboon, kept under confinement by Brehm in North Africa, which "had so capacious a heart that she not only adopted young monkeys of other species, but stole dogs and cats, which she continually carried about. . . . An adopted kitten scratched this affectionate baboon who certainly had a fine intellect, for she was much astonished at being scratched and immediately examined the kitten's feet and without more ado bit off the claws."

The Makapansgat australopithecines had not only the baboon's wit to recognize those portions of their antagonists' anatomy, in which their strength and fury lay, and to deprive them of their power, but also the manual skill to hack and saw off the offending parts, and in addition the understanding to abstract from these parts the vital portions, and, most of all, the intellectual ability to turn them against their possessors.

No better illustration of these abilities has been found than is illustrated by the horse (zebra type) remains; there, apart from the cranial fragments, we find no vertebrae or any portion of the limbs above the hock. The australopithecines wanted the distal part of the hind limb, the part with the "kick" in it. Similarly with the chalicotheres, the

tree-browsing creatures that dragged down branches with their split-clawed hooves; six of them are represented in the deposit, but of bones other than cranial fragments we found only one of their claws. With the antelopes, too, of all 293 represented (39 large, 126 medium, 100 small, and 28 very small) the parts of the legs below the ankles and wrist joints were taken into the cave by the hundreds, but only four of the hoof phalanges are left to tell the tale of what they were used for. Obviously the parts below the hocks would have been useless as food; they were needed desperately as tools, as double-ended clubs.

The most numerous of all skeletal fragments found in the deposit are 369 lower jaws (mandibles) of antelopes; the next most frequent are the 336 double-ridged lower ends of their humeri. Clearly no accident had been responsible for our discovery years ago that baboon and australopithecine skull fractures on the one hand and the double-ridged humeri on the other hand bore a reciprocal relation to one another; but this greater frequency of mandibular fragments was quite unexpected.

The angle of an antelope half-mandible, if swung by its front end, can cut through flesh like a scimitar; the incisor teeth, or the broken front end of an antelope's lower jaw, can penetrate an animal's belly like a sharp sword point; but the greatest service such a jaw can render is with its sharp serrated teeth to saw through skin, flesh, or wood. The smaller the antelope the narrower the saw blade formed by its molar-premolar series of teeth; and the closer it approximates that most fundamental of all human tools, the linear edge—the schoolboy's pocket knife, the housewife's carving knife. Of the smallest types of antelopes, such as the duiker, no vertebrae or limb bones of any sort were to be found, only skull fragments; and of these skull fragments, no less than 53 are these narrow little knife blades (see pl. 4).

The upper jaws of antelopes, unlike those of carnivores, are not furnished with ferocious fangs, but the dental arcades in their palates form a regularly serrated broad arch; and this makes as perfect an abrasive surface as primitive humanity required down to Mousterian and later times. Right down to modern times, among the Bavenda and Bapedi tribes of the Transvaal, the palatal tooth series of oxen are employed in the scraping and softening of skins. There is little likelihood that the Australopithecinae used skins for clothing, but they needed implements to scrape meat off bones and fat off skins for food. The hundreds of isolated maxillary teeth, like the hundreds of madibular teeth found in the breccia, show that these natural scrapers and saws experienced the hard use that justifies their profuse occurrence in the deposit.

This is not the place to delve more deeply into the individual functions subserved by each of the bones of the antelope body in the hunting work and domestic economy of the manlike apes; but it is relevant to

discuss tools and their place in the origin and development of human speech to show the general bearing of the information gleaned from this deposit upon academic tool concepts, as well as upon living man's distinctive attributes.

THE SECONDARY STATUS OF STONE

It has been customary hitherto to imagine that stone formed man's first real tool material, and that, although man has been a hunter for about 1,000,000 years, he never seriously used teeth or tusks as tools or employed bones and horns (and then only as tool parts) until the Aurignacian epoch, i. e., about 25,000 years ago. There is, of course, no question that in the Aurignacian and succeeding archeological periods these osteodontokeratic materials found numerous novel technical and artistic applications in human industries, but those very novelties have merely served to conceal the primary or ancestral usages discussed here. The palatal scraper has been overlooked; and the saw, regarded heretofore as an acquisition of neolithic or, at most, mesolithic antiquity, has been revealed at Makapansgat as the prime possession of primitive mankind.

Skeletal parts, having been adapted by nature to destructive ends, were a complete answer to the early hunter's prayer for tools; yet the relative indestructibility of stone has exercised so mesmeric an influence upon terminology-loving archeologists that the primary place of these skeletal or osteodontokeratic materials in the paleolithic domestic economy of man has been either obscured or completely hidden. Just as metals came after stone and did not replace stone in human economy but only led to new uses and applications of stone, so Makapansgat shows that stone pebbles came after bone, tooth, and horn, and when first introduced as missiles and choppers, pebbles did not and could not supplant all the uses skeletal materials subserved in human economy; pebble tools merely assisted their osteodontokeratic forerunners by taking over to some extent the functions of the chopper and cutting edge.

The ancestral osteodontokeratic culture enforces upon us, first, a recognition of the limited tasks that even our metal tools, however complicated, can execute, and second, an appreciation of the comprehensive response of osteodontokeratic tools to those tasks in their basic forms from the outset. Archeology's teeming terminology, based not so much on the work tools do but on fine typological variations, creates the false impression that the variety of tools needed by stone-age man should correspond in some degree with the immensity of our lithic nomenclature, which is chiefly geographical. Basically, however, the human hand can perform but three kinds of motion, namely, pulling objects toward the body (or adducting), pushing

them away (or abducting), and twisting (or rotating) them inwardly or outwardly.

The named results of those movements depend, of course, on the amount of bodily weight and momentum added to these adducting, abducting, and rotating manual movements in the three dimensions of space. Thus the unaided body can squeeze and crush with its hands and arms (as can the great apes and many other mammals); but only heel-furnished man can rotate the whole body around stabilized feet and therewith dance a jig, plant a fist in a face, throw an opponent in wrestling, or hurl a projectile with accuracy.

Amid the superabundant nomenclature our predecessors have invented for the entertainment and instruction of their fellows to describe the movements of their own limbs and hands, and of their own and other creatures' bodily parts, however, we cannot afford to lose sight of the basic simplicity of adducting (pulling), abducting (pushing or thrusting), and rotating (twisting) manual and body movements; because, so far as the tools held in human hands are concerned, their actions and effects are equally simple at root. They depend for their named effects simply upon whether what we pull or push or rotate is sharp or blunt, and the speed or force with which the movements are executed.

Amid the glut of household and technical terms word-making human beings have further elaborated down the ages as names and synonyms for their various tools, to express all the different actions they have named as being performed by means of those tools, and to describe all the seemingly divergent results or end products of those actions, we should also recognize that there are only two things a man can do with a tool, namely, hold it or let it go. If in the process of letting it go, throwing or hurling it, he aims it at an object, he may hit or miss, but, if his throwing is accurate, its result will be the same as that of the tools in his hands. If he retains the tool in his hands it can only cut or pound according as it is sharp or blunt.

If a hooked, sharp object, like the canine tooth in the upper or lower jaw of a hog, hyena, or baboon, is pulled through soft tissues it is said to slash or lacerate; if we push or pull a serrated edge, like the mandible of an antelope, over skin or meat it slices or saws; if we rotate any long, sharp object, like a bone sliver or quill, we bore, drill, or penetrate into cavities or tissues and doubtless twist their contents around the slender tool we have inserted.

The forceful pulling (or downward or inward blow) of a sharp, pointed object, whether incisor tooth, horn, or broken bone, results in the piercing or stabbing of flesh or the digging of earth, the name depending on the thing pierced; a forceful pushing or upward and outward blow may poke, jab, split, thrust, or gouge objects, the named

effect depending largely on the bluntness or, if sharp, the width of the tool.

The forceful pull and push of a blunt, serrated object like an antelope palate can scrape, grate, abrade, or rasp off fat and flesh from skin and bone, or bark and rind from branch and stem. Persistence in scraping or rubbing leads to various named effects like braying, shredding, or polishing, depending on the material scraped.

The forceful inward or outward blows of objects with business ends as blunt as long bones or wooden billets can result in variously named effects such as pounding, hammering, cracking, or smashing; but, if the object wielded has a flattened platelike form and is furnished, like the mandible, scapula, or innominate bone, with more or less narrow and even linear borders, it is a natural blade and can hack and chop, or cleave and split as neatly as sword or ax.

Apart from hurling then, pounding, cleaving, scraping, stabbing (or digging), and slicing (or sawing) may therefore be defined as the five basic operations carried out by men with tools. From one or another of these basic operations is derived every other implemental procedure in our most modern machine shops and our largest vocabularies. These five basic operations, and many others that can be given names, were all comprehensively subserved by the osteodontokeratic culture.

Now when man or protoman began to employ pebbles for cutting as well as hurling or pounding they could not meet all five of these needs as well as osteodontokeratic tools did—they were but accessory tools. Not until man had learned to fashion pebble tools and other stone tools sufficiently sharp-edged and sharp-pointed to be permanently substituted for tusks, antelope mandibles, and horns could they begin to replace them. Consequently osteodontokeratic tools continued to be used alongside stone tools down through the ages. Stone tools, however sharp or massive and useful as missiles, could never become substitutes for bones and wood as clubs until they became hafted to bone or wood; at the outset pebbles could only assist man to fashion better clubs from wood than protoman could find naturally in bones. There were also among osteodontokeratic tools primal tools, such as palatal scrapers and mandibular saws for some of whose uses stone-age man apparently never found entirely suitable lithic substitutes. The effectiveness of the osteodontokeratic armamentarium, despite an advanced knowledge of stone, is nowhere better illustrated than by its persistence in the Arctic, Pacific, and Antarctic cultures until recent times.

This incapacity of pebble tools to meet all the implemental needs of protohumanity demonstrates the futility of imagining, with William L. Straus, Jr. (1955, p. 133), that tool making "represents the greatest distinction of man," or with Oakley (1951, pp. 69–81), that "tool-

making, as distinct from using," might be employed to distinguish the Australopithecinae from the later members of the Hominidae; the unjustifiable presumption in both instances being that tools were not made until some of them were fabricated from stone. It would be as reasonable to suggest that metal-age man differs mentally from stone-age man, or atomic-age man from carriage-drawn man, as to hold that the making of tools from pebbles necessarily implied a cerebral revolution in bone-, tooth-, and horn-using humanity. That is also why the discovery of pebble tools and an australopithecine maxillary fragment at the Limeworks site is not incongruous.

TOOLS AND SPEECH

The deposits of Taungs, Sterkfontein, and Makapansgat have told thus far a coherent story not of fruit-eating, forest-loving apes but of sanguinary pursuits and the predaceous habits of protomen. These South African manlike apes were human not only in being two-footed, in maintaining the upright posture, and in having the facial form and dental apparatus of humanity; they were also human in their cave life, in their love of flesh, in hunting wild game to procure their daily food; but most of all they were human in employing skeletal parts to subserve the function of implements in the business of obtaining and preparing that food, in getting it and dividing it.

The Makapansgat Limeworks has provided detailed information about the implemental intelligence of the South African protomen, their osteodontokeratic clubs and choppers, pounders and scrapers, projectiles and daggers, saws and knives, and has announced the transition to pebble tools. In his remarkable essay on "The Processes of History," Teggart (1918, p. 102) said: "Languages are made up of words, but these are not consciously and systematically elaborated; like the names in a scientific classification they come into existence only as occasion demands and are elicited by objects, actions and events. Before 'plowing,' 'sowing' and 'reaping' could have been named these actions must have been performed and recognised."

Just as the language of agriculture was based upon the nomenclature of farming actions and the tools with which those farming actions were performed, so man's earliest babblings must have been intimately concerned with, nay erected upon, his "nomenclature" of hunting actions and the tools with which those actions were performed. These hunting tools were the skeletal parts of animals; the prime and perpetual objects, upon which they acted, were also animals and their parts; the tools themselves were activated by the hands and bodies of the hunters while their bodies and limbs were in certain positions or postures; their entire food or bodily sustenance, so far as we know about it, consisted of animals and their parts. Their entire thought processes concerned

animals and their parts. If, therefore, words are elicited by objects, actions, and events, and if the fundamental object of inquiry in any language is its idea system, as Teggart claimed, and if the aim of speech, as he pointed out, is not the interchange of meaningless words but the conveyance of ideas, then clearly the ideas these most primitive hunters wished most to convey to their fellows throughout their entire lives concerned entirely animals and their parts, whether hunting or eating, whether preparing their tools for hunting, or dividing, by their means, the spoils of hunting.

Leslie A. White (1942) has realized that the essential difference between man and ape in respect to tools is not that man is more inventive: the difference lies in the persistent place tools occupy in human thinking. "In the ape, tool experience is a series of discrete episodes; the inner experience begins and ends with the overt act. In man tool experience is a continuum. Though the overt expression of the experience is disconnected and episodic, the inner experience is an uninterrupted flow and it is the symbol, the word-formed idea, that makes this continuity of experience possible" (op. cit. p. 372).

The actions and thoughts of hunting life were just as frequently and repeatedly being imagined, performed, and experienced by the Australopithecinae as by primitive hunting mankind. The Australopithecinae recognized the implemental significance of these skeletal parts; they took them into their caverns and out upon their hunting expeditions to subserve those same hunting ends. Dare we say that with them tool experience was not a continuum? Did they not also give "names" to their tools and the actions they performed with them? Or were they, like deaf mutes, speechless and content only with gestures? We cannot say, but many distinguished scholars from Rae and Tylor to Paget and Johannesson (see Paget, 1951, pp. 82–94) have insisted that human speech had its origin in gestures. Again, as Oakley (1951, p. 72) has rightly observed, a human child "is usually beginning to talk at the age of two years; yet at that age a brain capacity of 650 cc. is probably well within the normal range. Thus one cannot assume that an adult *Australopithecus* with a brain of that size was incapable of speech."

Gestures only become meaningful when they symbolize actions; actions attain specific significance as soon as they are regularly and repeatedly performed by purposeful tools. According to White (1932, p. 72) "the ape does not preserve his tools, nor does he talk about them. Man does both. Civilization may be defined as the accumulated products of man's tool and symbol capacities; the former gives us the material side of civilization and the latter the intellectual and spiritual."

Kroeber (1928, p. 336) had drawn attention a few years previously to the chimpanzee's inability "outside of posed problems to manufac-

ture tools or lay them aside for the future." The Makapansgat australopithecines differed from the chimpanzee in bringing to their caverns the material for their tools, in preserving them, and in laying them aside for the future; in brief, they had developed an osteodontokeratic culture.

The Australopithecinae may not have talked about their works, their tools, and the actions performed with their aid; nor am I aware of any evidence that articulate speech, as we term it, was employed by any human type preceding *Homo sapiens* (see Paget, op. cit.). There can, however, be little doubt that these australopithecine makers of osteodontokeratic tools, these followers of antelope-hunting techniques, these dissectors of animal bodies had a correspondingly adequate number of distinctive gestures and signals, manual, implemental, and doubtless vocal, for communicating their intentions while assembling tools for, and employing those tools in, their hunting, and for designating their wishes in respect to those tools when dividing the spoils of the chase. In so doing they were laying the foundations upon which was erected the superstructure of articulate speech.

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The History of the Mechanical Heart

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[With 4 plates]

Can you imagine a machine that could operate 70 to 80 cycles per minute, or about 42 million cycles per year, exerting a force of 5 to 10 tons each 24 hours, continually (without once stopping) for 50 to 100 years? Such an amazing machine is the human heart. It never stops working from the time we are born until we die. It has been estimated that the heart beats 3 billion times during the Biblical life span of three score years and ten, pumping a total of 250 million quarts of blood—almost enough to fill a large football stadium, and exerting a total effort which, if it were all applied at once, could lift the biggest battleship afloat 14 feet out of the water.

The title of this paper might suggest that man has now been able to create an artificial machine with the same fantastic properties and capabilities as the human heart—a mechanical heart that might serve as substitute for the real human organ. Medical science has succeeded in developing a mechanical heart, but this machine thus far has been able to perform the functions of the heart for only a very brief period of time during cardiac surgery. The mechanical heart is nonetheless a significant advance in medical science.

Before anything was known about the real function of the human heart, many types of unlikely characteristics were attributed to it. It was held as the seat of all emotions, the center of love and hate, courage and cowardice, sympathy and ruthlessness, virtue and vice. Parted lovers, frustrated artists, and disappointed statesmen have

been said to have died of "a broken heart." Cruelty has been blamed on a "hard heart" or even "no heart at all," while kindness has been said to be due to a "soft heart" or a "very large heart."

As early as 1700 B. C. an Egyptian surgical papyrus described the heart as a central organ in the thorax from which vessels were distributed to various parts of the body. Among the ancient doctrines was the belief, ascribed to Hippocrates of Cos (460–370 B. C.), that the heart was not subject to disease, because of its compact and massive composition. In an anatomic treatise on the heart of 400 B. C. were included descriptions of the valves of the heart, the ventricles, and the great vessels. The author of the treatise erroneously circulated the belief, which was widespread among the ancients, that the arteries were filled with air while the veins contained blood.

Galen of Pergamon (A. D. 138–201) described a concept of the heart and the blood vessels which was universally accepted for nearly fourteen centuries. Modern authorities disagree in the interpretation of Galen's concepts (Fleming, 1955), but there is general agreement that Galen thought that at least a portion of the blood from the left side of the heart reached the right side by means of "invisible pores" in the septum, the wall separating the right and left auricles and ventricles.

The rapid development of anatomical knowledge during the sixteenth and seventeenth centuries ultimately led to the present-day understanding of the functions of the heart (Willius and Dry, 1948). As early as the thirteenth century, the Arabian physician Ibn an-Nafis suggested the general scheme of pulmonary circulation and denied the existence of the "invisible pores" in the septum as taught by Galen. Again in 1553 Michael Servetus (1509–1553) discussed the existence of the pulmonary circulation; and Andrea Cesalpino (1524–1603) postulated the general circulation of the blood. None of these contributions, however, exerted a pronounced influence in correcting the Galenic theory, and it was not until William Harvey (1578–1657) published his famous treatise "De Motu Cordis" in 1628 that the theory of the circulation of blood was generally accepted. Harvey had studied at Padua where the chair of anatomy was held successively by Andreas Vesalius (1514–1564), who also denied the presence of the "invisible pores"; Matteo Realdo Colombo (1516?–1559), who conceived the pulmonary circulation in part; Gabriello Fallopio (1523–1562), who demonstrated the coronary vessels by dissection; and Hieronymus Fabricius (1537–1619), who described the valves of the veins. It was after he returned to England that Harvey continued his studies, and in 1628 finally published his famous treatise. The crux of Harvey's concept was that the actual quantity of blood as determined by measurement made it impossible for the blood to follow any other course than to return to the heart by way of the venous sys-

tem. With the development of the microscope, Marcello Malpighi (1628–1694) added the missing piece of the puzzle by the demonstration of the capillaries.

It seems likely that once the importance of the heart was realized, various thoughts must have been given to methods and means of replacing the heart by some artificial means. One such notion was expressed as early as 1812 by Julien-Jean-Cesar La Gallois (1770–1814), who observed: "If one could substitute for the heart a kind of injection . . . of arterial blood, either natural or artificially made . . . one would succeed easily in maintaining alive indefinitely any part of the body whatsoever (La Gallois, 1812). (See pl. 1.) It remained, however, for other workers actually to undertake such experiments.

Techniques that were later employed in experiments leading up to a mechanical substitution for the heart originated with the first attempts at blood transfusion. To Richard Lower (1631–1691) of the Royal Society of London goes the credit of performing the first direct blood transfusion in February 1665. The results were published in the first volume of the Philosophical Transactions for December 1666 (Maluf, 1954).

Even though early experimenters in the field during the seventeenth century recommended the use of volatile "staghorn salt" or "salmiak spirit" as an anticoagulant, the inability to cope with the natural phenomenon of blood clotting (among other factors) brought about a decline of blood-transfusion experiments until the nineteenth century.

Two French physiological chemists, Jean Louis Prévost (1790–1850) and Jean Baptiste André Dumas (1800–1884), found that whipping or twirling blood resulted in the deposition of fibrin on the churning instrument and prevented clotting in the defibrinated blood. This discovery led to a new series of experiments in blood transfusion, even though the famous French physiologist François Magendie (1783–1855) presented experimental data to show that defibrinated blood was toxic. An indecisive battle for and against the use of defibrinated blood raged for several decades.

In 1885, the saliva of the leech was found to contain a substance named "hirudin," which prevented the coagulation of the blood, and it was used as an anticoagulant in blood transfusions until 1915, when it was found that some samples were highly toxic. Heparin was first prepared from liver in 1916, but it was not used in medicine until it was purified in 1933. Its action as an anticoagulant appears to be the prevention of the conversion of prothrombin to thrombin.

One of the early nineteenth-century transfusion experiments, which may have been the earliest extracorporeal blood circulation of a living organism, was performed by James Blundell (1790–1878), an English

obstetrician, at Guy's Hospital in London. In an attempt to determine whether blood could be transfused by a syringe "without becoming unfit for the purposes of life," Blundell circulated a dog's entire blood through a special pump, which he termed an "impellor," without ill effects to the dog. Blundell reported prior to 1834 (Castle, 1834):

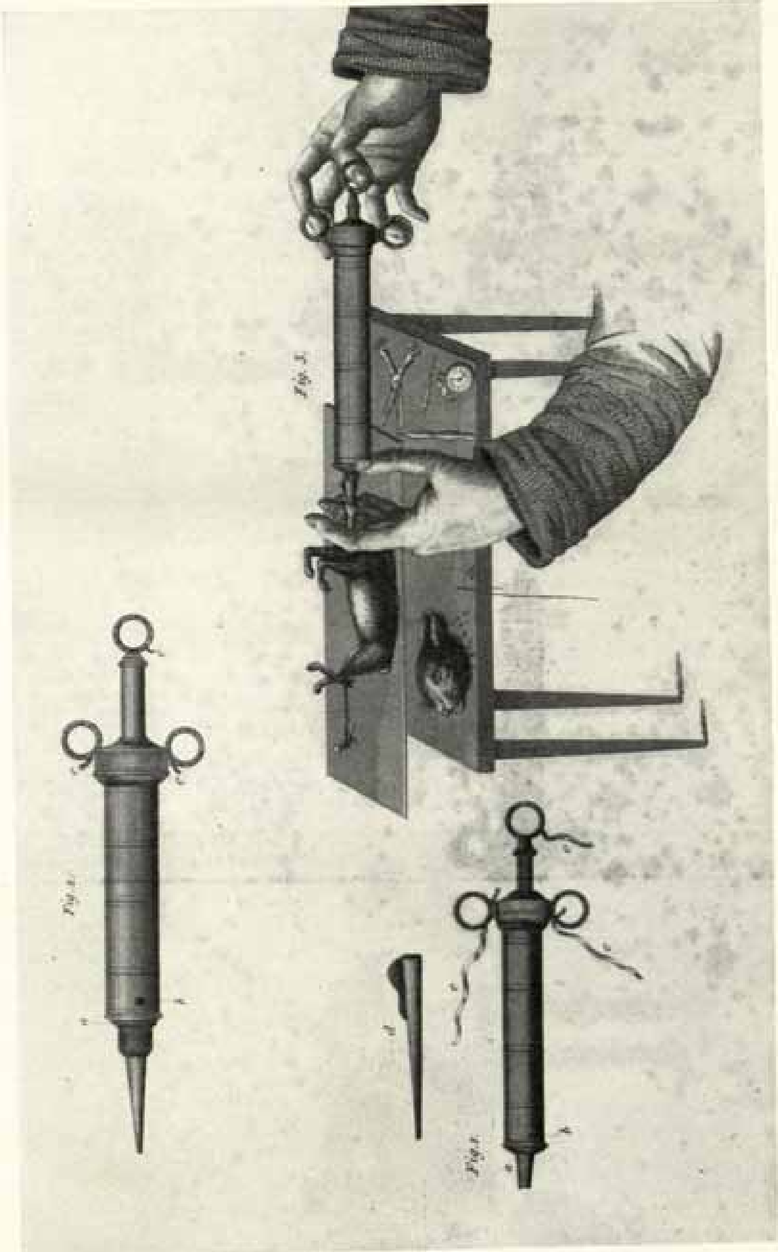
> Directing towards the heart a tubule inserted into the femoral or carotid artery, and the corresponding veins, I placed near to these tubes a cup in communication with a proper apparatus, then allowing the blood to rush from the artery into the bottom of the cup, by means of an instrument called an impellor . . . I absorbed this fluid into the barrel of a syringe, and returned it to the veins, so adjusting the return to the eruption from the artery, that more than an ounce of blood was never allowed to accumulate in the cup or the syringe at one time . . . the operation was carried on for twenty or thirty minutes together, the blood rushing from the artery during the whole time, so that all the blood in the body of the animal must have passed the syringe, and this too repeatedly, the dog, however, not appearing to suffer materially in consequence.

Aside from this very remarkable experiment by Blundell, experiments that eventually led to the conception of a mechanical substitution of the heart dealt with the perfusion of living organs and tissues.

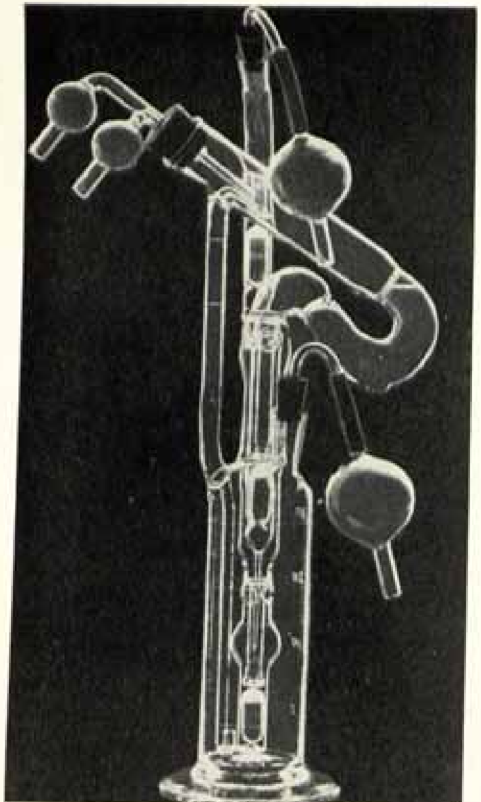
In 1828, a Frenchman named Kay showed that artificial perfusion with blood was capable of restoring irritability of dying muscle, and in 1846, Wild, a German, described what is probably the first perfusion of the isolated heart (Garrison and Morton, 1943.) In 1858, Charles-Edouard Brown Sequard (1818–1894) observed the reestablishment of certain cerebral functions by circulating blood through the vessels of a head separated from its body, while in 1866 Élie de Cyon (1842–1912) kept the isolated heart of a frog beating for 48 hours. From the laboratories of Carl Friedrich Ludwig (1816–1895) in 1868 came one of the first specially made apparatuses by which blood could be forced under constant pressure from a reservoir (Belt, Smith, and Whipple, 1920).

Henry Newell Martin (1848–1896), professor of biology at Johns Hopkins University, made "one of the greatest single contributions ever to come from an American physiological laboratory" (Garrison and Morton, 1943), when in 1880 he devised a new means of studying the activity of the mammalian heart. Henry Sewall, Martin's assistant, recorded: "I very well remember one morning, I think it was in the Fall of 1880, Martin said to me in effect, 'I could not sleep last night and the thought came to me that the problem of isolating the mammalian heart might be solved by getting return circulation through coronary vessels'" (Sewall, 1911). In Martin's own words, published in 1883:

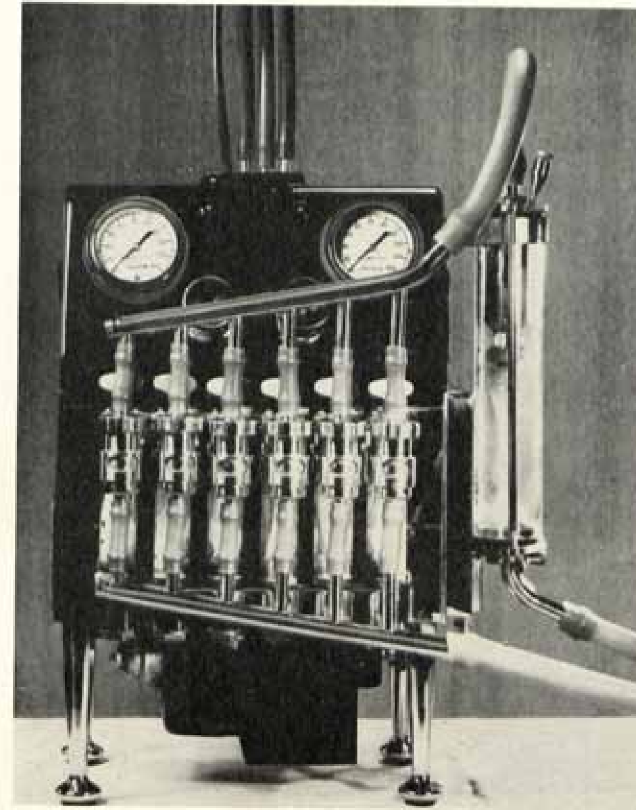
> The fundamental idea upon which all my work on the isolated mammalian heart has been based is to occlude all vessels of the systemic circulation except



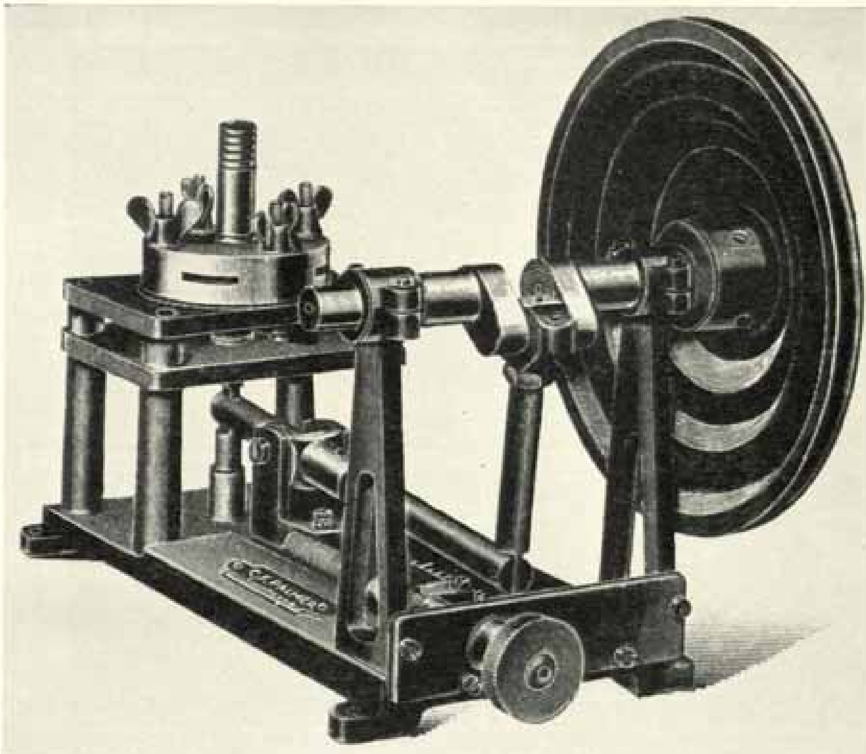
Le Gallois' experiments on a decapitated rabbit, 1812. Le Gallois expressed the notion of substituting "for the heart a kind of injection" to maintain "alive indefinitely any part of the body."



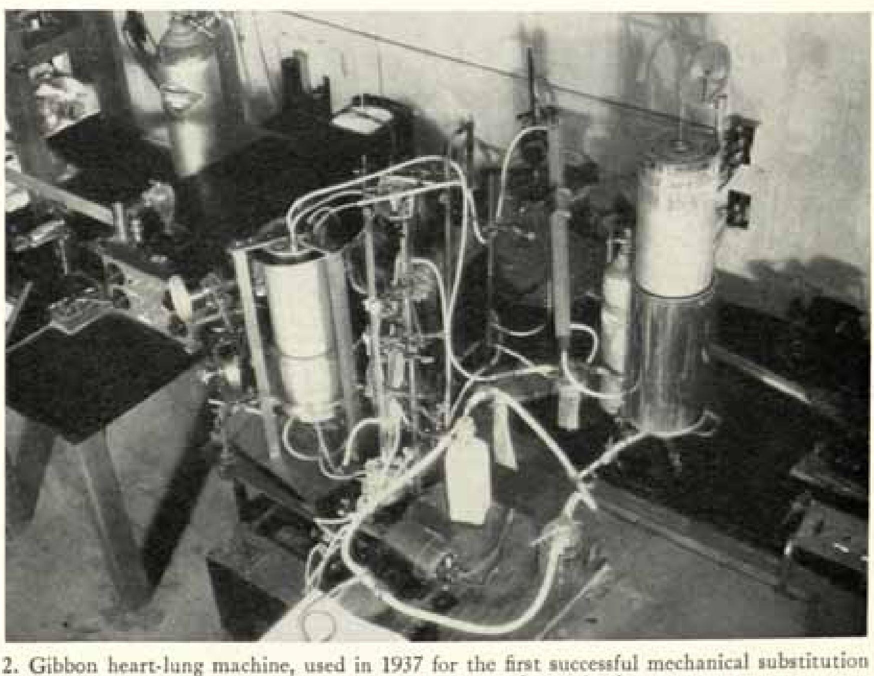
1. Lindbergh-Carrel perfusion pump. (Photographed by Schmidt and Haulenbeck, from "The Culture of Organs," published by Paul B. Hoeber, Inc., New York, 1938.)



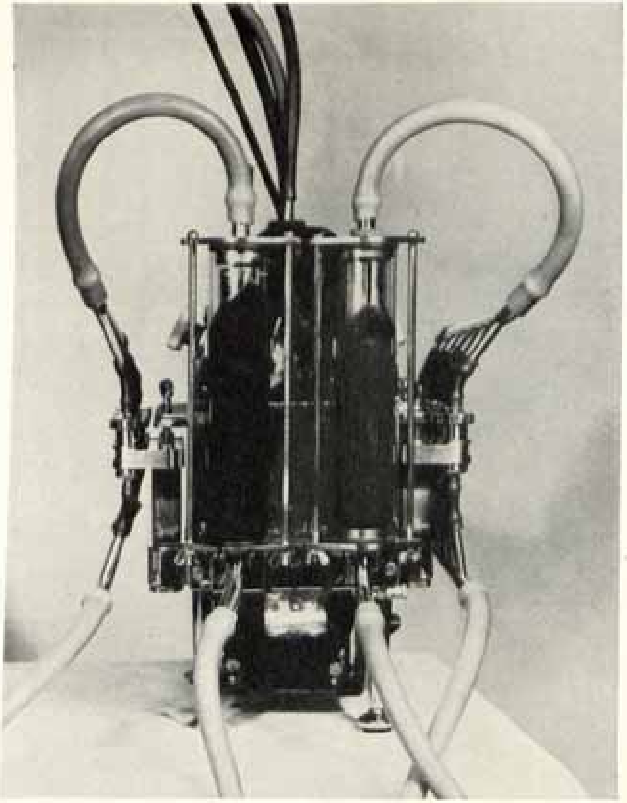
2. Dodrill-GMR mechanical heart, right side, set up for an operation on a human patient. Note the six individual pump units, six branch manifolds, and flowmeter.



1. Dale-Schuster double perfusion pump, made by C. F. Palmer, Ltd., of England, and proposed by Dale and Schuster in 1928 for use as a mechanical heart.



2. Gibbon heart-lung machine, used in 1937 for the first successful mechanical substitution of both the heart and lungs of an animal.



1. Dodrill-GMR mechanical heart, end view. Note the dark appearance of the venous blood in the left flowmeter, and the lighter color of the oxygenated blood in the right flowmeter.

2. A view of the operating room during a cardiac operation in which the Dodrill-GMR mechanical heart was used to bypass the human heart.

those supplying the heart itself, while leaving the pulmonary circulation intact. The heart and lungs being supplied with blood alone retain the vitality; all extraneous nerve centers getting no blood soon die with the remainder of the animal . . . so far . . . dogs only have been used, and defibrinated strained calf's blood has been the medium employed to nourish the isolated heart. (Martin, 1883.)

Martin's arrangement for the isolated heart and lung became known as a heart-lung preparation, a procedure which, with modification, has since been employed by many workers in the field.

Even though the ancients taught that the arteries carried blood mixed with air, it was not until the eighteenth century that the theory was proved. Antoine-Laurent Lavoisier (1743–1794) demonstrated that respiration caused chemical alterations in the respired air and that some of the oxygen, or "vital air" as he called it, was actually absorbed by the blood. With the increased interest in perfusion experiments, considerable attention was paid to the artificial oxygenation of blood.

In 1885 von Frey and Gruber of Germany devised an artificial lung by means of which aeration of the blood could be accomplished without interrupting the flow of blood to the region being perfused. They attached the piston of a syringe supplying the arterial pressure to a motor-driven wheel, thus creating pulsating pressure by mechanical means. In 1890, Jacobi devised an elaborate perfusion apparatus in which the blood was aerated by forcing a mixture of air and venous blood through a stretch of tubing at the end of which the blood and air were separated by means of gravitation (Belt, Smith, and Whipple, 1920).

In 1903 T. G. Brodie, director of the research laboratories of the Royal College of Physicians in London reported that he was able to perfuse an organ with the use of no other blood than that obtained from the animal itself—a considerable advantage over many of the types previously employed (Brodie, 1903).

Numerous other forms of perfusion apparatuses were devised during the first quarter of the twentieth century. In 1915, at Johns Hopkins University, D. R. Hooker devised a revolving flat disk which threw the blood in a thin film against the sides of an inverted glass bell jar. Also in 1915, at the University of Pennsylvania, A. N. Richards and C. K. Drinker described a method of oxygenating blood by allowing it to run through a silk curtain exposed to oxygen (Belt, Smith, and Whipple, 1920).

One of the most highly publicized perfusion pumps of all time originated in the Rockefeller Institute in New York City in the early 1930's. According to reports, in 1930 famed aviator Charles A. Lindbergh went secretly to work as a biomechanical assistant to equally famous biologist and Nobel prize winner Alexis Carrel (Anon., 1935;

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Ratcliff, 1936; Train, 1938). For years Carrel had been trying to keep organs alive for long periods so that physiologists could study their reactions.

On May 22, 1931, Lindbergh published anonymously in Science a brief report of an "Apparatus to Circulate Liquid under Constant Pressure in a Closed System" (Anon., 1931). By 1934, Carrel reported that a model had been developed which "permitted an entire organ to live outside the body." Reporting their success to the world in 1935, Lindbergh and Carrel described some 26 different experiments that had been performed. Organs that were successfully perfused included thyroid, ovary, suprarenal, spleen, heart, and kidney (Carrel and Lindbergh, 1935).

The perfusion pump, which was variously called "a robot heart" and "the glass heart" by the lay press, was described and illustrated by Lindbergh in the Journal of Experimental Medicine (Lindbergh, 1935). The apparatus consisted of two portions: one, the perfusion pump containing the organ and the perfusion fluid; the second, a chamber for the purpose of creating and transmitting a pulsating gas pressure to the perfusion fluid (pl. 2, fig. 1). In a comprehensive review of their work, Carrel and Lindbergh reported that with the construction of larger pumps "we can perhaps dream of removing diseased organs from the body and placing them in the Lindbergh pump as patients are placed in a hospital. There they could be treated far more energetically than within the organism, and if cured, replanted in the patient." However, Carrel concluded by warning the overenthusiastic that the method was "not as yet fully developed. Machines are always in the process of becoming. Their progress is almost unlimited. Therefore, the cultivation of whole organs has certainly not reached its final form" [1] (Carrel and Lindbergh, 1938).

In 1928, shortly before the Rockefeller Institute experiments commenced, at the National Institute for Medical Research in Hempstead, England, H. H. Dale and E. H. J. Schuster devised a pump (called a double perfusion pump) with the idea of using it as a replacement for the heart in carrying on both major and minor circulations of the whole body. The investigators, however, reported that "the pump has not yet been used for its original purpose of producing a complete circulation in the heartless animal."

The device, which served as the basis for many later experimental mechanical hearts, was designed so that two synchronously working pumps would theoretically carry on both the major and minor circulations of the body. According to Dale and Schuster, "in our experi-

[1] According to the Rockefeller Institute for Medical Research, "the Lindbergh-Carrel perfusion apparatus has not been in use at the Institute since 1938." An original model of the perfusion pump chamber is on exhibition at the Museum of the International College of Surgeons, Chicago, Ill.

ence, as in that of other workers, the use of the lungs for oxygenation preserves the blood in a much more physiological condition than does an artificial oxygenator." The original pump devised by Dale and Schuster (pl. 3, fig. 1) was made by C. F. Palmer, Ltd., of England.

In 1929, O. S. Gibbs of Dalhousie University, Nova Scotia, demonstrated an artificial heart before the Nova Scotia Institute of Science. The apparatus consisted of two small rubber bellows contained in a round brass box, with a lid and inlet and outlet valves at the base of the bellows. It was heated by nicrome wire wound on a pyrex tube with a car battery supplying the current. With this apparatus, a complete bypass of the heart was effected on cats for one to three hours, but no survival was reported (Gibbs, 1930). In 1930, at the request of R. L. Stehle of McGill University in Montreal, Canada, Gibbs prepared a similar "artificial heart" of the size suitable for use with dogs; and the following year, Stehle reported on its use on dogs (Melville and Stehle, 1931). While at the University of Georgia in 1933, Gibbs further reported on artificial heart experiments which were carried out on dogs at the Pharmakologisches Institute in Vienna, Austria (Gibbs, 1933).

For years physicians had been trying to find a safe way into the human heart to operate on its walls and its valves (King, 1941; Bailey, 1955). Most of these scientists believed that the practical answer to the problem was a mechanical heart to take over and give the surgeons a "dry field" free of blood so they could see what they were doing. The only argument was on how it should be accomplished. One group thought the way to do it was to make a substitute for one side (or both sides) of the heart and let the lungs do their work as usual. The other group wanted to bypass the entire heart as well as the lungs, and add oxygen to the blood by some artificial means. In either instance, the work in perfusion, which was performed primarily so that the physiologist could more carefully study the isolated organs, served as a basis for the new experiments.

In a review of pump oxygenators to supplant the heart and lungs, a University of Minnesota research group (Karlson, Dennis, Westover, and Sanderson, 1951) briefly outlined some of the many approaches to the problem. Commencing with the Frey and Gruber perfusion oxygenator of 1885, which we have already discussed, they describe such procedures as bubbling air or oxygen through the contents of a reservoir, or pumping the gas through tubing of the perfusion system along with the blood. In either case, bubble traps were necessary to prevent embolization. Spraying blood and oxygen together so that droplets of blood mix with a stream of oxygen has been tried. Blood filmed upon the inner surface of a slowly revolving cylinder or spiral, or upon a silk curtain mounted in an oxygen at-

mosphere, produces less foaming but is slow, and large quantities of blood are required. Glass plates, stationary cylinders, and inverted truncated cones have also been used as filming surfaces. Here the blood is exposed to oxygen as it runs down these surfaces.

The first report of a successful temporary substitution by an entirely mechanical apparatus for the functions of both the heart and lungs of an animal was made public by John H. Gibbon, Jr., of Philadelphia in 1939. (See pl. 3, fig. 2.) Using a pump oxygenator, Gibbon was able to maintain the circulation of cats for periods of 2 hours and 51 minutes. Thirteen experiments in all were performed, and four of the animals lived from 1 to 9 months after the experiments without signs of neurological change. Oxygenation was achieved by filming the blood on the inner surface of a vertical revolving cylinder (Gibbon, 1939).

Following World War II the interest in mechanical hearts and mechanical heart-lungs reached a new height, and by 1951 there were more than 30 such devices that had been built and tested throughout the civilized world.

Numerous reports of progress came from Europe. In 1948, Viking Olov Björk, working under Clarence Crafoord, of Sabbatsberg Hospital, Stockholm, Sweden, reported that a perfusion pump was employed on animals, performing the functions of the heart and lungs long enough to permit intracardiac operations (Björk, 1948; Crafoord, 1949). The following year, Jongbloed of the Physiological Institute of the University of Utrecht, Holland, announced a mechanical heart that was "considered ready for trial in man" (Jongbloed, 1949). The apparatus consisted of a battery of Dale-Schuster type pumps and an oxygenator of rotating spirals of plastic tubing in which the blood was filmed and exposed to oxygen (Jongbloed, 1951). The first artificial heart that could pump untreated blood without danger of clotting was claimed by Brull of the Université de Liège, Belgium, in 1950. (Brull, 1950) D. G. Melrose of the Post-graduate Medical School of London developed and described an apparatus similar to Björk's heart-lung but concluded that "the actual results of such interventions in human beings must at present remain largely conjecture." From the Municipal Hospital of Kampen, Holland, C. P. Dubbelman described a heart-lung apparatus (Dubbelman, 1951) and experiments employing 3 cows, 13 calves, and 2 dogs (Dubbelman, 1952).

Activity in the field in this country was equally keen and intense. Charles P. Bailey and associates reported that they had been working on the problem at the Hahnemann Medical College in cooperation with the engineering division of Drexel Institute of Technology, Philadelphia, since 1940 (Bailey, O'Neill, Glover, Jamison, and Redondo, 1951; Ellis, 1951). Sewell and Glenn at the Yale University School of

Medicine reported the successful use of an artificial heart in animals "to remove the coronary and thebesian flow from the right heart" (Sewell and Glenn, 1951; Anon., 1949a). Adrian and Arthur Kantrowitz of Montefiore Hospital of New York and Cornell University employed on animals a mechanical heart which consisted of a glass chamber and a standard roller-type pump in which "long-term survivals have been noted" (Kantrowitz and Kantrowitz, 1951). Out of a total of 61 cats used, the first 53 were lost in the process of developing the final technique, but the last eight all recovered from the procedure (Kantrowitz, Hurwitt, and Kantrowitz, 1951).

At the Mount Zion Hospital in San Francisco, another team of researchers described a simple roller-type pump on which animals "tolerated occlusion of the cavae for periods of 46 minutes with survival" (Leeds, Puziss, and Siegel, 1951). The report further noted "opening and suture of the right ventricle for short periods was also tolerated with survival of the animals."

In Washington, D. C., at Georgetown University Hospital, still another team (Broida, Freis, and Rose, 1952) developed a heart pump for substituting for either the right or left ventricle, "leaving the lungs and the opposite side of the heart to function normally." At Ohio State University, a group (Sirak, Ellison, and Zollinger, 1950) described a heart pump in which "animals were sustained by this apparatus for as long as twenty minutes with the ventricle open . . ." Of 10 dogs subjected to the procedure, there were 5 deaths, all due, according to the authors, to mechanical or technical failures of the apparatus. At Tufts College Medical School and the New England Medical Center, Boston, still another team (Wesolowski and Welch, 1951) employed a heart pump in 28 animal experiments in which the animals' own lungs were used as the means of oxygenation. Of the 28 animals, 21 (75 percent) recovered.

Other research teams who believed that the answer to success was to attempt a bypass of both heart and lungs, adding oxygen to the blood artificially, reported similar successes and failures.

Clarence Dennis and associates (Dennis, Karlson, Eder, Nelson, Eddy, and Sanderson, 1951; Anon., 1949b) at the University of Minnesota employed a pump oxygenator incorporating the oxygenation principle of Gibbon and the pump principle of Dale and Schuster. Survival in dogs subjected to intracardiac surgery was about 50 percent. Failure was believed to be due to traumatic effects on the cellular elements of the blood. At the University of Western Ontario, Canada, Russell A. Waud devised a heart-lung consisting of glass syringes operated by a special cam, and a large percolator serving as the oxygenator, which was reported to have been used successfully on over 100 dogs (Waud, 1952).

Also in Canada, at the Hospital for Sick Children and at the University of Toronto, W. T. Mustard and A. L. Chute recommended the use of actual lung tissue as a medium for oxygenating blood in a heart-lung machine. The use of a lung from another animal of the same species was found to be the experimental method of choice (Mustard, Chute, and Simmons, 1952). With this biological lung they reported that they had their first survival of an experimental animal in March 1949 (Mustard and Chute, 1951). Gibbon and his associates at the Jefferson Medical College of Philadelphia continued their experiments which were started in the 1930's. The reports indicated various degrees of success on dogs using a heart-lung machine built by the International Business Machines Corporation (Stokes and Gibbon, 1950; Anon., 1950; Lear, 1952; Engel, 1952; Miller, Gibbon, and Fineberg, 1953; Miller, Gibbon, Greco, Smith, Cohn, and Allbritten, 1953). From the Childrens Memorial Hospital of Chicago came the report (Potts, Riker, DeBord, and Andrews, 1952) that "dogs were kept alive one and one-half hours" using a heart-lung machine. Other centers where research on mechanical hearts and heart-lungs were carried on included Cedars of Lebanon Hospital in Los Angeles; Johns Hopkins University, Baltimore; Tulane University School of Medicine, New Orleans; University of Louisville School of Medicine, Louisville; and at the National Institutes of Health, Bethesda, Md.[2]

The interest in the field had built up to a feverish pitch by 1951. Then the first reports were made public that several of these instruments had been used on human patients. On April 5, 1951, Clarence Dennis and his associates at the University of Minnesota applied their heart-lung machine to a 6-year-old girl who was dying from a hole in the wall between the two auricles. The mechanical heart-lung was employed for 40 minutes, but too much blood was lost and the girl died. Even so, Dennis wrote in his report, "In spite of the tragic loss of the patient in question, we are inclined to feel encouraged with the performance of this apparatus" (Dennis, Spreng, Nelson, Karlson, Nelson, Thomas, Eder, and Varco, 1951).

On August 9, 1951, A. Mario Dogliotti of the University of Torino, Italy, performed what appears to be the first successful artificial extracardiac circulation in a human patient (Dogliotti, 1952). This apparatus was used to oxygenate the blood and to complement the activity of the heart during surgery on a tumor pressing on a man's heart. It was not, however, used for a complete bypass. On April 3, 1952, another medical research team at the University of Cincinnati College of Medicine and the Fels Research Institute, Antioch College, Yellow Springs, Ohio, used a heart-lung machine on a 45-year-old patient for

[2] Research Reports, Bio-Sciences Information Exchange, Smithsonian Institution.

oxygenating the blood for 75 minutes without apparent harmful effects. However, this heart-lung machine did not bypass the heart, but was used as an aid for relieving cyanosis (Helmsworth, Clark, Kaplan, Sherman, and Largen, 1952a, b; Anon., 1952).

During the Dallas meeting of the American Association for Thoracic Surgery, May 8–10, 1952, F. D. Dodrill of Detroit, Mich., presented a report in which he described a mechanical heart that was designed, built, and tested through the cooperative effort of a team of medical men headed by himself and engineers from the Research Laboratories Division of the General Motors Corporation. Results of some 65 successful experiments,[3] which had been performed on dogs, including right-sided substitution, left-sided substitution, and complete heart bypass, were reported, along with a description of the apparatus (Dodrill, Hill, and Gerisch, 1952a). The large number of successful experiments in which not a single animal was reported to have died of infection would probably have received wide acclaim and a good deal of attention by itself. However, before the paper appeared in the August 1952 issue of the Journal of Thoracic Surgery, an even more outstanding event took place, which overshadowed the initial report. On July 3, the Dodrill-GMR mechanical heart (pl. 2, fig. 2, and pl. 4, fig. 1) was used for the first successful total substitution of the left ventricle on a 41-year-old white male for 50 minutes during an operation at Harper Hospital in Detroit (Dodrill, Hill, and Gerisch, 1952b; Motter, 1953). Then on October 21, 1952, the same mechanical heart was used on a 16-year-old white boy for the first successful total bypass of the right heart in a human patient (Dodrill, Hill, Gerisch, and Johnson, 1953). Finally, an operation was performed on an 18-year-old girl in which the patient's heart was completely bypassed (Dodrill, 1954).

The criteria that the medical and engineering research group set up for design of the Dodrill-GMR mechanical heart consisted of 6 main points: 1, The machine must simulate the action of the human heart; 2, it must be small, compact, and of foolproof mechanical construction; 3, the parts of the machine coming into contact with the blood must be readily sterilized; 4, its pumping action must be gentle enough to prevent blood-cell breakdown, yet powerful enough to maintain an adequate blood pressure throughout the entire body; 5, the volume of donor blood used to fill the machine must be relatively small; 6, the machine and components must have adequate safeguards to insure uninterrupted functioning throughout the operation.

As the result of the investigation of numerous types of pumps, it was felt that every effort should be made to evolve a design in which the pressure to which blood cells might be subjected should never exceed

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[3] Supported in part by the Michigan Heart Association.

about half of that pressure which is considered safe. In addition, all passages through which the flow of blood must pass should be such that high velocities at localized points should be avoided. For this reason the finger cots with limited pressure action and weighted valves with large seats were chosen as pumping components.

In order to construct a machine that could be used for small children as well as large adults, they decided that the capacity of the machine should be variable. Thus the mechanical heart was designed so that the operator can use only as many mechanical pump units as are necessary to handle the patient's blood volume.

Since the element of sterility is a prime necessity in any operating room, it is doubly important in a machine in which the blood of a living patient will be circulating. Therefore, all parts of the glass, steel, and rubber mechanical heart that come into direct contact with the blood are carefully smoothed and coated with a nonwettable surface to prevent blood-cell breakdown and all are easily cleaned and autoclaved just as is any other surgical instrument.

The Dodrill-GMR mechanical heart was designed after the Dale-Schuster pump (previously mentioned) and consists of two independent units, one to take the place of the right heart and the other to take the place of the left heart. The pumping action is obtained by collapsing and expanding latex rubber finger cots with positive and negative air pressure. Collapse of the finger cots results in blood being drawn into the glass cylinders from the patient through inlet valves, while expansion of the finger cots forces the blood out through outlet valves. (See pl. 2, fig. 2, and pl. 4, fig. 2.)

Following its successful use, which made medical history, the Dodrill-GMR mechanical heart was named one of the top 10 scientific developments of 1952 by the National Association of Science Writers and received the Hektoen Bronze Medal for original investigation awarded by the American Medical Association in 1953.

Since Dodrill's successful use of the mechanical heart, John H. Gibbon, Jr., at Philadelphia's Jefferson Hospital performed the first successful operation on a human patient using a heart-lung machine. On May 6, 1953, Gibbon operated upon an 18-year-old girl and closed a large defect in the septum between the right and left auricles while the entire cardiorespiratory functions of the patient were maintained by the heart-lung machine for a period of 26 minutes during the intracardiac operation (Gibbon, 1954). Using the Melrose heart-lung apparatus previously mentioned, Aird and colleagues (Aird, Melrose, Cleland, and Lynn, 1944) operated on a 32-year-old patient at the Hammersmith Hospital, London, England, on December 9, 1953, "to assist the circulation . . . throughout a severe cardiac operation which would not have been attempted without some kind of artificial help." Even more recently at the University of Minnesota Medical

School a father's own lung was used in conjunction with a pump to bypass the heart of his 4-year-old daughter during intracardiac surgery (Warden, Cohen, Read, and Lillehei, 1954; Peters, 1954; Salisbury, 1954). Finally, in May 1955, Kirklin of the Mayo Clinic in Rochester, Minn., reported several successful repairs of septal defects in children using a modified Gibbon machine (Kirklin, Du Shane, Patrick, Donald, Hetzel, Harshbarger, and Wood, 1955).

Still a third procedure, called hypothermia, is proving somewhat successful and encouraging for intracardiac operations. As early as 1950 a group at the University of Toronto suggested hypothermia for carrying out cardiac surgery (Bigelow, Lindsay, and Greenwood, 1950; Bigelow, Callaghan, and Hopps, 1950). Normal body temperature is 98.6° F.; by chilling the patient as low as 78° F., the whole life process is slowed down so that instead of only 2 or 3 minutes while no blood is passing through the heart, the surgeon may have as much as 8 minutes to work within the heart without damage to the brain. On September 2, 1952, F. John Lewis and Mansur Taufic at the University of Minnesota performed a successful operation on a 5-year-old child with an atrial septal defect using hypothermia (Lewis and Taufic, 1953); and between January 9 and July 9, 1953, Henry Swan and associates at the University of Colorado performed operations on no less than 15 patients while they were in a hypothermic state. In 13 of these patients, circulation was stopped for periods varying from 2 to 8½ minutes, and the operation was performed on the open heart under direct vision with only one operative death (Swan, Zeavin, Blount, and Virtue, 1953).

While the procedures of cross circulation and hypothermia are significant advances, there is near unanimous agreement among thoracic surgeons that the eventual answer to the problem of open cardiac surgery is the temporary bypass of the heart using a mechanical pump in association with a means of oxygenation (the patient's own lungs or a mechanical oxygenator). True, the technical difficulties have not yet been completely solved. Most mechanical hearts and/or heart-lungs are expensive and complex requiring skilled persons to use them. Their use materially increases the magnitude of an operation because of the time required to attach the machine to, and later remove the machine from, the patient's circulatory system. The blood of the patient must be heparinized and its capacity to clot must be restored with protamine. Hemolysis and air embolism are hazards in most of the heart-lung machines. The solutions to some of these problems associated with extracorporeal circulation have already been found; others will certainly be solved in time to come.

All of this work with the mechanical heart is in its infancy. The results demonstrated to date by the various investigators working in this field offer

hope that eventually the heart may be bypassed for various types of intracardiac procedures. Blind procedures to correct intracardiac diseased valves represent a great step forward in surgery. Large numbers of patients have been relieved of their symptoms by these methods. It is probable, however, that a much more precise and exact corrective procedure can be performed on these deformed valves, if they can be exposed and the surgery done under direct vision. There is practically no surgical procedure carried out in any part of the body, aside from the heart, that is not under direct vision. (Dodrill, 1954.)

This "last frontier of surgery" is now being explored, and will undoubtedly soon be conquered. The original Dodrill-GMR mechanical heart is preserved in the Smithsonian Institution in Washington, D. C., not only as a monument to the team that designed and employed the first successful apparatus of this type for the complete bypass of the human heart, but as a monument to the combined efforts of medical and engineering research in general, and in particular to all scientists who have contributed to the exploration of this "frontier."

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Some Chemical Studies on Viruses[1]

By Wendell M. Stanley

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[With 3 plates]

Developments in the virus field during the past 20 years, mainly chemical in nature, have brought the molecules of the chemist and the organisms of the biologist into a new and very close relationship. As a result, a new dimension has been added to chemical structure, and new light has been thrown on that age-old question regarding the nature of life itself. Because chemical studies on viruses have progressed so rapidly during the past few years that it would be impossible to do justice to present knowledge in one lecture, I propose to devote most of my time to a discussion of the implications of this knowledge to general problems involved in that very interesting borderline region between the living and the nonliving worlds and to touch only lightly on some of the more significant relevant chemical studies on tobacco mosaic virus.

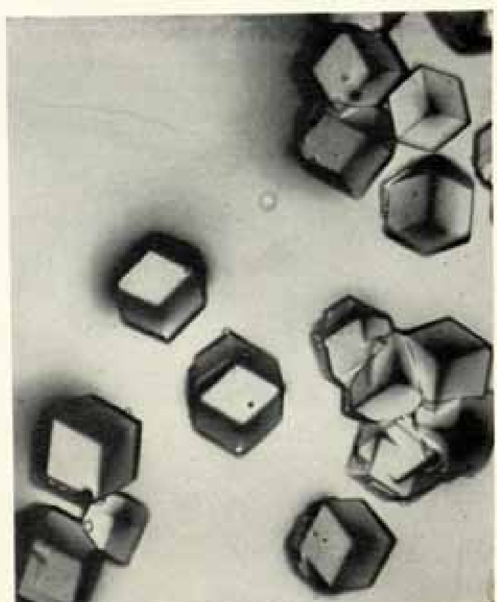
Mankind has undoubtedly wondered about the nature of the difference between living and nonliving things ever since the ability to think was acquired. We know that more than 2,000 years ago the noted philosopher Aristotle considered this very question, a question which everyone has undoubtedly thought about at one time or another. Now, Aristotle had very little in the way of experimental results to stimulate his thinking or to support his conclusions regarding the true nature of life. Yet this very wise man set forth a suggestion which we, today, in this ultrascientific world, can hardly surpass. Over 2,000 years ago Aristotle suggested that nature makes so gradual a transition from the animate or living to the inanimate or nonliving that the boundary line between the two is doubtful and perhaps nonexistent. In other words, he suggested the idea of a continuous spectrum or organization from the living to the nonliving, that chemical structure blends into

[1] Paper presented at a symposium in honor of Roger Adams at the University of Illinois, September 3 and 4, 1954. Reprinted by permission from The Roger Adams Symposium, 1955, John Wiley and Sons, Inc., publishers.

physiological function. We may ask what knowledge was available at that time to warrant such a suggestion, and the answer is that literally nothing was available save the sheer power of the brain of man. At that time man's physical powers of observation were limited to what could be seen with the unaided eye. No microscope was available, for this instrument did not come on the scene until many hundreds of years later. Yet Aristotle, and other philosophers to follow him, made the suggestion of smaller and still smaller living organisms extending to and literally blending with the nonliving world of metals and stones.

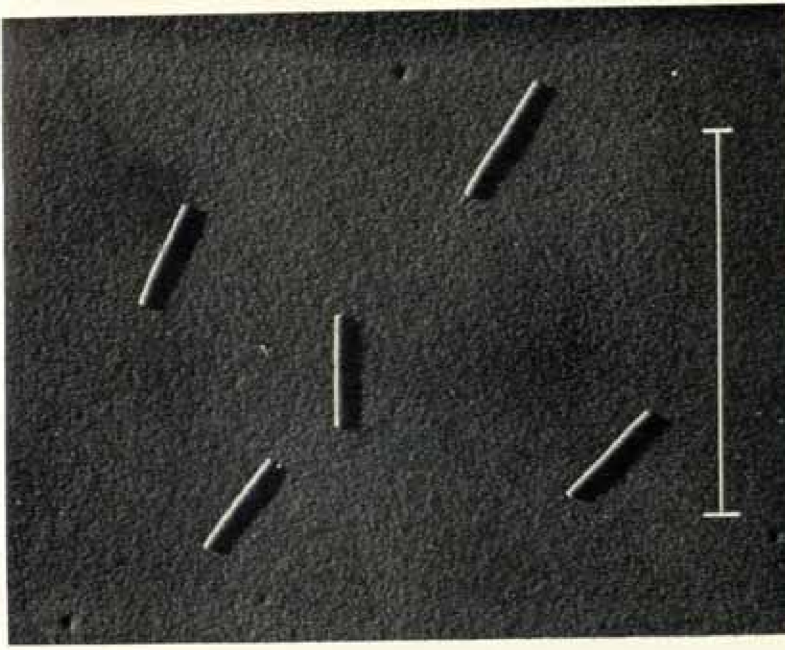
It was not until 1680 when van Leeuwenhoek invented the microscope that man first was enabled to see a new and hitherto unknown world of small living organisms. Yet even this remarkable invention, which eventually extended man's vision down to objects about 300 mμ in diameter, did little immediately to stimulate man's interest in this new microbial world. It was almost 200 years later before Pasteur, Koch, Davaine, and others proved experimentally that these microbes, discovered by means of van Leeuwenhoek's microscope and its successors, were actually responsible for certain infectious diseases. These scientists were extremely vigorous and very successful, for disease after disease was shown to result from the activities of these little living organisms, the bacteria. There followed what has come to be known as the "Golden Era of Bacteriology," during which the causal agents of many important infectious diseases were discovered. It was demonstrated that these bacteria could be grown on nonliving media and that they were, in truth, very small living organisms. Thus the new, usually accepted, borderline between the living and the nonliving worlds was pushed down to the range of about 300 mμ, immediately below which there was the void of the unknown. This void, or twilight zone, of the unknown extended down to the molecules of the chemist, or to about 10 mμ. Somewhere in this zone a new dimension was being added, either in the form of a specific relationship between two or more molecules or in the form of a unique type of chemical structure within a single giant molecule. Whatever the form of this new dimension, which confers the ability to reproduce or to bring about replication, it is obvious in retrospect that it should have been of great interest to chemists. Yet chemists tended to disregard this important and intensely interesting field for more than 50 years.

The thinking of the times was such that in 1892, when Iwanowski, a Russian botanist, found that an infectious disease of the tobacco plant, called tobacco mosaic, was caused by something which would pass through a bacteria-proof filter, that is, a filter which would hold back or retain all known living bacteria, he refused to believe his experimental results and concluded that his filters were defective. Iwanowski failed to recognize the fact that he had discovered a new type of infec-

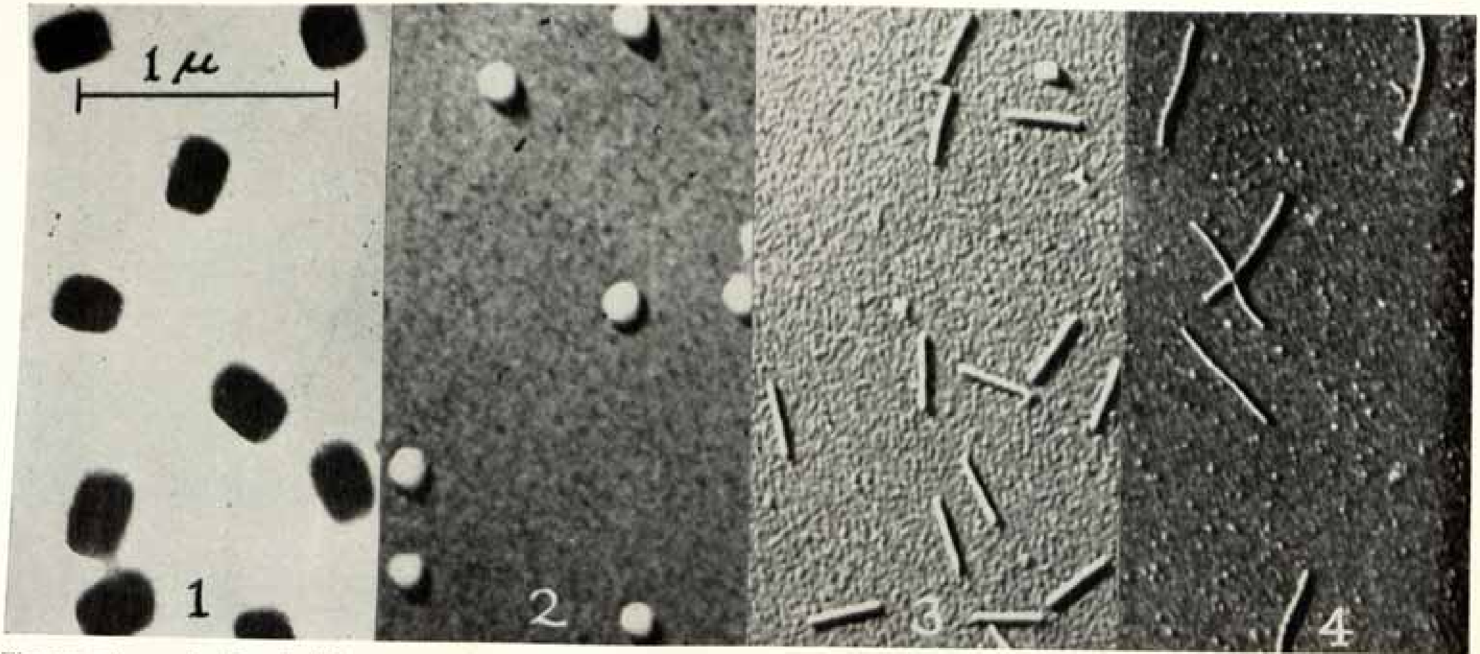


1 (*upper*).—Crystals of tobacco mosaic virus. $\times 675$. (From Stanley, Amer. Journ. Bot., vol. 24, p. 59, 1937.)

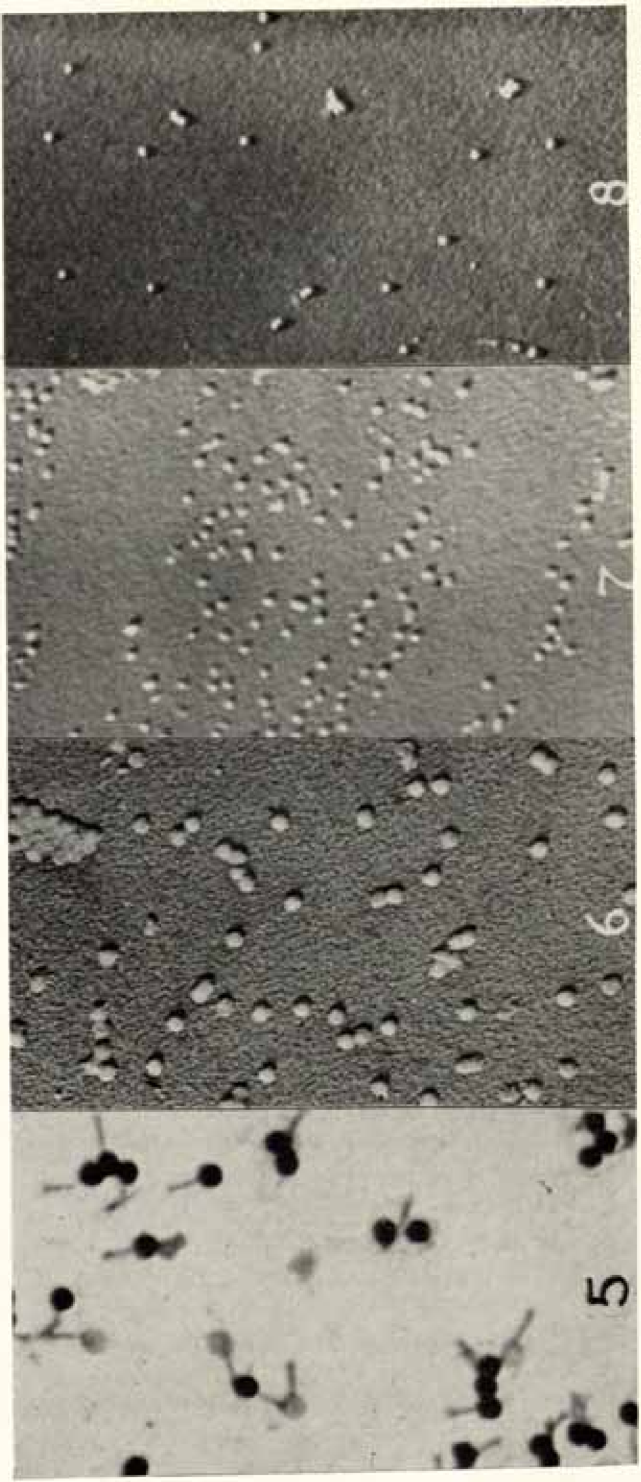
2 (*lower*).—Crystals of tomato bushy stunt virus. $\times 189$. (From Stanley, Journ. Biol. Chem., vol. 135, p. 437, 1940.)



3. Individual molecules of tobacco mosaic virus. $\times 60{,}000$. (Electron micrograph taken by R. C. Williams, Virus Laboratory, University of California.)



Electron micrographs of purified virus preparations. All are the same magnification, and all except 1 were prepared by the gold shadow-casting technique. 1, Vaccinia virus; 2, influenza virus (Lee strain); 3, tobacco mosaic virus prepared from hair cells; 4, potato X virus (latent mosaic of potato), hair-cell preparation. (From C. A. Knight, Symposia on quantitative biology, Biological Laboratory, Cold Spring Harbor, New York, vol. 12, pp. 115–121, 1947.)



Electron micrographs of purified virus preparations. All are the same magnification, and all except 5 were prepared by the gold shadow-casting technique. 5, T_2 coli bacteriophage; 6, Shope rabbit papilloma virus; 7, southern bean mosaic virus; 8, tomato bushy stunt virus. (From C. A. Knight, Symposia on quantitative biology, Biological Laboratory, Cold Spring Harbor, New York, vol. 12, pp. 115–121, 1947.)

tious agent, something we now call a virus, and was willing to believe that the infectious agent was merely comprised of bacteria which had passed through the holes in the filter. This was his unfortunate conclusion despite the fact that he had tested the filter many times against known bacteria and the filter had always retained such bacteria and despite the fact that he could find no bacteria in the filtrate. Recognition of the discovery of viruses was made quite independently just 6 years later by the Dutch botanist Beijerinck, who carried out similar experiments with the same disease. He passed the juice from macerated tobacco mosaic diseased plants through a bacteria-proof filter and showed that the filtrate would cause the disease when applied to normal plants. In addition he eliminated the possibility of the effect being caused by a toxin by showing that the juice from these filtrate-inoculated plants would still cause the disease after being passed through a second filter, and so on in a series. Beijerinck announced that he had discovered a new type of infectious agent, which he designated as a "contagious living fluid." If you analyze this description you will recognize that Beijerinck was not thinking in terms of bacteria or anything like bacteria, but of something new and different. The use of the words "living" and "fluid" is most significant, the latter especially so to chemists.

The same year Loeffler and Frosch discovered that the foot-and-mouth disease of cattle was caused by a similar filterable agent, and in 1901 Reed and coworkers made the first recognition of a virus disease of man, that of yellow fever. Since that time more than 300 different diseases of animals, man, plants, and even bacteria have been found to be caused by viruses. Among the virus-induced diseases of man are smallpox, poliomyelitis, measles, mumps, chicken pox, virus pneumonia, certain types of encephalitis, influenza, fever blisters, and probably the common cold. Virus diseases of animals include hog cholera, cattle plague, rabies, fowlpox, Newcastle disease of chickens, distemper, and certain benign as well as cancerous growths. Among the plant virus diseases are aster yellows, alfalfa mosaic, curly top of sugar beets, tomato bushy stunt, quick decline of citrus, tulip break, potato yellow dwarf, and peach yellows.

The earliest recognized property of the agents causing these diseases that was used to differentiate them from bacteria, namely, their filterability, has come to be recognized as untenable, for some of these viruses will not pass filters that will permit known organisms to pass. However, it has been replaced by certain other properties that are regarded today as characteristic of viruses. These emphasize the intimate relationship that exists between viruses and host cells, the fact that no virus has been grown on cell-free media, the fact that during growth or reproduction viruses can mutate, the fact that most but not

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all virus diseases are followed by a lasting immunity in recovered hosts, the fact that many virus-infected cells contain inclusion bodies, and the fact that, as a group, viruses are smaller than ordinary bacteria. It should be emphasized that no single one of these properties may be used to differentiate viruses from bacteria and that, despite the attempted separation based on the properties just mentioned, viruses have nevertheless been generally considered as merely small ordinary living organisms, somewhat similar to the bacteria. Needless to say, too ready acceptance of this conception delayed the chemical approach to the problem for several years.

The facts that viruses may multiply or reproduce, that they may change or mutate and adapt themselves to new conditions, that they are specific in their action in that a given virus occurs or causes disease only in certain hosts, and that a lasting immunity follows most virus diseases have been used as arguments for the living nature of viruses, for these properties have been generally regarded as characteristic of living things. For a time there were but few dissenters, and the large majority of the workers in the virus field saw no reason why viruses should not be considered small, invisible, living organisms. This conviction became even stronger with the discovery that some viruses were actually larger than certain bacteria. However, in 1931 Galloway and Elford reported that the virus of the foot-and-mouth disease of cattle was only about 8 to 12 mμ in diameter, only slightly larger than the familiar hemoglobin molecule of the chemist and actually considerably smaller than some of the hemocyanin protein molecules. Here, therefore, was a living organism that was smaller than an accepted protein molecule! Was it possible that all the metabolic activities usually associated with living organisms could be packed into a volume no larger than that occupied by a single molecule of the chemist?

Evidence of a growing unrest and general dissatisfaction with this situation became noticeable in the writings of the time. This is readily understandable since prior to 1935 about all that was really known about viruses was the fact that, in general, they were smaller than bacteria, that they possessed the ability to grow or reproduce within certain kinds of living cells, and that they could mutate or change and adapt themselves to new surroundings. Practically nothing was known about their basic nature. They could not be seen by means of the optical microscope, since, in general, they appeared to be smaller than 300 mμ, which is near the lower limit of this instrument, and the electron microscope had not yet appeared on the scene. It was not known whether they were still smaller ordinary living organisms or some new type of infectious agent. There was considerable discussion regarding their probable nature. Some scientists

thought they were proteins; others thought they were carbohydrate in nature; still other scientists thought they were lipid or fatlike; and, of course, the main discussion centered around the question whether they were living organisms or nonliving entities.

In order to resolve this chaotic situation it seemed desirable to attempt to concentrate and purify one of the medium-sized viruses and learn something about the nature of the purified material. At this time no such virus had ever been obtained in pure form; hence little or nothing was known about the physical and chemical properties or true nature of such a virus. Needless to say, these small viruses appeared to be very mysterious, although today it is exceedingly difficult to appreciate the early aura of mystery which surrounded them. The virus selected for study was the one that was discovered first, namely, tobacco mosaic virus. Extracts of plants diseased with this virus were subjected to the ordinary methods of protein chemistry, and in 1935 it was found that an unusual material, which could be obtained in the form of long, needlelike crystals, seen in plate 1, figure 1, could be isolated from these extracts.

This material was soon found to be a nucleoprotein having a particle or molecular weight far greater than that of any known protein, namely, of the order of 50 million. When solutions containing only 1 part per billion of this material were applied to normal tobacco plants, it was found that these plants came down with the tobacco mosaic disease, and from these plants additional quantities of this same unusual crystallizable nucleoprotein could be obtained. This material was not present in extracts of normal plants. The same material was also obtained from other kinds of plants diseased with tobacco mosaic, and it seemed probable that this material represented the infectious agent or virus. However, because of the fact that viruses had been generally regarded as living organisms, there was a persistent tendency to doubt that this crystallizable nucleoprotein actually represented tobacco mosaic virus. There were many suggestions that this material was merely a pathological nucleoprotein associated with the disease and that the true infectious agent or virus had not been isolated.

Fortunately, methods were gradually developed by means of which it was possible to correlate a given virus activity with a given physical entity, and, by means of a series of such correlation experiments, results have been obtained in the case of tobacco mosaic virus which permit the conclusion that, beyond a reasonable doubt, the crystallizable nucleoprotein rod, 15 mμ by 300 mμ in size, actually is tobacco mosaic virus. During the past 19 years no experimental data inconsistent with this conclusion have been obtained. This result indicates that a single molecule can carry within its own structure all that is necessary to predetermine reproduction or to cause replication and

hence that this unique characteristic is not dependent upon the interaction of two or more molecules in some new and unknown manner. This does not mean, however, that such interaction may not occur within living cells, but only that at one stage a single molecule can carry the complete message.

A few other viruses have been purified and subjected to similar correlation experiments, although usually to a lesser extent than for tobacco mosaic virus, and the respective characteristic particles are now generally accepted as the respective viruses. These other viruses have been found to exist in different sizes and shapes which are highly characteristic in each case. Some are pure nucleoproteins, and others are more complex entities. Some can be obtained in crystalline form, such as, for example, tomato bushy stunt virus, crystals of which are shown in plate 1, figure 2. Then, too, the advent of the electron microscope around 1940 was of the greatest importance to virus research since this instrument permits pictures to be taken of objects in the size range of the viruses, namely 10 to about 300 mμ, a range not covered by the optical microscope and the range of the unknown void between the organisms of the biologist and the molecules of the chemist. Although information regarding approximate sizes and shapes of viruses had been obtained earlier by indirect methods, for the first time it became possible really to see the viruses. For example, the individual particles or molecules that go to make up the crystals of bushy stunt virus were found by means of the electron microscope to be spheres 30 mμ in diameter. The individual molecules of tobacco mosaic virus, seen in plate 1, figure 3, were proved to be 15 mμ by 300 mμ, values in good agreement with those reached earlier by means of indirect methods.

From the outset the chemical studies on tobacco mosaic virus have been designed primarily to elucidate the nature of the chemical structure that is responsible for virus activity. The virus is stable between about *p*H 2 and *p*H 8. In dilute alkali or on treatment with detergents the protein and nucleic acid are split apart and the activity is lost irreversibly. In general, it has been found that the least destructive treatments which have resulted in separation of the nucleic acid have been those in which hydrogen-bond-breaking conditions have been coupled with salt treatment. Each of the components of this unusual nucleoprotein have been subjected to extensive analysis. The protein component comprising 94 percent of the structure was found to be composed of 16 of the amino acid building blocks common to most proteins. Regardless of the source of the virus, the relative amounts of these amino acids were constant. No D-isomers or unusual amino acids were found. Unlike sperm nucleoproteins, tobacco mosaic virus was found not to contain an excess of basic amino acids. As a matter

of fact, this virus has a preponderance of dicarboxylic amino acids; hence the protein is acidic in nature. The nucleic acid, comprising 6 percent of the virus structure, was found to be composed entirely of ribonucleic acid. Because of the acidic nature of the protein component the nature of the linkage between nucleic acid and protein has elicited much interest. It appears likely that the guanidino groups of arginine are so arranged as to be available for linkage to nucleic acid and that this arrangement is much more specific than similar linkages in the sperm nucleoproteins.

When the nucleic acid is split from the virus under conditions in which presumably only hydrogen bonds are broken, the protein component can yield a homogeneous protein subunit which appears to have a molecular weight of about 18,000 to 20,000. It has also proved possible to obtain a nucleic acid-containing degradation product having a molecular weight of about 360,000 which, although inactive, can nevertheless react serologically in a manner similar to the original virus and can reaggregate to form long rods having the characteristic diameter of 15 mμ. It may also prove meaningful that a subunit preparation of molecular weight about 120,000 and having no nucleic acid can reaggregate in a similar manner to form rods of 15-mμ diameter. This result may indicate that the protein alone can carry the specific information necessary to enable formation of a characteristically shaped rod. A noninfectious protein has been isolated from diseased plants which appears to be similar to this subunit in that it can likewise aggregate to a rod having a diameter of 15 mμ. Although none of these aggregation products has been found to possess virus activity, the fact that a protein can aggregate to form a definite and highly specific structure may prove of considerable importance in connection with the elucidation of chemical structure characteristic of this virus. Furthermore, the fact that this subunit appears to consist itself of about 6 to 8 sub-subunits of about 18,000 molecular weight provides a direct entree to structural work of importance to the organic chemist, for peptide chains of that size have now proved susceptible of direct structural analysis and synthesis.

Some results of Knight and Harris in the Virus Laboratory are of interest in connection with structural considerations. These workers found that on treatment of tobacco mosaic virus with the enzyme carboxypeptidase about 2,600 threonine residues per mole of virus were released without causing any change in biological activity. If each threonine residue is considered to represent one peptide chain in the virus, the resulting subunit would have a molecular weight of about 18,000. This subunit does not appear to consist of simple chains having an equivalent number of N-terminal amino acid residues, for extensive search for those groupings by Fraenkel-Conrat

of the Virus Laboratory has been unsuccessful. The failure to find sufficient N-terminal groups to match the C-terminal groups of threonine has been interpreted by Fraenkel-Conrat to indicate the presence of a cyclic structure in which the N-terminal groups are linked by peptide bonds to ω-carboxyls of glutamic or aspartic acids. It is, of course, not known how important such a structure, if it actually exists, may prove to be in the virus field.

It must be remembered that Knight has found that carboxypeptidase treatment of other viruses has resulted in the release of several different amino acids and not, as in the case of tobacco mosaic virus, exclusively of threonine. In any event, considerable information regarding the chemical structure of an important subunit of the protein component of tobacco mosaic virus has been obtained and the complete elucidation of the chemical structure of this subunit does not seem impossible. As indicated earlier, the nucleic acid component of the virus was found to consist exclusively of ribonucleic acid. Despite extensive investigation of this component, nothing new or unusual has been found to date, and any interest that may develop in this area must await further development of nucleic acid chemistry. Tobacco mosaic virus provides a unique source of a very pure ribonucleic acid preparation, and this material is being studied by a variety of newly developed techniques. Fortunately there is great activity in nucleic-acid chemistry, and it does not seem unreasonable to expect that important structural developments may result.

It has been known for a long time that viruses can mutate to form new strains which cause different disease manifestations. Now, one may well inquire as to the nature of nucleoproteins isolated from a given kind of host diseased with different strains of the same virus. As a result of an immense amount of very painstaking work, the most important and significant discovery has been made that, when tobacco mosaic virus mutates, the strains that are formed possess characteristic differences in chemical structure. In some cases there are differences in the relative amounts of certain amino acids present in the virus strains, and in other cases there are differences in the kind of amino acids that are present. Thus, sometimes, at least, mutation is accompanied by the incorporation of a new amino acid into the virus structure. The well-known tendency for isolable mutants to form when a virus is grown in an unnatural host may result from a selection process due to the new environment, but it might also result from the absence of certain building blocks in the new host cells which forces the use of available substitute building blocks and that this results in the new strain.

The transformation in virus or biological activity that may accompany mutation can be most dramatic. For example, ordinary tobacco

mosaic virus never kills Turkish tobacco plants, yet the $J_{14}D_1$ strain of this virus kills every young Turkish tobacco plant which it infects. Viruses can mutate, and the accompanying change in disease manifestation can be exceedingly drastic. Therefore, if a host contains a virus, even though a very mild or latent virus, the possibility of the formation of a very virulent or even lethal virus strain always exists.

Attempts to achieve mutation by changing the structure of tobacco mosaic virus by means of known chemical reactions have been made from time to time during the past 15 years. Although acetyl, carbobenzoxy, phenyl ureido, and chlorobenzoyl derivatives of tobacco mosaic virus have been prepared and found to be biologically active, no heritable mutation was achieved, for the progeny resulting from infection of plants with such derivatives always consisted of ordinary tobacco mosaic virus. It was also found that the sulfhydryl groups of tobacco mosaic virus could be abolished by treatment with iodine without affecting the ability to produce ordinary tobacco mosaic virus. Furthermore, experiments by Knight and by Fraenkel-Conrat in the Virus Laboratory have indicated that the removal of about 2,600 threonine residues or the addition of about 1,000 leucine residues per mole of tobacco mosaic virus has no apparent effect on the infectivity, the symptoms, or the nature of the progeny on infection of susceptible hosts with such derivatives. Thus, although these results indicate that various groups including amino acids can be added to or removed from the virus structure without measurably altering the biological activity, the fact that, in nature, structural changes do accompany the formation of mutant strains leads one to expect that sooner or later a structural change by means of a known chemical reaction will prove to be heritable and hence will represent a mutation. Needless to say, this result, if achieved, will be of the greatest importance.

Now, in order to place tobacco mosaic virus in proper perspective with viruses generally, I should like to close by presenting a bird's-eye or electron-microscope view of a series of viruses having different sizes and shapes. The structures shown in plates 2 and 3 are all at the same magnification and range from the large elementary bodies of vaccinia which are around 300 mμ in size down to the small particles of bushy stunt virus which are around 30 mμ. Thus, this series overlaps accepted living organisms at one end and approaches very closely to accepted protein molecules at the other end and actually serves to fill in the void that formerly existed between the organisms of the biologist and the molecules of the chemist.

In figure 1 of plate 2 are shown the elementary bodies of vaccinia which occur in the vaccine used to protect against smallpox. This virus is considered to be a strain of smallpox virus, and here we have an example of a mutant or altered strain of a virus which has been

found to be useful as a means of immunization against a more virulent strain. This virus appears to have a limiting membrane and a type of morphological differentiation which can hardly be regarded as characteristic of molecules. This structure probably represents the result of the interplay of many molecules.

The virus shown as No. 2 on plate 2 is influenza virus, which appears as white fluffy balls of about 120 mμ. This virus was responsible for one of the greatest outbreaks of disease within the knowledge of man. It has been reliably estimated that approximately 500 million people had influenza during the winter of 1918 and that of these about 15 million died. Here in the United States alone over 400,000 people died within 4 months during that epidemic. In order to place this in proper perspective it has only to be remembered that our total battlefield casualties during World War I and World War II add up to approximately the same figure. Here, therefore, is a single virus disease which, in 4 months, caused as great a loss of life in this country as occurred among our soldiers on the battlefield in two great world wars. It is also noteworthy that in 1918 the causative agent of influenza was unknown, for it was not until 1932 that human influenza was shown to be due to a virus.

No. 3 of plate 2 is the familiar tobacco mosaic virus which exists in the form of rods 15 by 300 mμ. Of considerable interest is the fact that Williams of the Virus Laboratory has shown that the rods of this virus have a hexagonal cross section. Each rod or molecule appears to have a crystalline structure.

The virus shown at the right (No. 4) of plate 2 is known as the latent mosaic of potato virus or sometimes as the healthy potato virus. It consists of crystallizable nucleoprotein rods which are thinner and longer than those of tobacco mosaic virus. This virus is thought to be present in all, or almost all, of the potato plants grown in the United States, yet it does not cause an obvious disease and our plants appear healthy. However, it is not present in potato plants grown in certain European countries. If the only experimental material available were the potato plants of the United States, it would be most difficult, if not impossible, to prove the existence of this virus. Extracts from one potato plant would have no effect on a second plant because it would already contain the virus. It is only by virtue of the fact that potato plants without the virus are known to exist and the fact that this virus causes obvious disease manifestations in certain other plants that it was possible to establish the existence of the latent mosaic of potato virus. In the absence of this information, this virus would be regarded as a normal constituent of our potato plants. Now it may be useful in any consideration of problems such as the nature of genes or the cancer problem to wonder how many similar entities

may exist today in nature without our knowledge. This possibility, plus our knowledge that viruses can mutate, provide adequate reason to pause for thought.

The next virus, shown as No. 5 on plate 3, represents particles of the T_2 coli bacteriophage, an agent that has the ability to infect and bring about the lysis or solution of certain bacterial cells. As can be seen, the particles of this virus are sperm-shaped and, like vaccinia virus, appear to be distinguished by a morphological differentiation which can hardly be regarded as characteristic of molecules.

The virus shown as No. 6 on plate 3 is of considerable interest since it is responsible for tumors or papillomas in rabbits which, in certain species, have been found invariably to progress and become cancers. This is a small, spherical virus about 44 mμ in diameter. Because the transition of the benign virus-induced tumor to the cancer appears to be accompanied by the disappearance of the virus as an infectious agent, this disease offers a most interesting experimental approach to the cancer problem.

The virus shown as No. 7 on plate 3 is that of southern bean mosaic, and it is a crystallizable nucleoprotein having molecules 31 mμ in diameter.

The final virus (No. 8) shown on plate 3 is tomato bushy stunt, the individual molecules of which are 30 mμ in diameter and the crystals of which were shown on plate 1, figure 2.

Now, as can be seen from the virus structure shown on plates 2 and 3, the viruses close the gap which formerly existed between the organisms of the biologist and the molecules of the chemist. Although the particles of any given virus appear the same, the particles of different viruses vary greatly in size, in shape, and in composition. Some are crystallizable nucleoproteins, and others consist of particles containing protein, nucleic acid, lipid, and carbohydrate. Some particles have properties quite consistent with those of the molecules of the chemist, whereas others have a degree of morphological organization apparently including in some cases a membrane, and this is hardly consistent with the molecular world. These may, therefore, represent borderline organisms. But all the viruses, regardless of vast differences in structure, are tied together by virtue of the common thread of virus activity. The fact that no virus has as yet been grown in the absence of living cells must mean that they are not independent metabolically but are dependent upon the metabolism of the host cell. This in turn must mean that they possess the unique ability to enter into the metabolic chain of events within cells and, hence, to guide what a cell does.

This unique ability of viruses to direct cellular metabolism represents the very heart of the virus problem and undoubtedly also carries

the key to the nature of life itself and possibly the key to the cancer problem. Despite their small size the viruses represent a potential source of information which may be far more important for mankind than the atom bomb or nuclear energy. Good health is essential for the full enjoyment of the blessings of a seemingly boundless source of energy, and mankind cannot have good health as long as certain virus diseases and cancer continue to exist. If we can but discover the secrets carried within the virus structures we will have gone a long way toward making the world a better place in which to live. It may appear amazing that Nature selected the borderline between the living and the nonliving worlds to house secrets of such great importance, yet sober reflection will reveal the wisdom, if not the necessity, for this course of action. Real properties of matter are but reflections of the degre of organization within, or the structure of, matter. The viruses, bridging the gap between organisms and molecules, have just that degree of organization or chemical structure which is necessary to provide for an expression of certain necessary properties, part of which lie in the world generally regarded as nonliving. Certainly some viruses are single molecules, and the nature of the chemical structure characteristic of such virus molecules is a challenging problem for the chemist. Some viruses appear to consist of many molecules interacting in some special manner, and the elucidation of this interaction also represents a challenging problem. However, as yet there appears to be no clear line of division, and it is still possible to agree with Aristotle's suggestion of more than 2,000 years ago that Nature has made so gradual a transition from the living to the nonliving world that the boundary line between the two is doubtful and perhaps nonexistent.

The Scent Language of Honey Bees[1]

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[With 2 plates]

IT IS A RELAXATION to turn from the pressing problems of our own community life to study for a while the social life of the honey bee, which is very interesting and quite different from our own. Only a small proportion of the two million different kinds of insects that exist today live in communities, and of these only a few share the honey bee's habit of living in a large and well-organized society. We know more about the mode of life and the behavior of the honey bee than that of any other social insect, because the economic value of its honey and its wax made it worth while for man to domesticate this insect, with the result that its activities have been kept under close observation for many centuries.

As in all other social insects, the family forms the social unit, and there has been no integration above that level; never does one come across a number of families associating together to form a community in the way that happens in the case of man. Nevertheless a honey-bee colony can reach a considerable size, and it may come to contain as many as 70,000 worker bees, all of them the progeny of one fertile female, their queen. The queen lays all the eggs, and the workers carry out all the other work of the colony. The efficient functioning of this large family is clearly impossible unless its members are able to communicate with each other effectively, and recent researches have shown that taste and smell play an important role in the methods of communication used by honey bees.

BEE SCENT

Over 50 years ago—in 1901, to be exact—Frank Sladen recorded that he had noticed a distinct and somewhat pungent odor arising from a swarm of bees that he was putting into a hive. He noted,

[1] Reprinted by permission from Discovery, January 1955.

moreover, that at the same time many of the bees at the entrance of the hive were rapidly beating their wings (this action is known as "fanning") and standing in a characteristic attitude—with the tip of the abdomen raised so as to expose a portion of the membrane that connects the fifth and sixth segments of its dorsal surface. Sladen then took several newly killed worker bees, dissected off this membrane, and showed that this material was capable of attracting other bees. He thus established that the bee's scent was associated with this membrane, and proceeded to his final conclusion, which was that the scent (and not the noise of the vibrating wings, as had hitherto been supposed) is the means of allurement that enables a fanning bee to attract its companions and encourage them to enter the hive.

The scent organ is exposed in other circumstances when it would be useful for a bee to attract its friends. It has been noted, for example, that bees which are collecting from a dish of strong sugar solution usually scent in this way, and the frequency of this scenting tends to be proportional to both the concentration of the syrup and the ease with which it is obtainable. As often happens when one studies other aspects of bee behavior, one finds that there is much variation between different individuals; when one watches a number of bees collecting from the same dish, he sees some bees that do not scent even when collecting very rich syrup, whereas other individuals scent even when the syrup is much diluted. The extent to which bees expose their scent organ when they are working on flowers has not been settled; some observers have seen them perform this action, and the Indian honey bee is said to do it frequently while collecting nectar from flowers.

As one might expect, honey bees can use the scent they give out as a guide to themselves on a return visit to a source of sugar or nectar, as well as to attract their companions. Moreover, recent experiments have shown that this scent has other surprising and important properties—the bees of each colony produce a distinctive scent, which is different from that of other colonies.

RECOGNITION OF COMPANIONS

Some experiments that shed light on the bee's ability to recognize members of its own hive have been carried out at Rothamsted. The apparatus used in these experiments is shown in figure 1; it includes two small dishes which are set down in a field about 30 inches apart; each dish is surrounded by an open box which serves as a windshield. The box in the center does service as a partition and also as an extra windshield.

Two colonies of bees, *A* and *B*, are placed 50 yards or so away from the pair of feeding dishes, and the stage is now set for our first experiment. The experimental procedure is as follows: On the first

day a group of 50 bees from colony *A* are trained to collect sugar solution from dish *a*, and the thoraces of these bees are daubed with white paint; during this day colony *B* is not allowed to fly, and dish *b* is kept empty.

On the second day colony *A* is not allowed to fly and dish *a* is empty, while 50 bees from colony *B* are trained to collect sugar syrup from dish *b*, and their thoraces are marked with blue paint.

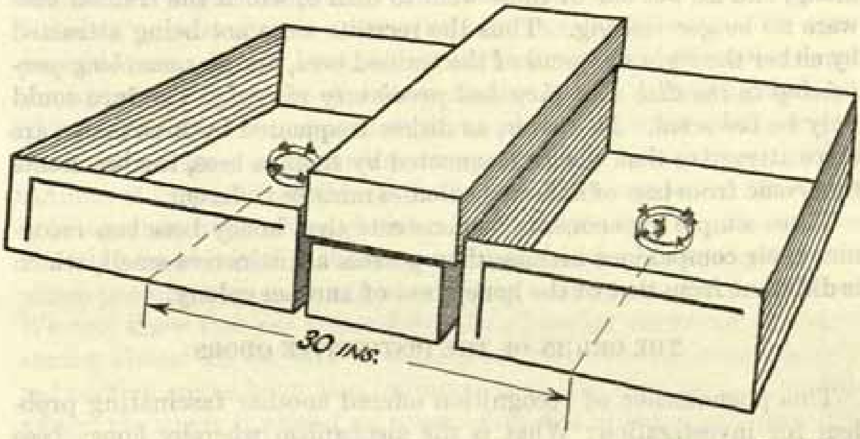


FIGURE 1.—Apparatus for studying the attraction of companions. The two glass dishes are surrounded by a brood chamber and separated by a nucleus box.

As soon as the group of bees from colony *B* have been marked, colony *A* is also allowed to fly. Both dishes are now filled with sugar solution. For a period all unmarked bees coming to either dish are killed and ignored, until similar numbers of the marked bees from both colonies are seen to be foraging from their respective dishes. From this time on all unmarked newcomers are marked with the same two colors, according to the dish that they visit, but now the daubs of paint are put on their *abdomens*, so that they can be distinguished from the guides which were marked previously.

When about a hundred newcomers have been marked in this way the experiment is stopped. At the end of that day the two colonies of bees are opened, and all the marked bees inside them are killed and recorded. It is then found that most of the newcomers from colony *A* have visited dish *a*, at which their hive companions foraged, whereas most of those from colony *B* went to dish *b*.

This experiment, which we have repeated at Rothamsted many times, has demonstrated that when hive mates and bees from another colony are foraging in similar numbers from nearby dishes that contain exactly the same food supply, the hive mates are much more attractive than the strange bees, so that one must conclude that the hive mates are recognized in some way.

In another experiment using the same apparatus, bees from one colony were trained to dish *a*, and no bees at all were trained to dish *b*. Both dishes were then supplied with sugar syrup. During the next 2 hours 45 recruits went to dish *a*, but only 3 visited dish *b*. Dishes *a* and *b* were then exchanged, and after some initial confusion the trained bees now proceeded to visit dish *b*—in other words, a new dish on the old site. During the next 15 minutes 9 more recruits came along, and all but one of these went to dish *a*, which the trained bees were no longer visiting. Thus the recruits were not being attracted by either the sight or sound of the trained bees, *but by something pertaining to the dish that they had previously visited*. The lure could only be bee scent. Moreover, as dishes frequented by hive mates are more attractive than dishes frequented by strange bees, the bee scents that come from bees of different colonies must be different.

These simple experiments demonstrate that honey bees can recognize their companions because they possess a distinctive smell, which is different from that of the honey bees of another colony.

THE ORIGIN OF THE DISTINCTIVE ODORS

This phenomenon of recognition offered another fascinating problem for investigation: What is the mechanism whereby honey bees come to possess these distinctive odors? Further experiments showed that these odors were not inherited, and these were followed by a series of experiments which proved that they derived from the food supplies that had been eaten by the bees.

These experiments were of two kinds. In the first set of experiments, colonies were divided into portions; the different portions of each colony were fed with different kinds of honey, and the bees in the differently fed portions were shown to possess different odors. In the other set of experiments, all the food supplies were removed from several colonies; all these hives were then taken to a Welsh moor, where they could obtain nectar from only a single species of flower, namely ling (*Calluna*); all these different colonies, after feeding on the same diet, came to possess the same odor.

FOOD SHARING

These results in turn suggested still more interesting problems. It is easy to understand how all the bees in a colony acquire the same scent when the food supply is homogeneous, as in the instance just cited where all the bees fed on the same kind of nectar, but it is not easy to understand how they all produce the same scent when a mixture made up of many different kinds of nectar is taken into the hive. Another set of experiments answered this question by demonstrating that the

mixture of foods taken into any hive is evenly shared among all the bees in that hive. For these experiments, radioactive sugar prepared by the Radiochemical Centre at Amersham was used. The experimental procedure for these experiments is quite simple. A marked bee is trained to collect sugar solution from a small glass tube, and when radioactive sugar is substituted the bee proceeds to collect the radioactive syrup quite happily. The bee now carrying its fill of radioactive sugar returns to the hive, and what happens to that "labeled" sugar after it enters the hive can be followed with comparative ease. Every bee that receives some of the radioactive sugar can be spotted by means of a Geiger counter. By collecting a sample of bees from the hive one can discover what proportion of the colony has acquired some of the radioactive sugar, and by taking periodical samples it becomes possible to find out the rate at which the sugar is being distributed through the colony. Some striking results have already been obtained in this way, and published. Other experiments, which promise to give even more exciting results, are still in progress. We now know that one stomachful of radioactive sugar can be shared among almost all the bees in a large colony. The experiments with radioactive sugar have also indicated that this sharing is a random affair; the sugar is passed on irrespective of the recipient's age or of its occupation.

These facts about the food-sharing habit help to explain the results of the field experiments on bees' scent. The floral nectars and pollens brought into any colony contain the different and distinctive scents of the different flowers from which they come. When those foods have been digested, derivatives of those chemicals that account for the various floral scents accumulate in the scent glands of the bees, and because each bee in that colony has received a more or less equal share of each and every item of food reaching the hive, each bee will produce a similar scent.

THE DIFFERENT FOOD SUPPLIES OF NEIGHBORING COLONIES

The food-sharing experiments showed how the bees in any one colony come to share the same foods, and so to produce the same odor, but this is only one of the conditions necessary before the food-derived odors will enable the bees to distinguish between the scent of their companions and that of the honey bees of other colonies.

Of equal importance, the bees of different colonies must obtain different mixtures of foods. Why should this happen, even if the colonies happen to be living in the same apiary?

In each colony many thousands of bees are collecting food supplies, and if these bees foraged quite independently neighboring colonies would obtain almost identical mixtures. However, the well-known

discoveries of Prof. Karl von Frisch have explained why this does not happen. He proved that successful foragers, returning to their hive, give samples of their booty to their hive mates so that they may know what scented food they should search for, and immediately afterward the foragers perform a dance which tells their hive mates the direction and distance away from the hive to the crop.

Von Frisch's students have shown that this message system is so widespread that bees seldom need to find new crops for themselves; nearly all of them collect from crops that they have been told about. In consequence, the colony, not the individual bee, becomes the foraging unit, and neighboring colonies usually gather quite different proportions of the various kinds of nectar and pollen that are available to them.

Thus, by food sharing between forager and recruit different colonies collect different food supplies, and by food sharing between all the bees of each colony those supplies are so evenly distributed that the bees of each colony produce the distinctive odor that enables them to recognize one another.

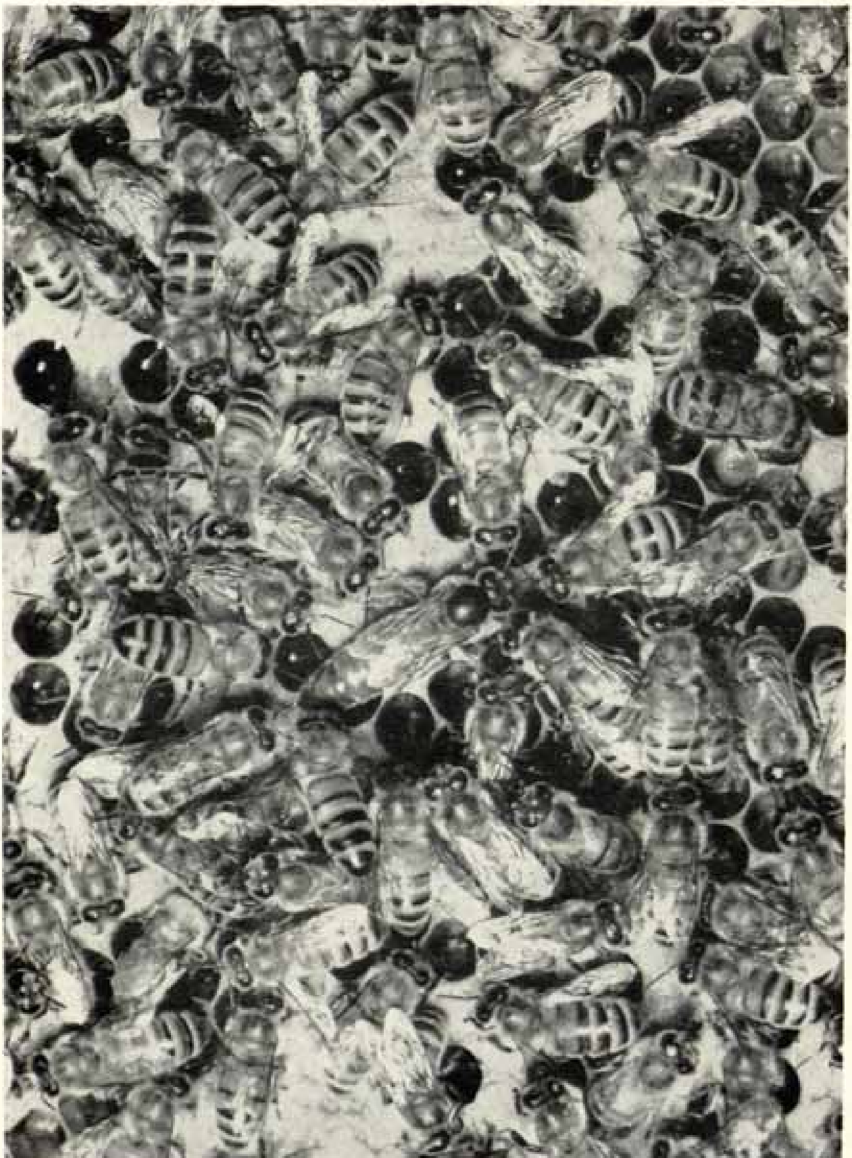
THE USE OF THE DISTINCTIVE ODORS

In nature one does not expect complex mechanisms to be preserved unless they are of some advantage to the animals that possess them, so it is legitimate to ask what use the honey-bee community makes of its distinctive odor. What advantage, if any, does the honey bee gain from its ability to recognize companions? If one bee meets another bee on a flower, it is doubtful whether either would obtain any advantage from being able to recognize the other as a hive mate; it seems highly improbable that the distinctive odors have evolved and been perpetuated because they were of use in this situation.

But there is one circumstance in which the recognition of hive mates is of great value to bees. At those times of the year when there are insufficient flowers to provide all the bees with food, they often try to steal the honey that is stored away in the honeycombs of other colonies. In such conditions the ability to recognize hive mates and to distinguish them from all other honey bees will enable the colony to defend itself against attempts at robbery by members of other colonies.

However, the honey-bee community does not defend itself by attacking every invader that does not possess the community odor. Strangers are only attacked in certain circumstances. In order to investigate those circumstances, two colonies of differently colored bees were placed close together, with their entrances only 2 inches apart, so that bees often went into the wrong colony by mistake (fig. 2). When good supplies of nectar were available, the intruders were

Returned foragers fanning and scenting on the alighting board of their hive. (Photograph by Günter Olberg.)



A queen bee with her attendant workers. (Photograph by R. V. Roberts.)

allowed to enter the strange colony, but when nectar was short the strangers were attacked and thrown out, often being killed in the process.

In further experiments, carried out at the end of the season when no nectar could be collected, bees from one of the two colonies were trained to visit dishes filled with sugar solution, but no syrup was made available to bees from the other colony. When this happened I found that the colony whose foragers were collecting syrup would tolerate strangers from the other colony, although these intruders went into it without food; on the other hand, the colony that was not foraging attacked strangers even if they were carrying full loads of rich sugar solution. This experiment showed that the chance of

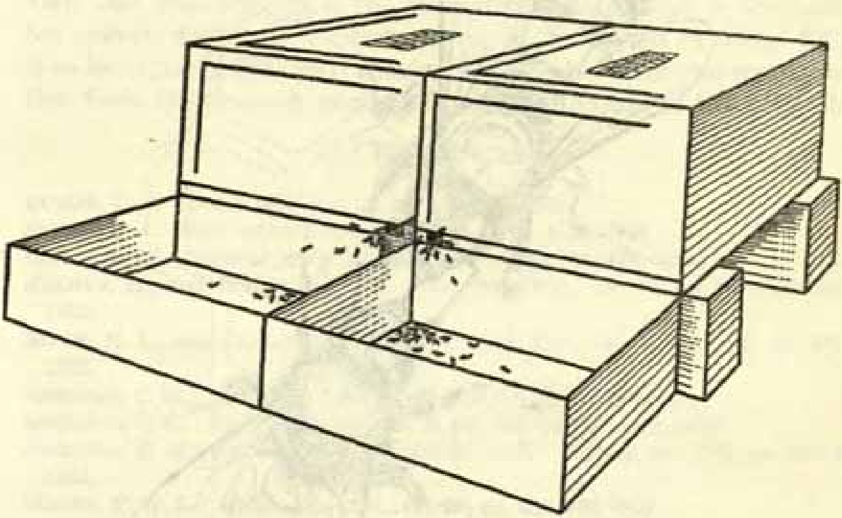


FIGURE 2.—Community defense. Two hives are placed together, with their very small entrances only 2 inches apart. Empty boxes in front of the hives receive any dead or injured bees.

successful entry was determined by the behavior of the bees in the colony which the intruder tried to enter. The fact that robbing occurs when foragers are not otherwise employed and that colonies are mostly guarded by unemployed foragers makes this result understandable.

The production of a common and distinctive odor, which enables the colony to defend itself against members of other honey-bee communities, is a very important consequence of the habit of food sharing, and it must have provided an important stimulus for the evolution of this habit—better sharing means better defense, and so a greater likelihood that the community will be able to survive and to perpetuate its kind.

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THE ROLE OF FOOD SHARING IN COLONY ORGANIZATION

We have seen how food sharing is associated with the production of distinctive odors, and so with the recognition of companions and with the defense of the community. It can thus be appreciated that food sharing serves, indirectly, as a means of communication between the members of the colony. This is one of the most interesting aspects of food sharing, but this habit has other uses connected with communication, which are equally important.

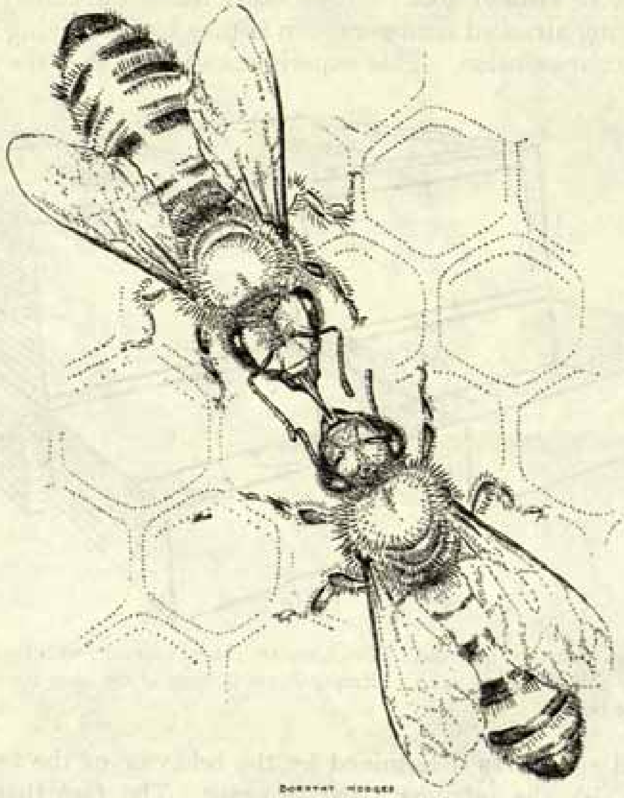

FIGURE 3.—Food being passed from one bee to another. Food sharing is the system of communication that welds the honey-bee colony into a social unit.

It plays the key role in the system of communication which enables the new forager to learn about suitable crops, in that the new recruits always receive a sample of the crop the colony is working; their first flight becomes a search for a crop with a similar scent. The food-sharing habit enables the worker bees in the colony to be appraised of the presence of their queen; a substance derived from her body is conveyed from bee to bee in the shared food, and in the event of any deficiency in that substance they take steps to rear another queen.

In addition, it probably helps to ensure an effective division of labor in the colony, which has to be so integrated that a suitable proportion of the worker population carries out each of the various tasks necessary for the maintenance of the colony. Evidence of this attribute of food sharing is now accumulating. There are, for example, the observations of Dr. Martin Lindauer, who studied how the activities of bees engaged in collecting water are regulated to suit the colony's need for water; when much water is required, the collectors are able to give up their loads as soon as they reach the hive, but when the need diminishes they cannot dispose of their load so quickly, and then they do not go out of the hive to collect any more.

More and more facts are being accumulated which support the view that food sharing is the *basis* of communication in the honeybee colony, and since communication is the essence of social life it is to be expected that food sharing will receive more and more attention from the research workers who study the life of the honey bee.

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The Army Ants

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[With 2 plates]

The Dorylines, one of the eight major subfamilies of ants, range throughout the Tropics and sub-Tropics of the world. They have survived very successfully from early Tertiary times, or at least 65 million years, on the basis of the unique combination of a nomadic behavior pattern with a fully carnivorous way of life. All that we now know about these ants and their relatives supports Wheeler's (1913) surmise that an exclusively carnivorous diet could not have persisted together with a fixed nest unless colonies were to become very small. In the ponerine and myrmecine subfamilies, which presumably are direct offshoots of the doryline ancestor, a largely carnivorous diet is widely characteristic as are fixed nests, but in species following this pattern small colonies are the rule (Haskins, 1951). But in doryline evolution the problem of large colonies and a carnivorous diet has been solved through a nomadic pattern of existence.

The dorylines have an impressive reputation of long standing as marauding insects, typified by Wheeler's (1913) characterization of them as "the Huns and Tartars of the insect world." General descriptions of their interesting temporary nests or "bivouacs" were available in the earlier literature, and from the observations of Savage (1849) and Vosseler (1905) in particular on the African species of *Dorylus* (*Anomma*) and of Sumichrast (1868), Belt (1874), Müller (1886), Bates (1863), and others on the New World ecitons, it seemed that in all probability the nomadic way of life must characterize the entire subfamily.

Reading this literature in 1930, as a psychologist interested in problems of "instinct," I was at once struck by the impressive breadth of the *Eciton* problem and by the fact that no real solution had been found. On preliminary consideration, the prevalent hypothesis of food exhaustion (Vosseler, 1905) seemed doubtful to me as an explanation of nomadism in these ants, yet no good alternative presented

itself in the literature. This problem seemed to represent an excellent opportunity for studying "instinct" in a social insect, and I had been looking for a widespread group pattern evidently influenced in fundamental ways by hereditary mechanisms.

Because Barro Colorado Island, the Smithsonian Institution's Canal Zone Biological Area, is a relatively undisturbed area of tropical forest in which representative Central American forms such as army ants are accessible for investigation, this situation afforded the best opportunity for carrying out basic phases of the research. In 1932, in my first investigation (Schneirla, 1933) on the Island, the phenomenon was appraised and a tentative solution was formulated. This was strengthened into a theory in three subsequent investigations on the Island (Schneirla, 1938). Now, after completion of eight investigations on the Island with other studies elsewhere in Central America (Schneirla, 1949; Schneirla and Brown, 1950, 1952), it is possible to offer a systematic account and interpretation of the behavior and biological characteristics holding not only for the terrestrial species of *Eciton* on which these studies have concentrated but probably to an appreciable extent for dorylines in general.

Gradually, through this work, an appreciation developed of what the "instinct" problem entails for one who would investigate it in the natural situation. The term, after all, is just a word representing our concept for a behavior phenomenon characteristic of the species; "adaptive" in that it fundamentally benefits species survival, and somehow basically dependent upon the genetic nature of the insects themselves. But the solution of a behavior pattern such as the raiding and nomadism of army ants as a complex system of activity, and an understanding of its hereditary basis (in this case what has kept the pattern predominantly in operation in this subfamily of ants for more than 65 million years) is not likely to fall readily into our hands. Rather it requires us to investigate the entire way of life of the animal, both in its behavioral or psychological and its biological aspects. This is a suggestion of the problem I have pursued with the army ants as material and Barro Colorado Island as base.

Probably more than one-tenth of the more than 140 species known for the three genera which constitute almost all of the tropical American dorylines are represented by colonies on the Island. Some ten of these species are encountered with considerable frequency, particularly the terrestrial *Eciton* (*Eciton*) species, *E. burchelli* and *E. hamatum*. These species are correctly termed "terrestrial" in that their daily raids are predominantly carried out and their temporary nests are typically situated on the surface of the ground or even in the vegetation. Studying them, we learn something of the characteristics of less accessible subterranean species as well.

The German term "Wanderameisen" emphasizes the roaming life which the ecitons lead. The branching columns of species like *Eciton* (*E.*) *hamatum* and *Eciton* (*H.*) *crassicorne* and the swarm or column of *Eciton* (*E.*) *burchelli* and *Eciton* (*Labidus*) *praedator* are frequently encountered in the forests of the Island, and one may be sure the ants issue from a temporary colony "bivouac" somewhere in the general vicinity. But finding colony headquarters is never an easy matter. Without observing the correct clues one may follow the column in the wrong direction, away from the home site, a mistake easily made in the afternoon particularly. Even if by dint of sharp eyesight, some agility, and some luck we are able to follow the column in the correct direction, it is possible under certain conditions to pass the actual bivouac without noting any signs of its presence. The ordinary task of column-following is made interestingly more difficult by the fact that each species—the golden-yellow *hamatum*, the darkish-brown *burchelli*, the reddish-black *praedator*, and others—in its own way is color-camouflaged and merges readily with ground colors in the typically dim light of the forest. The course usually is a rough one: through tangled masses of vines with prickly palms as occasional hazards, wild pineapple thickets and a variety of natural mazes formed around fallen trees, up and down steep ravine banks and across elevated bridges formed by lianas, the army ants go readily but not always the human investigator. The main center of raiding and hence the base columns run most frequently through the heaviest growth. There the living prey is most plentiful, and so it is there the advance raiders turn most readily in response to movement and odors from their insect booty, and it is there the human investigator must go if he would follow them.

We find *Eciton* colonies by hiking the trails to intersect the raiding lines, then by tracking down the colony base by following the columns. This means that the trail system of the Island has been an indispensable asset to searching for and studying *Eciton* colonies in a systematic way. Almost without exception even our short-term studies of ecitons must begin with the bivouac, and almost the only way to find this home site is to follow *in* the raiding columns. In other parts of the Tropics, where trails and roads tend to run outside the forest by human preference, one follows the stream beds in survey work, and the going is considerably slower. In a one-man investigation of 6 months on the Island in the dry season of 1946 (Schneirla, 1949), I worked with 30 colonies of *hamatum* and nearly 20 of *burchelli*, studying two colonies continuously for more than 4 months, and other colonies over shorter intervals—a schedule hardly feasible in a forest other than that of Barro Colorado Island lacking a central system of trails. The techniques of finding and working with army ants depend upon these basic paths first of all.

A major behavioral and biological problem in this investigation has been the nature, basis, and adaptive properties of that most peculiar of insect nests, the *Eciton* bivouac. As mentioned before, *Eciton hamatum* and *burchelli* may be properly termed "terrestrial" species because their raiding and their bivouacking are carried out mainly above ground. Without any active excavating and without any manipulating of fallen materials, colonies of these species form a domicile with their own bodies. A typical bivouac of *Eciton hamatum* is shown in plate 1, upper, a cylindrical mass hanging as most of them do from the underside of some projecting surface to the ground. In addition to the sides or under surface of logs, other typical places are the spaces between buttressed tree roots, masses of brush, or even the undercut banks of stream beds or the overhanging edge of a rock. In the "nomadic" phase of its activity cycle, a colony in these species forms a new bivouac of this kind each evening, somewhere in the outlying area of the day's raid, and these tend to be open clusters similar to the one represented.

The characteristic *Eciton* ability to cluster their bodies, as well as the manner of clustering, depends first of all upon an anatomical characteristic, the opposed recurved hooks present on the terminal tarsal segments of the worker's legs. These hooks may be seen in plate 1, lower, and figure 1. The first ants to settle in a new place catch into a rough or soft surface by means of their tarsal hooks, or rather are pulled into this anchored position as newcomers run upon them as they stand and stretch them out in a hanging position. In fact the hooks are really anchored by the added weight of others that have crawled down over the body of the first ant, fixing it in place and soon immobilizing it.

In the nomadic phase a new bivouac cluster is formed at the end of each further day of raiding, and this is a most interesting event to watch. In the advanced and most complicated stages of raiding in the afternoon, caches of booty tend to be formed at each busy junction of raiding trails, increasing in size as more and more ants are knocked around and forced out of traffic. As darkness comes and raiding ceases, such clusters grow. Events become increasingly complex at these places as an exodus develops from the old bivouac, and the crowding and complications of traffic, with the tendency to stop and cluster when progress is impeded in darkness, account for the starting of hanging clusters from elevated ceilings near such places, generally at several of them before one nears completion as the new bivouac. As each new cluster begins, the initial slender hanging threads may become ropes which extend to the ground, depending upon a continued flow of traffic to the place. As the ropes continue to grow they are joined together into a single columnar mass. At

first this mass is small in diameter, but as more and more ants pour into it the wall spreads outward from the center, and so a symmetrical cylinder results. Since *Eciton* bivouacs typically grow from the top downward, first in hanging ropes, then joined together as they increase in length, the diameter tends to be largest at the top, and the mass usually tapers inward toward the bottom. *E. burchelli*, in which the workers seem to be stronger in their bivouacking processes, can form taller bivouacs from a surface to the ground, or pouches when the clusters form higher up. I have seen bivouacs of this species at heights of 20 meters or more from the ground, as in the hollows of great trees. The more frequent forming of elevated bivouacs by *burchelli* than by *hamatum* may be due to the fact that the former species extends its raiding masses into trees in far larger numbers and more frequently than does *hamatum*.

The ecology of the *Eciton* bivouac is a complex and devious problem. We have tried to understand why *Eciton* bivouacs, seen in the daytime, generally are found with appreciable overhead shelter, in places less exposed to sunlight and more humid than elsewhere in the general environment. The answer does not seem to be that the first ants to cluster have hit upon a good site through direct sensory discrimination of atmospheric differences. At the time when the clusters are actually forming in the evening, various places in the general forest have an equal and minimal illumination and are nearly alike in their temperature and humidity. Investigation of the process leads us to the conclusion that the optimal character of the bivouac is achieved accidentally and indirectly. This is suggested by the fact that the bivouacs are formed near trail junctions, which are established under daylight conditions, when environmental differences in light and dryness have some effect upon the behavior of the ants, causing them to avoid places of extreme stimulation. Also, the bivouacs typically hang from elevated surfaces, which are likely to afford some protection to the cluster when it is exposed to the general environment on the following day.

The interior of the bivouac, where the brood is sheltered and the single colony queen rests, offers an impressively stable environment to these more susceptible members of the community as well as a central resting place for the worker population. The hanging cluster traps a cubic area of atmosphere which does not reach the extremes of temperature and dryness attained by the general forest environment, but in general is somewhat cooler and drier at night and somewhat warmer and more humid during the day. This result is achieved rather indirectly, on the whole, although mainly as a result of worker behavior. The indirectness may be suggested first of all by the fact that, when resting, workers cluster more closely together at night in

reaction to the lower temperatures of the forest at that time, the bivouac walls become tighter and better conserve heat produced internally (by the brood in particular). Conversely, after dawn, when increasing light excites growing numbers of ants to leave the bivouac walls, as the raid grows, this wall thins out, usually develops small apertures, and is undercut at the bottom. The effect is to increase the internal air circulation as well as to cool the atmosphere in the interior through evaporation so that the internal temperature of the bivouac does not rise to the height reached by midday in the environs. The incubation properties of the bivouac represent an important factor in *Eciton* life, for with less regular atmospheric conditions in the nest, the stages of brood development could not have their typical regularity in timing. More than a limited irregularity in these biological processes would surely have important distorting effects in the *Eciton* activity cycle.

An *Eciton* colony is a complex organization that contains in its regular membership not only a fertile queen and a great horde of neuter females or workers, but also an immense brood of developing individuals (usually all workers), and in addition many non-insect guests or "ecitophiles" (beetles and others) ranging to parasitic forms. The *Eciton* workers, which carry on the raiding and other labors of the colony, make up most of the social unit and may number into some hundreds of thousands as in the case of *Eciton burchelli*. Colonies of *Eciton hamatum* usually are much smaller than those of *burchelli*, and probably average not much more than 150,000 workers. In strictly subterranean species, such as *Eciton praedator* and *Eciton crassicorne*, the populations seem to be larger on the whole, judging especially from the durations of the emigrations.

A population component of great importance in *Eciton* life is the brood, which is always present at some stage of development in any functional colony. Without their broods, these colonies cannot exist very long. Throughout the year, at fairly regular intervals, the population of the colony is increased by the emergence of successive great new broods, which virtually always consist entirely of workers. In the case of *Eciton hamatum* we have counted more than 40,000 individuals in a single all-worker brood, probably the typical brood size for that species. Single broods of *Eciton burchelli* are much larger, approaching twice the size of those of *hamatum*.

Of course the colonies do not continue to grow indefinitely by the addition of new broods. There are at least two measures of population control exerted in the normal environment: one, losses involved in the daily raiding forays, in which great numbers of workers are lost in combat with insects whose nests are pillaged; the other, natural hazards such as exposure to environmental extremes, particularly

in the dry season. The result is that on the whole, during most of the year, the majority of colonies do not change greatly in size, notwithstanding the regular addition of large worker increments from new broods.

There is one major departure from the annual series of all-worker broods. In the last months of the rainy season, evidently a time of exceptional plenty for most colonies of army ants, many *Eciton* colonies seem to increase their colony populations very appreciably. There often follows a further exceptional occurrence, namely, the production of a bisexual brood consisting of a great many males and a very few queen individuals. Such broods occur most frequently in the first third of the dry season. Through an intricate process which we have studied in some detail, production of the sexual brood leads to a two-way division of the colony, another process of importance in population control.

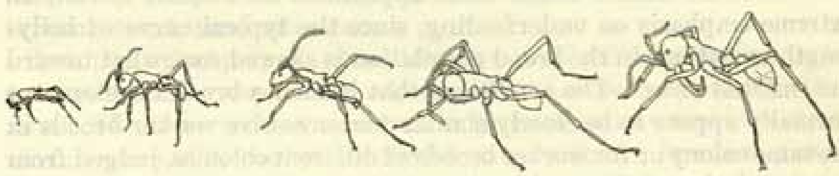


FIGURE 1.—Representative workers from the population series of an *Eciton hamatum* colony. Differences in size and structure through the population are represented here by individuals arbitrarily selected from the minim and major extremes and the intervening 20-percentile points. Body lengths: minim worker, 2.9 mm.; major worker, 9.9 mm.

The ecitons exhibit in an outstandingly regular way that important social characteristic, polymorphism—the occurrence of morphological differences through a population of one sex, in this case the female sex. The workers present differences in both size and form. The main differences are shown in figure 1. The worker series from the largest through the intermediate to the smallest size is not a broken series of radically different types but a smooth and gradual one on the whole. The five worker types of *Eciton hamatum* shown in the figure represent arbitrary steps in a regular series ranging from the smallest or minim workers (about 2.9 mm. in length) to the largest or major workers (about 12 mm. in length). The largest workers have disproportionately large heads and anterior bodies, an anatomical peculiarity which ends, as in a burst of glory, with the enormous head and mandibles of the major workers. These individuals are characterized by their huge sickle-shaped mandibles and by the great strength which can be exerted in closing and holding them shut. The jaws, together with the stings and poison glands, make the major workers formidable foes of any intruders into bivouacs or raids.

It seems probable that the entire membership of any *Eciton* all-worker brood is the product of fertilized eggs of essentially equivalent genetic constitution and that the principal difference in the conditions of their development depends upon the amount of food received. Statistical evidence is available indicating a different growth rate for the larvae of minim, intermediate, and major workers. It would appear that the differences are established very early, and probably depend first of all upon the order in which the eggs are laid, with the first-laid eggs having an initial advantage which is thereafter maintained to produce major-worker types, those laid later in the series a disadvantage resulting in successively smaller castes. Major workers are the first to mature as larvae and to spin their cocoons and first to emerge from their cocoons as mature pupae, with degrees of difference to the extreme of the minim workers, which are last in these respects in both *hamatum* and *burchelli*. In the development of an *Eciton* all-worker brood there appears to be a trend toward an extreme emphasis on underfeeding, since the typical curve of body-length variations in the brood population is skewed somewhat toward the smallest sizes. The conditions that influence brood development normally appear to be closely similar for successive worker broods in the same colony or for worker broods of different colonies, judged from our population studies on broods and adult populations.

It is very probable that the emergence of the major-worker type is a strategically important factor which made possible the evolution of these *Eciton* species as terrestrial forms. In the deep forest environment that evidently prevailed throughout tropical America in late Jurassic times, a condition very probably congenial to the evolution of surface-living social insects, there also existed vertebrates like the anteaters and the coatis in particular which might have curbed this emergence of the *Eciton*, except for the appearance of an effective protective measure such as the major workers. Anteaters, and particularly the terrestrially and arboreally active tamanduas, are very numerous in the Barro Colorado forest, yet never have I seen one of them molesting an *Eciton* bivouac. The large and delicate brood inside the exposed temporary *Eciton* nest would be a very palatable find for the tamanduas and no doubt for the coatis also, were it not for these major workers with their formidable bites and stings.

Notwithstanding their effective equipment, the majors, because of their clumsy oversized foreparts and unwieldy mandibles, play a minor role in the normal work of raiding. As they trudge the trails, they are characteristically shunted to the side by the more agile travelers of smaller castes. These last, and particularly the intermediate workers, are the normal killers of prey and carriers of booty. Far from accompanying as "officers," as Belt (1874) thought, and direct-

ing traffic, the major workers often stand around or blunder in the paths of others. But although their function in traffic appears to be mainly negative and indirect rather than specifically directive, it is an important function, since collisions and traffic blocks incidentally play a contributory role in the development of *Eciton* raids and the emigrations which occur as their sequels. Although the major workers never are seen carrying anything, the submajors normally carry larger booty objects, and are particularly effective in carrying the large male larvae when these are present in the colony. On the whole, booty objects are carried, roughly, in relation to size by the workers, with the smallest burdens carried by the minim workers. Workers, major and submajor, as well as the largest intermediates, play a particularly useful role in the construction and maintenance of the bivouac. Because of their long legs and well-developed tarsal hooks, these individuals become strong parts of the substructure in the temporary nest, and normally can hold together under external disturbances such as wind or rain.

It is plain that polymorphic differences in the *Eciton* worker series account for a corresponding relative specialization as in many other ants. The intermediate workers are prominent in activities outside the bivouac and do the bulk of the effective raiding. Because of their size, moderate proportions, and agility they are better suited for ferreting out, attacking, and transporting booty, and laying down chemical trails and traveling on them through varied and difficult terrain, than are the largest and smallest castes. On the other hand, the *Eciton* minors are an asset in transporting and feeding the brood, particularly when it is in the egg and earliest larval stages. When a colony has a brood of eggs or very young larvae, these generally are found in large boluses in the center of the bivouac, surrounded and permeated by minim workers. So these diminutive workers, which presumably received the least amount of food and were most stunted of all in their own larval brood, come into their own as mature workers through being physically best suited for the early transport and feeding of the young brood, a function of critical importance in colony life.

The pillaging activities of the dorylines mark them as a unique subfamily among ants—one with a constant predatory challenge to the environment. Two principal types of raiding pattern are found, exemplified by the column-raiding *Eciton hamatum* and the swarm-raiding *burchelli*, and apparently expressed in degrees of difference through the dorylines. The most arresting and dramatic raids are those of the swarms that are formed daily by *burchelli* colonies (fig. 2). The *burchelli* forays grow much larger than the somewhat similar mass raids of *praedator*, and cause far more commotion in the forest.

For an *Eciton burchelli* raid nearing the height of its development in swarming, picture a rectangular body of 15 meters or more in width and 1 to 2 meters in depth, made up of many tens of thousands of scurrying reddish-black individuals, which as a mass manages to move broadside ahead in a fairly direct path. When it starts to develop at dawn, the foray at first has no particular direction, but in the course of time one section acquires a direction through a more

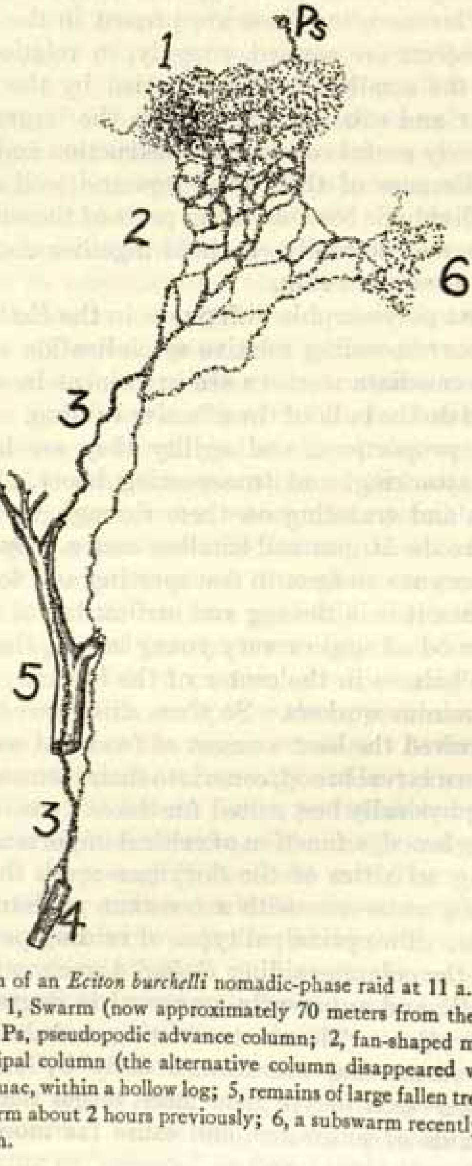


FIGURE 2.—Diagram of an *Eciton burchelli* nomadic-phase raid at 11 a. m., after about five hours of raiding. 1, Swarm (now approximately 70 meters from the bivouac and about 15 meters wide); Ps, pseudopodic advance column; 2, fan-shaped mass of consolidation columns; 3, principal column (the alternative column disappeared within the following hour); 4, the bivouac, within a hollow log; 5, remains of large fallen tree, a spot thoroughly raided by the swarm about 2 hours previously; 6, a subswarm recently formed by division of the main swarm.

rapid advance of its members and soon drains in the other radial expansions. Thereafter this growing mass holds its initial direction in an approximate manner through the pressure of ants arriving in rear columns from the direction of the bivouac. The steady advance in a principal direction, usually with not more than 15° deviation to either side, indicates a considerable degree of internal organization, notwithstanding the chaos and confusion that seem to prevail within the advancing mass. But an organization does exist, indicated not only by the maintenance of a general direction but also by the occurrence of flanking movements of limited scope, alternately to right and left, at intervals of 5 to 20 minutes depending upon the size of the swarm.

The huge sorties of *burchelli* in particular bring disaster to practically all animal life that lies in their path and fails to escape. Their normal bag includes tarantulas, scorpions, beetles, roaches, grasshoppers, and the adults and broods of other ants and many forest insects; few evade the dragnet. I have seen snakes, lizards, and nestling birds killed on various occasions; undoubtedly a larger vertebrate which, because of injury or for some other reason, could not run off, would be killed by stinging or asphyxiation. But lacking a cutting or shearing edge on their mandibles, unlike their African relatives the "driver ants" these tropical American swarmers cannot tear down their occasional vertebrate victims. Arthopods, such as ticks, escape through their excitatory secretions, stick insects through repellent chemicals, as tests show, as well as through tonic immobility. The swarmers react to movement in particular as well as to the scent of their booty, and a motionless insect has some chance of escaping them. Common exceptions, which may enjoy almost a community invulnerability in many cases, include termites and Azteca ants in their bulb nests in trees, army ants of their own and other species both on raiding parties and in their bivouacs, and leaf-cutter ants in the larger mound communities; in various ways these often manage to fight off or somehow repel the swarmers.

The approach of the massive *burchelli* attack is heralded by three types of sound effect from very different sources. There is a kind of foundation noise from the rattling and rustling of leaves and vegetation as the ants seethe along and a screen of agitated small life is flushed out. This fuses with related sounds such as an irregular staccato produced in the random movements of jumping insects knocking against leaves and wood. This noise, more or less continuous, beats on the ears of an observer until it acquires a distinctive meaning almost as the collective death rattle of the countless victims. When this composite sound is muffled after a rain, as the swarm moves through soaked and heavily dripping vegetation, there is an uncanny effect of inappropriate silence.

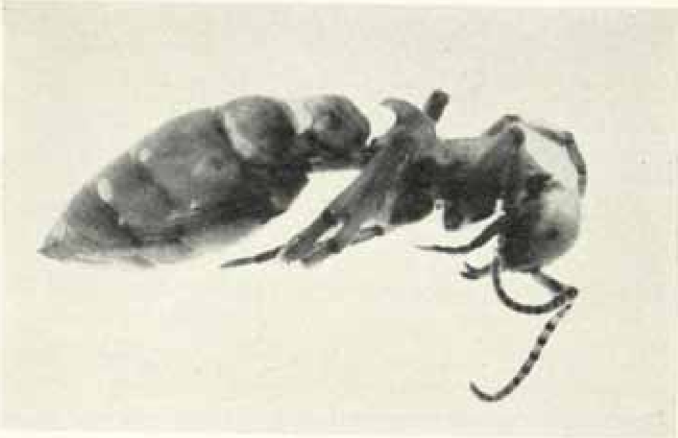
Another characteristic accompaniment of the swarm raid is the loud and variable buzzing of the scattered crowd of flies of various species, some types hovering, circling, or darting just ahead of the advancing fringe of the swarm, others over the swarm itself or over the fan of columns behind. To the general hum are added irregular short notes of higher pitch as individuals or small groups of flies swoop down suddenly here and there upon some probable victim of the ants which has suddenly burst into view. These flies cannot be feeding to any extent, for they rise again instantly. Very probably they are ovipositing on the prey, with their eggs subsequently carried along incidentally into the bivouac where those unconsumed with the booty may develop along with the *Eciton* brood. Now and then, in a laboratory nest containing *burchelli* workers and larvae, I have observed maggots that may be the young of these flies. It is probable that their entire life cycle is intimately intermeshed with that of the *Eciton*.

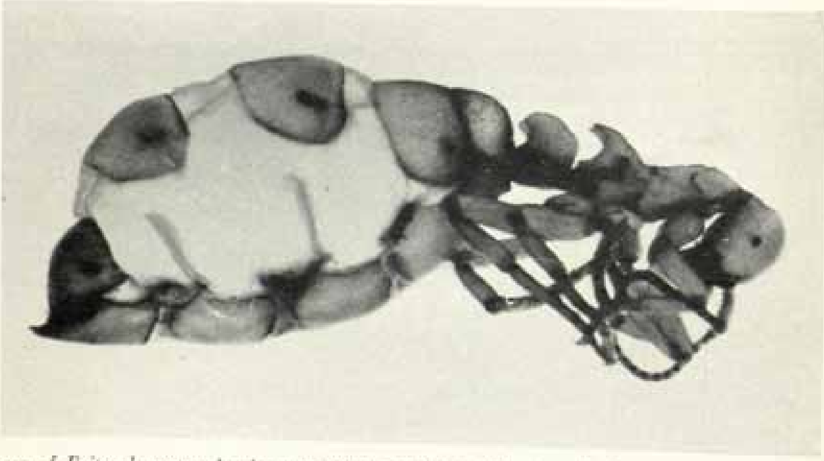
No part of the more prosaic clatter, but impressive solo effects, are the occasional calls of antbirds. One first catches from a distance the beautiful crescendo of the bicolored antbird, then closer to the scene of action the characteristic low twittering notes of the antwren and other common frequenters of the raid. For locating swarm raids these are most useful clues as a rule, since the birds ordinarily are to be heard at or near the scene of action from the time of first morning light when the raid begins. However, the calls are not an infallible clue to the raids by any means, for in the respective mating seasons of the different species, they may be heard almost anywhere in the forest *except* around the *Eciton* swarm raid. In collaboration with our investigation of 1948, Dr. Robert Johnson carried out an intensive behavior study of the antbirds attending *burchelli* swarms (Johnson, 1954). The birds do not feed upon the ants except accidentally—rather they feed on the flushed-out insects which are snatched up by them in quick flight from nearby perches. In between these captures the birds utter a characteristic call. Their music and actions are an inseparable part of this forest phenomenon.

Burchelli raids have the characteristic form represented by an example in figure 2. In the morning, from shortly after its beginning at dawn, the size of the mass increases through a steady stream of recruits from the bivouac entering along the consolidation trail through the fan of columns to the swarm. By midmorning (in the nomadic phase), with the swarm perhaps 90 meters or more from the bivouac and more than 15 meters wide, outgoing traffic has decreased and the principal trail is dominated by a thick procession of returning ants, mainly booty-laden, moving toward the bivouac. The haul—forest invertebrates of many descriptions, fragments of arthro-

1. A typical cylindrical bivouac of *Eciton hamatum* (colony '46 H–D) hanging from a log to the ground. This bivouac appears as it was found, except for some clearing away of vines and rubble around the cluster for the photograph.

2. Closeup of a small portion of cluster wall in a bivouac of *Eciton hamatum*. Note that most of the ants hang head downward, a feature due to the placement of their tarsal leg hooks.





Queen of *Eciton hamatum* in the contracted condition (above) and the physogastric condition (below). The queen is physogastric only for a few days in the early and middle part of the statary phase; otherwise she remains in the contracted position.

pod bodies, and items of insect brood—is rushed along in the clutches of workers in the heavily thronged, 3- to 5-cm.-wide columns. The variety of captures, from tarantula femurs to ant eggs, gives evidence of the wide tribute levied by the swarmers upon forest life.

In his population studies of forest-flora life, Dr. Eliot Williams (1941) was impressed by the capacity of the ecitons to deplete the small life of a raided locality. One day, early in his investigation, when he laid down his quadrat frame on a hill near the Barbour-Lathrop trail, prepared to scoop up the soil and its faunal contents for a biological census, he was perplexed at the paucity of living things discovered. Other trials in the vicinity turned out similarly. The mystery was explained when we compared notes and I recalled that on the previous day an *Eciton praedator* swarm had worked that hillside.

It is difficult to know how extensively the ecitons must cut into the population of small forest life. A *burchelli* colony is capable of heaping more than one measured gallon of booty in just one of its forward-area caches, and by conservative estimate there are 50 colonies of this species on the Island. The inroads of this and the numerous other *Eciton* species must constitute an important factor in the forest balance, operating against a rapid insect progeneration often cited as threatening to man.

Although *burchelli* swarms typically are larger than those of the subterranean *Eciton praedator*, the two species, both common on Barro Colorado Island, are similar in this respect: In both species the swarm advances broadside with alternate "flanking movements" as a rule, wheeling first to one side and then to the other. "Pseudopodic columns" extend similarly from the front and flanks of the mass in both, and in both there is a comparable fan-shaped complex of columns in the rear from which a single consolidation column leads to the bivouac.

Watching the swarm raids, first of all one gains the impression that movement in the mass is utterly confused, with ants here and there clustered in frenzied excitement, fighting and stinging their struggling captives, elsewhere scurrying about or moving in circuitous columns which appear to run in every direction. Nevertheless, appropriate analysis soon demonstrates convincingly that the swarm is effectively organized.

In these respects *Eciton* behavior represents a somewhat unique problem in social psychology, for no animal below man is able to function away from home in organized groups as sizable and at the same time as regular and complex in function as these swarms. For this reason I have found *burchelli* swarm organization worth investigating in some detail (Schneirla, 1940). It can be said that there are no leaders in these swarms except in a very temporary and limited sense, and that

not in the sense of human leadership; but the swarm at any stage is "directed" collectively in a complex manner through the activities of all ants participating in the raid (Schneirla, 1941).

Very different are the raids of *E. hamatum*, which I have studied as an example of the *Eciton* "column-raiding" pattern (Schneirla, 1933, 1938). This species is a frequent sight in the Barro Colorado forest. Operations in its relatively narrow files are marked by large, shiny, white-headed majors and smaller khaki-colored "soldadas," the former colliding frequently, the latter overrun frequently, according to the ebb and flow of traffic in two directions.

This species, also a true terrestrial *Eciton*, builds up and carries through its raids in the daytime, and typically emigrates after dark. In the morning, when one follows along in the direction taken by most of the booty carriers, and takes the correct turn at junction points, other things being equal he may be able to locate the bivouac. There are other cues, useful although far from infallible, such as the fact that the base of a "Y" junction usually is on the bivouac side. If no booty carriers are seen, and the junctions are irregular, the problem is more difficult. In the afternoon, and particularly in late afternoon, booty carriers are likely to be numerous, but usually they seem to be traveling in equal numbers in the opposite directions, and the bivouac seems to be hidden behind a screen of farflung and confused lines of traffic.

The answer is found when the raid is studied as a developing phenomenon. For this the columns must be traced out at regular times during the day, and transitions investigated appropriately. A *hamatum* column raid, like a *burchelli* raid, also generally begins at daylight with radiations in all directions around the bivouac, then soon becomes directionalized. But in this pattern, in the nomadic phase, two or more, frequently three, trail complexes develop, each with its principal trail leading from the bivouac to a peripheral zone of branching columns. The sketch in figure 3 represents one *hamatum* raid mapped at midmorning. Starting from the bivouac, we set out to follow one of the three main routes on which ants hurry to and from the bivouac. Booty-laden ants are almost all returning to the bivouac and for some distance the trail is followed by a single column, unbroken by branches other than short ones in places where the ants continue to raid up trees or in masses of vegetation. Earlier in the morning there were branch columns here in profusion, but most of these dropped from use once the area had been largely worked out. The single meandering base column is likely to continue outward for 50 meters or more, then to have a major division; and in all likelihood whichever branch we follow will have further divisions at shorter intervals as it is traced outward. In effect, the ants have established a complex spreading system of columns resembling a tree, in which a single trunkline from the

bivouac first divides into limb columns, which in turn divide and redivide into branch columns, these finally into twig columns. The twig columns end in small scurrying groups of foragers.

The other main trail systems are similar, each with its base trail, its branching and rebranching secondary trails. They differ only in secondary details concerning the routes and distances, how much outgoing traffic pours into each, and how much booty is returned. All these differences may influence which of these principal routes is to be taken in the eventual emigration of the evening.

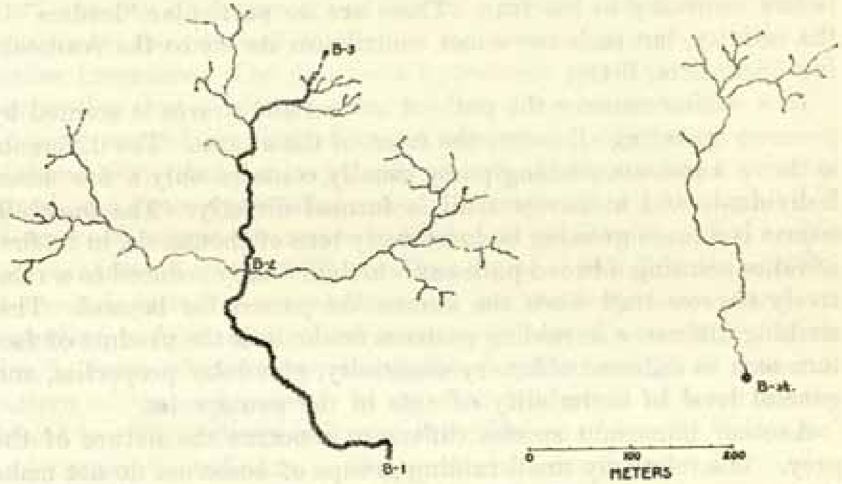


FIGURE 3.—*Left*, raiding and emigration in the nomadic phase: B-1, Wednesday's bivouac and emigration route to B-2, from which a complex 3-system raid developed on Thursday. Thursday evening the colony emigrated about 350 meters to the new place, B-3, from which a similar raid developed on Friday, and so on for 16 days, until the phase ended with the enclosure of the larval brood. *Right*, sketch of a raid in the statary phase, when the colony has an enclosed brood (passing through the pupal state) and is bivouacked in a hollow log or tree. Raids are much smaller than in the nomadic phase. The statary phase lasts 20 days and ends with the emergence of the pupal brood as new workers.

The small groups of ants in the outskirts are the pioneers, first to extend the raid into new territory, first to rush back, exciting ants in the rear, when booty is found. Occasionally each such group divides, as when it grows oversize or a natural obstacle is met, and a forking of the trail results. In the train of each of these "pushing parties" there is a two-way column joining its path with older routes in the rear and eventually with the bivouac, and thus all parts of the system are connected.

The *Eciton* raid travels on scent trails made by the ants themselves—the basis of orientation in all *Eciton* raiding. The existence of a chemical trail on the path followed by every column may be

shown by simple tests such as displacing a leaf or other surface over which the ants run, which always disrupts traffic until the pathway unit is replaced or the break is rescented. The chemical trail is first laid by ants in the advance group, which indicate their entrance into new terrain by crawling slowly forward in a hesitant, meandering way. Each pioneer moves only a short distance beyond the end of the scent trail, but in this excited advance it rubs its abdomen against the ground, reflexly releasing a secretion (anal gland?) which starts a new section of trail. The trail is thus extended in relay fashion by a succession of individuals, each moving out only a few centimeters before returning to the rear. There are no particular "leaders" in the activity, but each newcomer contributes its bit to the roadmaking (Schneirla, 1941).

In a similar manner the path of a *burchelli* swarm is scented by pioneers operating all across the front of the swarm. The difference is that a *hamatum* pushing party usually contains only a few dozen individuals and a narrow trail is formed directly. The *burchelli* swarm is a large growing body of many tens of thousands, in its first advance scenting a broad pathway which is finally reduced to a relatively narrow trail when the swarm has passed far beyond. This striking difference in raiding patterns no doubt is the product of factors such as different olfactory sensitivity, glandular properties, and general level of excitability of ants in the two species.

Another important species difference concerns the nature of the prey. The relatively small raiding groups of *hamatum* do not make the clean sweep of small forest life that the swarmers achieve. Most of the *hamatum* booty consists of soft-bodied insect young, the larvae and pupae of other ants and wasps in particular. Only when their raids are largest and the foragers most excitable do they capture adult insects in any numbers. Normally, the occupants of invaded insect nests may even escape the column raiders by exploding in all directions from the nest exit at the first invasion, carrying their brood off before many of the raiders arrive on the scene. Well after the soldadas have gone, they return. But although the column raiders do not make as clean a sweep as the swarmers and are more selective in their captures, they are far from ineffective. Their multiple treelike systems usually cover an area up to 200° around the temporary nests to a distance of 300 meters or more, and great amounts of booty are taken. In all probability, it is the fact that their types of prey are largely different and competition only partial in this respect that has made possible the coexistence of these two species of wide-ranging carnivorous ants as terrestrial forms in the American Tropics.

There are two scenes that recur most vividly in my reminiscing about army ants. One is a great swarm raid in full swing with ant-

birds flitting about and calling from underbrush perches; the other is that moment near the end of a nighttime emigration when a previously monotonously plodding column begins to show an excited rushing about of workers, indicating that at last the queen is about to pass. The problem of *Eciton* nomadism has been a fascinating one to study.

That the dorylines are characterized by a nomadic existence has been known to science for more than a century, particularly from the observations of Savage (1847) on African driver ants, and Bates (1863), Sumichrast (1868), and others on the American forms. But the frequency of occurrence of the emigrations and their causes or, conversely, the cause of failures to move were quite obscure in the earlier literature. The dominant hypothesis was Vosseler's (1905) assumption that a colony moves on when it has exhausted the supply of prey around its temporary nesting place. The suggestion of Müller (1886) that a colony needs more food when it has a growing brood, and hence moves about more, although teleological, was much closer to what now appears to be the actual explanation. But nearly 50 years later it was possible for Heape (1931) and Fraenkel (1932) to conclude from the current literature that the doryline ants move on according to food scarcity and hence are a case of irregular "emigration." From what we now know, the dorylines emerge as a special pattern of true *migration*. In my first few weeks of work on the Island in 1932, findings indicated the existence of specific "nomadic" and "statary" conditions in the terrestrial ecitons, related to active and inactive stages respectively in brood development (Schneirla, 1933). Laboratory and field results increasingly supported a theory of cyclic nomad-statary phases, alternation of these opposite phases depending upon energizing of the worker population by successive broods in their active and passive stages of development (Schneirla, 1938).

Emphasis was first placed upon cross-sectional surveys and upon the study of the major turning points in the postulated cycle. A record of three complete cycles, accomplished by a colony of *E. hamatum* in somewhat more than four months, is sketched in figure 4. The first complete record of a cycle was obtained in 1936. Soon after my arrival early in the evening on August 5, I was fortunate enough to find a *hamatum* colony in bivouac just behind the laboratory, near Snyder-Molino 2, then in deep forest. From their almost concealed cluster located far beneath a large log, the ants were found at dusk pouring out in a single heavily thronged column in which were seen large numbers of newly emerged callow workers. Masses of callow workers were seen in the bivouac walls, and a considerable number of cocoons remained unopened. Almost all the cocoons had been opened that night before the colony completed its

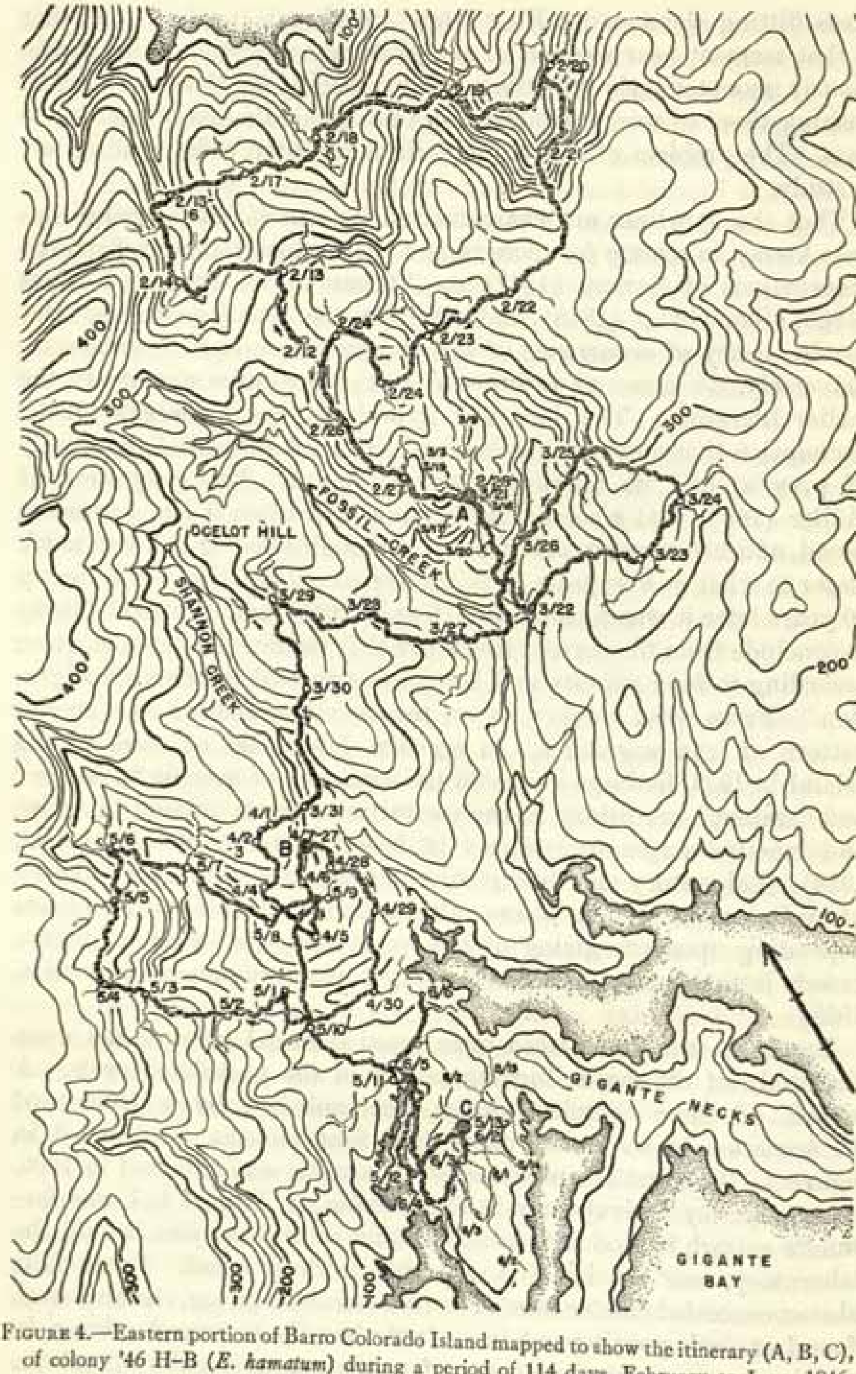


FIGURE 4.—Eastern portion of Barro Colorado Island mapped to show the itinerary (A, B, C), of colony '46 H–B (*E. hamatum*) during a period of 114 days, February to June, 1946. Double circles indicate successive statary sites; small circles indicate nomadic sites; double broken lines indicate successive routes of emigration; dotted lines indicate the principal routes of some of the daily raiding systems. Contour interval, 6.1 meters. Scale: length of the arrow indicating north-south direction (lower right corner) 300 meters.

movement to a site in Lutz Creek, and a great heap of empty cocoons around the vacated spot indicated that the colony had opened most of its brood at this place. Another clue to a long occupancy of the site was a whitened circular area on the rock exactly where the bivouac base had rested, evidently caused by the protracted action of *Eciton* chemicals.

Next day the colony developed three extensive trail systems in a large raid in Lutz Valley. In the evening it emigrated over the principal trail of the central system and before 11 p. m. had mainly completed its new bivouac across Donato trail. This pattern of large daily raids and nightly emigrations was repeated during the next 17 days (a nomadic phase of 18 days), in which the colony moved in an irregular course to a site near Barbour-Lathrop 12. In the meantime a large new brood attained its full-term development. At the last nomadic site the spinning of cocoons by these mature larvae was in full swing, a process greatly assisted by workers laying the larvae on wood detritus and shifting them about at intervals (Beebe, 1919). Next day the first processes of enclosure seemed to have been completed for most of this brood. Now, clustered deeply under a large log on the hill east of Barbour-Lathrop 12, the colony remained for 19 days, a "statary" phase which coincided with the pupation of the current brood. Between August 24 and September 11 the bivouac shifted only about 25 centimeters farther beneath the great log. Daily raiding was always much less vigorous than in the nomadic phase, indicated by the use of only one trail system each day rather than two or or three as in the active phase (fig. 3). Each day after dusk the ants were found retreating into their bivouac, generally issuing in some other direction on the following day. In this way the colony "boxed the compass" in its successive raids from the statary site and managed to strike most sections of a circular area approximating 300 meters in radius.

These facts, first of all, oppose the hypothesis that colonies of this doryline species are forced to emigrate when they have exhausted the prey in a given area. For example, two days after this colony had left its site near Barbour-Lathrop 3 after a one-day stand, another *hamatum* colony stopped nearby and remained there 20 days, raiding in the area as it passed through a statary phase. If there was booty enough in this area to hold the second colony for that number of days, it is difficult to understand the moves of our record colony to its last two nomadic sites as based on scarcity of prey. It is similarly difficult to believe that the booty supply in the vicinity of the statary site was more plentiful than in other localities at which the latter colony remained only for a one-day stand in its nomadic phase—certainly not seventeen times more plentiful.

On the other hand, at the beginning of the study there was a precise coincidence between the emergence of a callow brood and the beginning of a nomadic phase of maximal activity and regular emigration; later the maturation and enclosure of a larval brood coincided with the passing of the colony into a statary phase of minimal raiding and no emigration; finally the colony entered a further nomadic phase when the latter brood emerged as callow workers. On the last day at the second statary site, circumstances were closely equivalent to those at the site vacated when the study began. On this day the colony staged a large 3-system raid, the mature pupal brood was released from cocoons, and the colony moved to a new site at the day's end. On the second emigration of this new phase, it was discovered that the colony had a new brood of very young worker larvae. It had come full circle in just 37 days after leaving the first site.

This coincidence of events in colony behavior and brood condition has been established as the rule not only for *E. hamatum* and *burchelli*, but also for related species. Surprisingly enough, the described nomadic-statary cycle occurs throughout the year, in both rainy and dry seasons, with an unbroken succession of overlapping broods and correlated activity cycles. This was confirmed by studies of 31 *hamatum* colonies and 19 *burchelli* colonies for various lengths of time in the dry season and early rainy season of 1946 (Schneirla, 1949) and of comparable series in these species for various lengths of time in a study extending from the late rainy season of 1947 through most of the dry season of 1948 (Schneirla and Brown, 1950). Colony '46 H-B of *E. hamatum*, while on record from February 12 to June 5, 1946, completed three full nomad-statary cycles and began a fourth (see fig. 4), as follows: Cycle 1, nomadic 16 days, statary 21 days, total, 37 days; cycle 2, nomadic 17 days, statary 20 days, total, 37 days; cycle 3, nomadic 16 days, statary 20 days, total, 36 days. This study ended after a further series of four nomadic days. In the course of the 49 observed emigrations in these three complete cycles, the colony moved from the area north of Barbour trail to the area of Gigante Point on the opposite side of the Island, an overland distance of 2 miles, and a total distance of somewhat more than 5 miles traveled in the successive emigrations. Throughout this entire time the correspondence of changes in colony activities and brood condition was exactly as we have described it for the colony studied in 1936. There was only a secondary difference in the duration of the phases, which in *hamatum* are most frequently 17 days in the nomadic phase and 20 days in the statary. *E. burchelli* is somewhat more variable in its nomadic phase, varying from 11 to 15 days. The statary phase of this species is less variable than the nomadic, with a mode of 21 days.

None of the hundreds of colonies in this species which have been studied at various times of year in these investigations has failed to show the described correspondence between brood condition and the colony activity pattern, with the exception of one natural case in which the queen had died and all semblance of the normal pattern characteristic of the species had disappeared. Such cases may be not infrequent, but extinction must be rapid, as indicated by our tests. Without further broods, as our field experiments show, regular nomadic function disappears in a colony, and the only way in which the worker population can be saved is by fusion with another colony of the species.[1]

The timing device of these recurrent and surprisingly regular cycles is no external event such as the lunar phases which influence rhythmic behavior in many other animals. Rather it lies within each colony, in the casual relationship between brood condition and colony behavior. An active larval brood as it grows provides more and more tactual and chemical stimulation to the adult workers, who are correspondingly responsive. (The nature of the intimate stimulative relationship normally prevailing between workers and brood has been demonstrated in laboratory observations and tests.) The brood thereby energizes the colony in an accelerating manner during its larval development. A great raid then ordinarily occurs each day, leading by complex stages into a colony emigration sometime after dusk. However, the essential increment of social stimulation vanishes abruptly when this larval brood matures and becomes enclosed in cocoons, and without it the level of colony excitement falls to a new low at which raids are always too small to provide a basis for emigration. Each statary phase ends when the emergence of a mature pupal brood as highly active callow workers suddenly raises the colony excitation level to a point at which the large daily raids and emigrations can occur. The hordes of newly emerged workers lose their initial excitatory effect after a few days of further maturation, whereupon they behave essentially like ordinary adult workers; however, in the meantime a new larval brood has reached a condition of high stimulative potency, so that a nomadic colony function continues without a break until this brood in its turn is mature, and so on.

Thus the key to periodic emigration evidently lies in the fact that when the colony is overstimulated with sufficient intensity and persistence, the population responds to environmental excitation at a high level of energy and participation. Each morning the initial stimulus

[1] After the queen has been absent for more than a few hours, fusion can occur when the colony crosses paths with another of its species. This event throws interesting light on the normal adjustments of workers to the colony queen and upon the unifying effect of her odor in the colony (Schneirla, 1949).

to exodus is provided by daylight, but the invasion of the environment cannot exceed the low statary level unless an active brood provides the essential stimulative increment. During the morning the outgoing rush is diverted into trailmaking, capturing and transporting booty. It is normally depressed at midday in a kind of general "siesta effect," perhaps attributable to a combination of radiation, heat, and desiccation (Schneirla, 1949). When this temporary lethargizing effect disappears early in the afternoon, the exodus again bursts forth, but now advances rapidly along one or more of the established channels (Schneirla, 1938, 1944b), gaining such headway that no normal or accidental extrinsic or intrinsic change can halt it more than temporarily. Theoretically, the beginning of a raid in the morning marks the start of an emigration, but trail conditions and internal colony conditions are not propitious for a continued exodus until late afternoon. Then, when failing light at dusk brings raiding activity to a halt, foragers drain into the trails and actually augment the force of the exodus already under way. When this exodus has been completed by resettlement in a new place, the colony remains moderately quiet in the bivouac until daylight again acts upon it.

These statements are derived from studies of the terrestrial *Eciton* species. It is probable that the fundamental principle of brood stimulation as a hyperenergizing factor also applies to the subterranean species, doubtless with certain secondary variations in the mechanism.

The nomadic "instinct" in these terrestrial army ants thus finds its basis in the dynamic, reversible, and repetitive relationship between reproductive processes and social behavior. Since the stimulative effect of the broods is the driving factor in the process, the *Eciton* cyclic pattern rests first of all upon the queen (pl. 2)—source of the immense broods. This curious individual is much larger than her sterile sisters, the workers, and wingless throughout life (Gallardo, 1920; Wheeler, 1925). The queen of *Eciton hamatum* is capable of producing more than 40,000 eggs in a single batch, all of them laid within about one week midway in each statary phase. In the *burchelli* queen, which produces even larger broods, Hagan (1954) has found a total of about 2,400 ovarioles, each judged capable of producing 20 or more eggs in a series. Since every brood is produced as a unit and is laid within a few days, its members pass through their successive developmental stages and reach full maturity almost in step. These are basic facts for the occurrence of the cycle.

Since the turning points in the colony activity cycle are correlated in a relatively precise manner with major changes in brood development, the pacemaker function must somehow depend upon whatever sets the queen at regular intervals from a resting condition to a further prodigious feat of egg production. The idea of an attunement

to some rhythmic environmental event such as lunar cycles at first seems attractive; however, in neither of the established *Eciton* species does the rhythm show any identifiable coincidence with any environmental periodicity. Moreover, numerous colonies studied simultaneously in 1946, 1948, and 1952 passed concurrently through very different stages of the cycle. This turns our attention to the organic process itself; however, the idea of a purely visceral rhythm or some other regular organic process endogenous to the queen as pacemaker has been weakened by evidence of her close dependence upon the external situation of the colony.

The nature of the controlling event has been clarified by studies of brood-adult relationship in the colony in relation to changes in the queen (Schneirla, 1949). When each successive brood approaches larval maturity, the social-stimulative effect of this brood upon workers nears its peak. The workers thus energize and carry out some of the greatest daily raids in the nomadic phase, with their byproduct larger and larger quantities of booty in the bivouac. But our histological studies show that, at the same time, more and more of the larvae (the largest first of all) soon reduce their feeding to zero as they begin to spin their cocoons. Thus in the last few days of each nomadic phase a food surplus inevitably arises. At this time the queen apparently begins to feed voraciously. It is probable that the queen does not overfeed automatically in the presence of plenty, but that she is started and maintained in the process by an augmented stimulation from the greatly enlivened worker population. Within the last few days of each nomadic phase, the queen's gaster begins to swell increasingly, first of all from a recrudescence of the fat bodies, then from an accelerating maturation of eggs. The overfeeding evidently continues into the statary phase, when, with colony food consumption greatly reduced after enclosure of the brood, smaller raids evidently bring in sufficient food to support the processes until the queen becomes maximally physogastric. These occurrences, which are regular and precise events in every *Eciton* colony, are adequate to prepare the queen for the massive egg-laying operation which begins within about one week after the nomadic phase has ended.

My theory, therefore, is that the queen is set off into each new reproductive episode in a feedback fashion by inevitable events in the colony activity cycle. It is a striking fact, however, that the instigating factor itself is an indirect outcome of events depending upon the queen's own function at an earlier point in the cycle.

Interestingly enough, this complicated set of events works out so that when the colony is emigrating nightly over a lengthy, rough, uneven route of 200, 300, or more meters in length, the queen is in a contracted condition and well able to withstand the trials of the

journey. Repelled by bright light, she never leaves the bivouac in the daytime, but is drawn from the cluster in the course of the nightly exodus and must then run the distance with a thick entourage of workers obstructing her variously in the frenzy of their excited activities. Throughout the nomadic phase the queen lays no eggs, and is in the condition shown in plate 2, upper, with contracted gaster. Tough exoskeletal armour plates, now overlapped closely, protect the vital part of her abdomen, and her powerful legs carry her over the most uneven paths, easily overcoming physical impedances in the difficult route despite being trammeled by her pellmell retinue of workers.

When the queen reaches one of the periodic climaxes in her existence and is delivering the enormous mass of eggs that she then produces, her gaster is so greatly distended with maturing eggs that the exoskeletal plates are forced far apart and the intersegmental membranes are tightly stretched between segments. Her gaster then may become 22 mm. or more in length (equal to her total body length in the contracted condition) and very bulky. Although the tightly stretched membranes of her gaster are very tough and tests show that the queen is able to walk about even when physogastric, carrying workers, undoubtedly a long run in an emigration would prove to be a great risk. But at such times, when the queen's condition makes her exceedingly vulnerable to jarring or abrasions, the colony is passing through a statary phase and no emigrations occur. The queen then remains at the center of a quiescent mass and has at least a week for undisturbed recuperation in the bivouac after the eggs have been delivered. This is all the more remarkable because it is an indirect outcome of her own rhythmic physiological processes.

Although most of the workers must have relatively short lives, our studies on Barro Colorado show that the normal function of a colony queen may be a long one. We have been able to keep queens on record by marking them permanently in a distinctive manner. With iridectomy scissors, one or two minute triangles of cuticle are cut from the edge of abdominal sclerites. The cut edges soon darken, so that the queens can be recognized readily when they are removed from their colony. Many recoveries have been made after several months, and a few after one year. The longest record thus far is that of a *hamatum* queen (colony '48 H–15), marked on December 23, 1947, and reidentified by means of her unique mark on April 3, 1952, nearly 5 years later. She was in vigorous condition and carrying out a normal reproductive function late in May 1952, when her colony was last seen. This queen therefore had a functional life of at least 4½ years, in which an estimated total of 45 broods (probably more than 1,800,000 individuals) had been produced. In 45 nomadic phases, with 16 emigrations each on the average, it is estimated that her colony traveled

at least 70 miles during the interval between marking and recovery. How much longer this queen may have functioned before the intervention of supersedure or normal death cannot be said.

How new colony queens are produced in the dorylines was a long-standing mystery (Wheeler, 1913, 1925). The specific solution for ecitons was obtained mainly through work on the Island. Almost all the broods produced at regular intervals in the colonies throughout the entire year are all-worker broods; however, at long intervals smaller broods of many males and a few queens are produced. Such broods arise most frequently in the first third of the dry season, apparently resulting from the initial effective impact of dry weather upon the queen (Schneirla, 1948, 1949). Apparently on Barro Colorado only a part of the colonies produce such broods in any one season. As an example, in a total of 52 colonies of *Eciton hamatum* and *burchelli* studied on the Island during 6 months in 1947–48, only four were found with sexual broods. These broods contained no workers, but only males and young queens (Schneirla and Brown, 1950, 1952). It is probable that the queen lays the usual number of eggs in such cases, mainly infertile eggs, but that in the early stages their number is greatly reduced. The total of individuals matured is roughly 1,500 males in *hamatum* and about twice that number in *burchelli*, with indications that only about six of the young queens emerge as callows. The normal nomad-statary process continues in a regular manner throughout the period of sexual-brood production, essentially as with a worker brood. The one difference is that the nomadic phase is shorter by nearly one week, depending upon a shorter period of larval development in sexual than in worker broods.

Through long-term studies on the Island, we have established the fact that a two-way colony division is the normal outcome of the production of a sexual brood by an *Eciton* colony. This process was investigated in detail on colony '46 B–I (Schneirla, 1949), colonies '48 H–12 and H–27 (Schneirla and Brown, 1950, 1952) and colony '52 B–I, which were studied through periods of 3 months or more in each instance, and in still other cases as well in the different years. Our results indicate that the sexual brood, from its early larval stage, has a strong attraction for a considerable section of the colony. Tests show that this unique attraction is based upon the distinctive odor properties of this brood. The effect leads to a counterattraction competing more and more widely with the drawing power of the regular queen, so that her position in the colony becomes somewhat ambivalent for large sections of the workers.

Colony division thus evidently develops through conflicting odor attractions which arise even while the colony still operates as a unit. The division process is more apparent when the fully developed young

queens emerge from their cocoons and receive the differentiated responses of workers, and it becomes an actuality when the males emerge a few days later. Emergence of the males sets off a maximum raid, somewhat more vigorous than with an emerging worker brood, and the colony moves off divergently on different raiding trails. Colony division thus may be understood as a special case of the initial emigration of a nomadic phase.

One difficult question concerns the fact that, although about six young queens normally emerge in a sexual brood, colony division never seems to produce more than two daughter colonies. The fact is that ordinarily only one of the young virgins can get established in a daughter colony—or two of them if the old queen is superseded. The entire process, including both the ascendancy of the successful queen and the rejection of the others, seems to be based on worker reactions to queen odors of different strengths and attraction, as well as on possible disturbance effects. As the two new daughter colonies move off divergently, each with its queen, the several unsuccessful young queens and perhaps also the discarded old queen are held behind ("sealed off") by workers in an interesting series of reactions which ends in their seclusion and final abandonment to the elements.

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The Hibernation of Mammals[1]

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[With 2 plates]

Most animals are cold-blooded: in all the invertebrates, and in the vertebrates, except the birds and mammals, the temperature of the body is approximately the same as that of the surrounding medium, rising and falling in harmony with its fluctuations. All animals that live in the sea are subjected to a comparatively small range of temperature variation that is not great enough to preclude an active existence throughout the year. Even in the sea, however, many of the inhabitants of the upper strata and of shallower waters show seasonal outbursts of activity (mainly in connection with reproduction), and the feeding activities of a great number of species are restricted during the colder times of winter. But animals living on land with air as the surrounding medium, particularly those that live outside the Tropics, are subjected to a far greater variation of temperature with the course of the seasons, and have been forced to adopt various means for coping with it. Hibernation is one of them.

In cold-blooded animals the metabolic rate varies, being greatest at high temperatures, and least at low ones. No animal can long withstand a temperature of much over 100° F.; for one thing, the proteins of the tissues are coagulated by great heat—though most animals could not survive even up to the temperature necessary for that to occur. Members of only a few groups, in which there are special arrangements for resisting frost, can withstand being frozen. With the onset of the chill of winter cold-blooded animals must therefore seek out some sheltered spot, to which frost will not penetrate, where they may safely remain until warmer conditions return. But many go further than this and enter into a state of torpidity in which the metabolism is reduced to the absolute minimum consistent with the preservation of life. Most people have at some time seen a queen wasp hibernating, perhaps behind a picture on the wall of an unheated

[1] Reprinted by permission from Discovery, vol. 15, No. 10, November 1954.

room, where it hangs motionless from some projecting shred which it grasps in its jaws, while its legs, wings, and antennae are folded down on the underside of the body just as they were when the insect was a pupa. In many insects there is a special kind of hibernation—*the diapause*—in which the life history is interrupted by the hibernation of an inmature stage. Thus some species pass the winter as eggs; others do so as partly grown or fully fed larvae, or as pupae. The diapause, however, is not necessarily a winter phenomenon. Numerous other invertebrates likewise have their own methods of hibernation; snails, for instance, creep into some sheltered cranny, and shrink as far as possible into the shell after making a door of hardened mucus to close its mouth.

Many of the cold-blooded terrestrial vertebrates similarly hibernate in some protected spot, often underground, where they remain motionless with all their activities reduced to a minimum. It is well known that frogs hibernate, though few people know where or how they do it—in actual fact, they bury themselves in the earth, or in the mud at the bottom of ponds and ditches. Toads and newts generally hibernate on land, tucked away in some crevice underground; one very rarely comes across them, and it is a matter for wonder that so many millions of them can be concealed all over the country every winter without being more frequently discovered. Snakes and lizards, too, are expert at lying up in some underground den where they are safe from molestation. Adders in particular like to take up winter quarters in crevices among the foundations of a dry wall, and when they wake after the winter they may often be seen basking in the early spring sunshine on some favorite warm stone before the growing herbage shoots high enough to conceal them from view.

Even some of the marine fish cease their usual activity in the winter, become torpid, and undertake a sort of hibernation. They are mostly those species that live upon the plankton, the mass of floating "water fleas" and other small animals and plants that swarm in such incredible quantities in the upper strata of the sea during much of the year. The basic organisms of the planktons are the diatoms, minute unicellular plants that start multiplying in countless millions with the lengthening hours of sunshine in the spring. Just as all flesh is grass, so all fish is diatom, for when this outburst of plant growth comes in the spring the herds of copepods and other minute floating Crustacea increase enormously and graze down the rich feeding that is provided for them. Some of the larger fishes—and the whalebone whales, too—are specialized for feeding upon this great abundance of animal life when it becomes available to them, and they filter out the swarming plankton as they swim through the sea water; among the fishes the mackerel and the basking shark may be particularly mentioned here. But

after the brilliant days of summer the mineral resources of the sea necessary for the growth of plants are temporarily depleted, and with the onset of the shorter days of winter the diatoms die down; when they decrease in quantity the exuberance of animal plankton fades away, leaving the filter-feeders short of rations. The teeming shoals of mackerel leave the upper strata of the sea and retire to deeper water where they lie inert waiting for the return of more favorable conditions in the spring. It is then that the fishermen make their great catches of trawled mackerel, sweeping up the shoals that lie torpid near the bottom.

Even the enormous basking shark, that may weigh up to three or four tons, is entirely dependent on the plankton for its sustenance. Throughout the summer months it basks in the sunshine of the upper strata of the sea, cruising along at about two knots and filtering out many tons of plankton from the sea water as it slowly forges ahead with its mouth wide open; thus the plankton is left stranded in the pharynx on the elaborate arrangement of gill rakers carried on each of the gill arches. But when the summer outburst of plankton dies down there is not enough food for these enormous animals, and they disappear from the surface waters. No one knows where they go, but recent research has thrown much light upon their probable whereabouts.

It was long believed that basking sharks migrated to distant or deeper waters during the winter of the temperate regions, in spite of the fact that specimens are occasionally stranded or sighted even during the depths of winter. Within the last few months new and startling information has been reported upon this subject. Careful investigation of a number of winter-caught basking sharks has shown that they do not possess gill rakers—that they are, in fact, without the means of obtaining their characteristic food. It is evident that with the approach of winter the basking shark sheds its gill rakers so that it is thereafter incapable of feeding, and that a new set of rakers slowly develops during the winter to erupt like another dentition in the spring. It is thus almost certain that the basking shark hibernates during the winter, as it cannot feed and is therefore incapable of any sustained activity. At this time of the year it probably retires to deeper water—perhaps seaward of the Continental Shelf—and then, like the mackerel, it proceeds to lie on or near the bottom in a state of torpidity with all its metabolic processes reduced to the absolute minimum; there it stays until the next year's crop of plankton provides a pabulum which its newly grown gill rakers can collect.

Parker and Boeseman have recently shown that when the plankton is reduced to its minimum during the winter there is not enough of it in each cubic meter of water to supply the energy necessary to keep

a basking shark swimming at even the slowest speed at which it can filter its food out of the water—if a shark were to continue feeding during the winter it would lose on the deal, for the energy produced by the plankton it could obtain would be less than that expended in the effort of collecting it! The shark therefore throws its gill rakers away, descends to the bottom in some quiet spot, becomes more or less torpid, and probably uses the stores of oil accumulated in its enormous liver as the source of energy to maintain a minimum level of vital processes until next summer when its feeding grounds are restocked.

It is, however, by no means certain that during the winter the shark draws upon the oil stored in the liver; there is justification for skepticism about this physiological question after the discovery that hibernating amphibians and reptiles do not utilize what appear at first sight to be their obvious reserves. In these animals a deposit of fat accumulates when they are not hibernating; it is laid down in special organs known as the "fat bodies," which are situated in the abdomen near the sex glands in the amphibians and near the under wall of the abdomen in the reptiles. But the energy needed to maintain the reduced metabolic rate during hibernation is derived not, as might be expected, from the stores in the fat bodies which appear to be reserved for the activities of breeding, but from the glycogen stored in the liver and muscles.

A BIRD THAT HIBERNATES

Most of the warm-blooded animals are able to meet adverse conditions without hibernating. They are well covered with fur or feathers to keep out the cold, and are able to find sufficient food to maintain their metabolism at its full level even in the depths of winter. Until recently it was believed that no bird hibernated, in spite of the ancient legends about swallows lying dormant conglobated in the mud at the bottom of ponds; the insectivorous species whose food disappears in winter nearly all migrate to regions where it may still be found. But since the war an American naturalist has discovered one of the most startling facts to be reported in ornithology during the last hundred years—he has found a bird that undoubtedly hibernates. Far away in the Chuckawalla Mountains of the Colorado Desert of California at the end of December 1946, he came across a specimen of a species of nightjar, Nuttall's poorwill, hibernating in a state of torpidity in a rock crevice of a deep canyon among the hills. The poorwill is an insectivorous summer migrant to parts of the southern United States whence it departs at the onset of winter to regions unknown. The new observations show that it does not go to the happy feeding grounds of the Tropics where insect food abounds at all seasons, but it gives up the struggle for existence and takes the

soft option. The bird found in the mountain canyon was sitting inert in its shelter, its respiration and heart rate reduced to so low a level that they could not be detected with the portable apparatus available in the field, and its temperature down to more than 40° F. below that normal for its active state. A ring was placed upon this bird's leg so that it could be identified, and for four successive winters it was found dormant in the same niche of refuge.

THE NOCTURNAL TORPIDITY OF HUMMINGBIRDS

Although the poorwill is the only bird that is definitely known to hibernate, there are others that go some way toward the reduced state of metabolism characteristic of hibernation. The hummingbirds that are the incarnation of activity during the heat of the tropical day relinquish their intense metabolic activity when they go to roost; their temperature drops and their rates of respiration and heartbeat fall—and this happens in some species not only when they sleep at night but even when they perch for an extended period during the hours of daylight. The metabolic rate of animals varies inversely with their size; the larger the slower. The daytime resting metabolic rate of those species of hummingbirds in which it has been measured is higher than that recorded for any other animal, and during active hovering it is about six times greater than the rate at rest. But during the nocturnal period of torpidity it falls to about one-twelfth of the resting rate, and the birds become cold, immobile, and incapable of flight.

The hummingbirds are not the only kind of birds that enter into a spell of torpidity when they are not in active movement. Dr. David Lack has recently shown that nestlings of the common swift become torpid when weather conditions are such that their parents cannot obtain the supply of insects necessary for feeding their broods; their temperature falls and they enter upon a state similar to the hibernation of the poorwill until more favorable conditions return. The nestling swift can withstand many days of fasting that would be fatal to the nestlings of most birds, and while it is denied the usual source of food its weight steadily falls as it uses up the energy obtainable from its tissues to maintain the bare minimum rate (the *basal rate* as it is called) of metabolism. It is particularly significant that the ornithological systematists have, on purely morphological grounds, classified the swifts, nightjars, and hummingbirds as closely allied families. The ornithologist who investigates the metabolism of the common European nightjar during its daytime period of inactivity will probably obtain some very interesting results.

Very few mammals hibernate, and it is peculiar that among the exclusively insectivorous ones most of the bats, which during the winter

must either migrate, starve, or hibernate, take the last alternative, whereas they might have been expected to choose the first, seeing that they are the only mammals capable of powered flight. A few species of bat, particularly in America, do migrate southward in the winter, but the majority of those inhabiting the temperate regions hibernate; nevertheless, their hibernation is by no means so complete as was once thought, for many species wake up at intervals and not only move about in the caves in which they pass the winter but go outside and fly from one shelter to another.

DORMICE AND HEDGEHOGS

A hibernating mammal like the dormouse rolls up into a ball when it becomes torpid, the head being bent down so that the chin rests on the abdomen. The hind feet are curled forward about level with the nose, and the hands, clinched into fists, are held either under the chin or alongside the cheeks. The eyes and mouth are tightly closed, the ears folded back downward close to the surface of the head, and the tail is tucked forward between the legs, its tip wrapping over the face and back. The body temperature is so low that the animal feels cold to the touch, and the muscles are held rigid so that the creature can be rolled along a flat surface without disturbing its pose. Dormice hibernate from September to April, but their sleep is not necessarily uninterrupted; their record for continuous sleep is 6 months and 23 days. Hedgehogs are much less regular hibernators, and often do not lie up for the winter until the end of the year, so that they may not be torpid for more than 3 months. Bats of the temperate regions vary; some species may hibernate for over 5 months, but here again many of them awake at intervals during the winter.

Hibernating mammals are aroused by warmth; extreme cold may also produce this effect. None of them, however, can normally withstand being frozen, hence the necessity for them to lie up in the protected nest of the hibernaculum where frost is excluded. Although bats make no nests, they hibernate in places such as caves where the temperature is fairly constant and, low as it may be, never drops to freezing. The alpine marmot and many allied species enter upon a true hibernation, but bears, contrary to popular belief, do not. Bears "den up" for lengthy periods during the winter, but they do not become truly torpid, and their normal basic rate of metabolism is maintained throughout their sleep; it is in the winter den that the cubs are born, and there that the mother nurses them for some weeks "licking them into shape." Similarly the badger may lie up for several successive days in extremely cold weather but it does not hibernate in Great Britain—what it may do in northern Europe has not yet been definitely ascertained.

Although hibernating warm-blooded animals are generally unable to withstand being frozen, recent work on the subject has shown that some species at least can be cooled to temperatures a few degrees below freezing point. When this process is carried out under the correct conditions a state of supercooling is attained in which the temperature is below 0° C., and the animal can be brought back to life on raising its temperature with suitable precautions, although it cannot revive spontaneously. But great care has to be taken not to disturb the supercooled state, for even a slight shock causes immediate crystalization of ice to begin throughout the body, and when that has happened completely there is no return. Cooling to spectacular subnormal temperatures, though not to anything approaching freezing, has recently been used as a form of anesthesia for the performance of surgical operations [2]—a technique that appears to be fraught with the greatest dangers in view of our present very inadequate knowledge of this new subject.

In warm-blooded animals the approach of the cold-blooded state of hibernation makes itself felt some time before its actual onset, and the animals react by making provision accordingly. Terrestrial mammals prepare a winter den or burrow of some sort, usually lining it with dry vegetation to form a snug nest; and even among the bats many species leave their summer haunts and withdraw to special hibernating retreats which they do not inhabit during the rest of the year. But hibernation is often interrupted—the dormouse, the marmot, and others, lay up stores of food in or near the nest which are, presumably, eaten when these animals, like the bats, awake at intervals. The onset, too, of winter torpidity is very irregular in many species; in the hedgehog sleep may last for only a few days at a time, with intervals of activity, until the winter is well advanced.

THE LONG LIFE OF HIBERNATORS

In the dormouse, and even more in the bats, normal summer sleep passes some way toward the torpid state characteristic of hibernation, as in the hummingbirds and possibly some others. So great is the difference between the active and resting metabolism in a bat that 1 hour of activity uses up as much food or fat stores as is used in more than 12 hours at the torpid rate. When bats are active their appetites are voracious, and were they active all the time they would, like shrews, need to eat their own weight of food daily. But the long periods of sleep spare them this necessity, and allow for the expenditure of the energy needed during flight, for most insectivorous bats are active for only a few hours at dusk and dawn. And there is a

[2] This technique is described in Chapman Pincher's article in Discovery, vol. 15, No. 10, pp. 443–446, 1954.

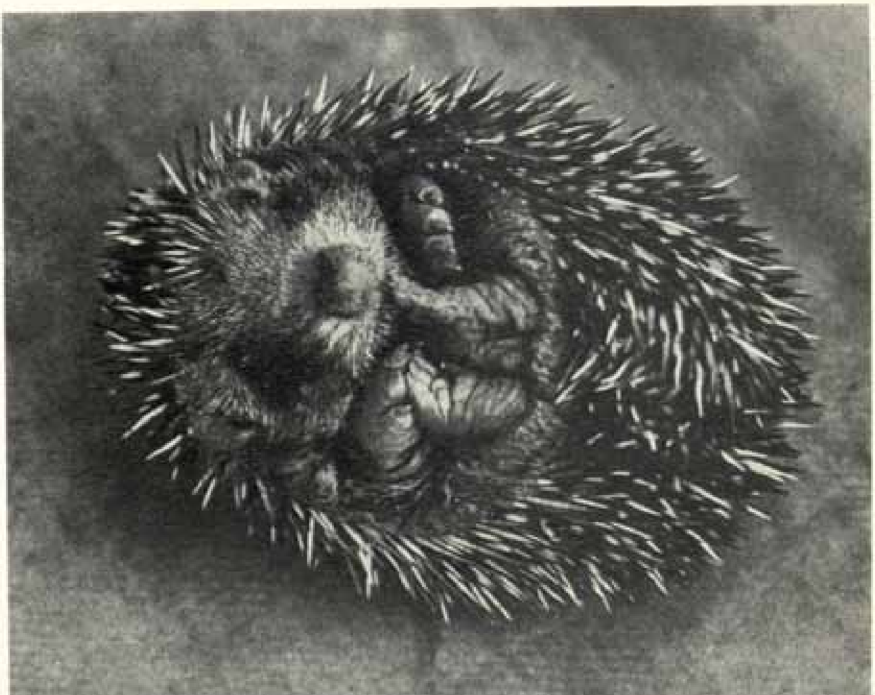
further result: the life span of a shrew is not more than 18 months, but that of a bat of similar size is 7 or 8 years or more. When it is remembered that some species of bat spend up to nine-tenths of their summer life in torpid sleep, and all of the winter in hibernation, it can be readily appreciated that the animal machine will not wear out so quickly as in animals that are active for a higher proportion of the 24 hours all the year round.

Hibernation in a warm-blooded animal is a very much more drastic process than in a cold-blooded one: the animal has in effect to relinquish its temperature regulation and become cold-blooded. All hibernating mammals get very fat before entering on the winter sleep, and the fat deposits not only serve to keep the metabolism going at its reduced rate during the winter, but their presence in the autumn provides, or helps to provide, the stimulus that starts hibernation, though the means by which they do so are not known. Low temperatures and scarcity of food are not the primary causes. Similarly in some kinds of wild bee the young queens that will found the new colonies of the following year start their hibernation almost as soon as they emerge from their brood cells in the middle of the summer; and swifts leave this country on their southern migration in August when the supplies of insect food are the greatest—these things are brought about by the *internal condition* of the animal and not in the first place by the state of the environment.

Mammals have a deposit of dark-colored fat and lymph tissue round the blood vessels in the neck, chest, and elsewhere, in addition to the general fat stores; it is particularly prominent in hibernating mammals. This deposit is large in the autumn but decreases to very small proportions by the middle of the following summer. This "brown fat" has been termed the "hibernating gland," but its functions are obscure, for it decreases in size during hibernation more slowly than the general reserves of fat.

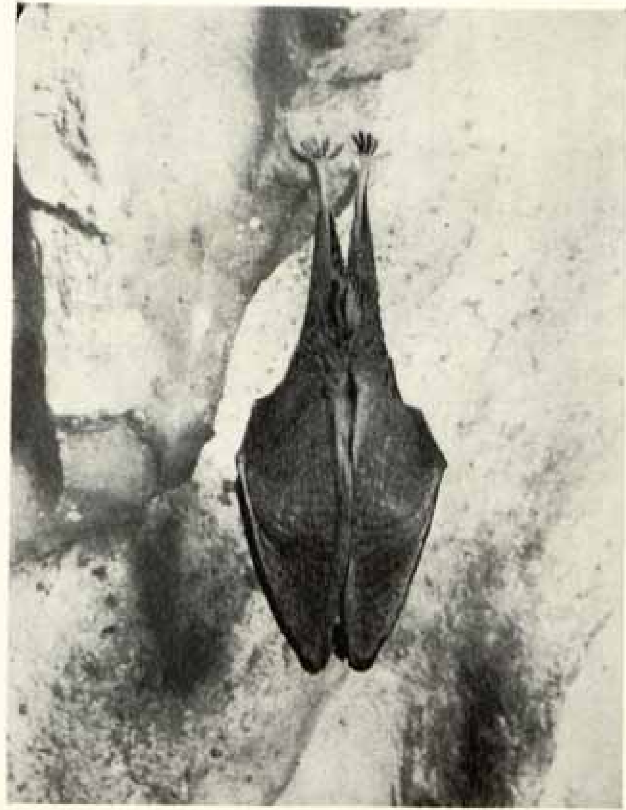
When a hibernating warm-blooded animal becomes cold-blooded and undergoes a decrease in temperature the rate of respiration also decreases. A torpid bat, for example, breaths about 25 to 30 times a minute for some three minutes and then pauses for three to eight minutes without breathing; its normal rate during active periods goes up to about 200 a minute without any pauses. In some species the rate during hibernation is lower still, so that it is very difficult to detect any sign of breathing at all. At the same time the rate of the heartbeat becomes very slow and the circulation is further retarded, in some bats at least, by the spleen swelling up to about seven times its normal volume, being distended with blood and acting as a reservoir for the main bulk of the blood while it is not being vigorously pumped around the body by the heart.

1. Hibernating dormouse.



2. The hedgehog, a less regular hibernator than the dormouse, lies up toward the end of the year and remains torpid for about three months. (Photo by the late A. R. Thompson.)

1. Small clusters of greater horseshoe bats hibernating on the roof of a cave.



2. Characteristic position of lesser horseshoe bat when hibernating or sleeping. It hangs by its feet, with its delicate wings tightly folded around the body. (Photo by J. H. D. Hooper.)

During hibernation the blood itself is altered in composition. Experiments on hedgehogs have shown that in hibernation the amount of sugar in the blood is less than half that present when the animal is active, but the amount of magnesium is more than twice as great. It has further been found that if active hedgehogs in summer are injected with insulin, which decreases the amount of blood sugar and increases the magnesium, and are placed in a low temperature (but above freezing) an artificial hibernation is induced which may last for many days. When such animals are later removed to a warm temperature they awaken in a normal manner and return again to the warm-blooded state.

There seems to be some doubt about the temperature of the body during hibernation, for most observers have recorded very low figures by taking the rectal temperature; but if the temperature of the blood within the heart is measured, an operation that can be done with a small thermocouple mounted in a fine hypodermic needle, much higher values are found. There appears to be a temperature gradient, the extremities being very cold but the center remaining considerably warmer. It is interesting to note in this connection that when nonhibernating animals have been subjected to great cooling, and reduced to torpor, they can be brought back to life only if the heart is warmed first while they are being revived.

CYCLIC CHANGES IN GLANDULAR ACTIVITY

In view of the great changes in the blood sugar during hibernation, and of the possibility of inducing an artificial hibernation by the administration of insulin, it is not surprising that striking cyclic changes have been found to occur in the insulin-producing gland of hibernatory animals—the islets of Langerhans in the pancreas. The pancreas produces a digestive secretion that is poured into the intestine through the pancreatic duct, but in addition it serves an endocrine function. Certain bunches of cells in its structure do not produce the fluid that is conveyed to the intestine through the duct, but manufacture substances that pass directly into the blood and have an effect on other parts of the body at a distance when carried to them by the blood stream. These clusters of cells form the islets of Langerhans, and one of their chief functions is the production of insulin, the substance that has such a profound effect upon the metabolism of carbohydrates in the body—if insulin is deficient in quantity the amount of sugar in the blood rises to an abnormal level which may be so great that the animal passes into a diabetic coma that terminates fatally. During hibernation there is a great hypertrophy of the endocrine tissue in the pancreas, the proportion of insulin-producing cells present being much greater than during the summer. But the islets

of Langerhans are not made up of uniform cells: there are two kinds, one of which is certainly the type that is chiefly concerned with the elaboration of insulin, and it is this type particularly that increases in numbers in the hibernating mammal.

The islets of the pancreas are, however, by no means the only endocrine glands that undergo a cyclic change during hibernation. The thyroid gland in the neck, the cortex of the adrenal glands near the kidneys, and the anterior lobe of the pituitary at the base of the brain, all participate in the changes. Of these the anterior pituitary probably takes first place in importance—it has been not inaptly called the "conductor of the endocrine orchestra" because its secretions have such a profound effect on the activities of all the other endocrine glands. The genital glands, which have an endocrine function as well as their primary one of producing gametes, undergo cyclic changes in the hibernators, as in other animals, but although they are dependent upon the activity of the anterior pituitary it is doubtful whether they play any important part in the phenomenon of hibernation.

All these glands are at their lowest phase of activity in the autumn, but during the winter there is a gradual recovery and in the spring they show a great spurt of development that is closely connected with the onset of the breeding season. As far as the thyroid is concerned this burst of activity is short; it is probable that increased temperature during the summer, and the great development of reproductive activity, are responsible for the regression that the gland undergoes from quite early in the spring. The small related glands, the parathyroids, undergo a parallel cyclic series of changes, but it is probable that they do not undergo any marked functional deficiency during winter. The adrenal is a gland of particular interest and many functions; its outer part or cortex contains a zone (the X zone) that is very greatly developed in hibernating mammals during the autumn and winter until the spring, but becomes so reduced as to be practically vestigial during the summer. The central part of the adrenal, the medulla, also undergoes considerable changes during the year, but no marked cyclic activity that can be correlated with hibernation has been identified. The activity of all these glands takes part in the thermoregulation of the body, but the exact role of each remains yet to be elucidated. It may not be out of place, however, to point out that the "anterior pituitary-thyroid-adrenal axis" is closely concerned with the peculiar "shock disease" that sometimes afflicts whole populations of animals, particularly those of rodents that periodically build up a peak of numbers far greater than the territory that they inhabit can support.

A last point: It has recently been shown that in some hibernating mammals the rate of clotting of the blood when shed is greatly re-

tarded, and this phenomenon has been interpreted as a special adaptation to hibernation. During hibernation the heartbeat is slow and weak so that the circulation rate of the blood is reduced; it is therefore suggested there is a greater risk of thrombosis—the clotting of the blood in the blood vessels—in hibernating mammals than in active ones. During the active state, on the other hand, the blood must coagulate rapidly in order to prevent fatal loss through a small wound. The cylic change in the clotting rate of the blood may well be, therefore, of particular importance to the hibernating animal.

Although the experimental removal of the anterior pituitary, with or without the destruction of the cortex of the adrenal glands, together with the injection of insulin, leads to a condition in which the regulation of the temperature is disorganized, and produces a state resembling an artificial hibernation, the role of the different glands remains very obscure—it is not yet known whether many of the changes in them are the causes or the effects of hibernation. Much still remains to be discovered—and the study of the physiology of hibernation and temperature regulation in the warm-blooded animals is not of academic interest only. It is probable that an increased understanding of the processes involved in hibernation will throw much light on the problem of survival in nonhibernating mammals, including man, when they are subjected to extremes of cold and exposure.

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Parasites Common to Animals and Man[1]

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[With 4 plates]

Of the more than one hundred species of protozoan and worm parasites reported from man, with the exception of those of doubtful status, few are sojourners in *Homo sapiens* exclusively. As a matter of fact, man shares with the lower animals a large number of endoparasites. Some of them are primarily inhabitants of animals and occur in persons only occasionally. Others, however, are in the main human parasites which sometimes occur in, or can be experimentally transmitted to, animals.

Among the parasites of man are species that undergo their entire development in human beings. Others occur in man as adult parasites only, and still others as larval parasites. In either case the life cycle of the parasites falling into these two categories involves an alternation between the human and animal host, the one harboring the adult parasite being known as the definitive host and the other, harboring its immature stages, the intermediate host. Man serves, therefore, as the definitive host for some internal parasites, the intermediate host for others and, occasionally, both as intermediate and definitive host for the same species.

Most of the parasites that find a haven in the human body have been acquired apparently as a result of man's long and intimate association with certain mammals, namely, dogs, cats, and rats, and with animals raised for food and fiber, namely, domestic ruminants and hogs. It is interesting but by no means surprising to note that man apparently has acquired more parasites, especially kinds that have become well adapted to him, from carnivorous and omnivorous animals, whose feeding habits he shares, than from herbivores. Among the parasites that man shares with domestic ruminants are certain nematodes known

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as trichostrongyles, normally acquired by their hosts through the ingestion of forage on which their larval stages may be present. It is not surprising therefore that these parasites are largely accidental sojourners in man, whereas among those he apparently acquired from carnivores and omnivores, some have become so well adapted to him that they are among the more common species he can harbor.

In this paper only a few of the parasites that animals share with man will be considered. The parasites selected for discussion are among the most important ones in temperate regions, including the United States.

HUMAN PARASITES ACQUIRED THROUGH INGESTION OF ANIMAL FOOD

The parasites that man commonly acquires through the consumption of animal food include four species, of which three are cestodes, or tapeworms, and one is a roundworm, or a nematode.

CESTODES

The broad tapeworm.—One tapeworm, commonly referred to as the broad tapeworm, or the fish tapeworm, and known to zoologists as *Diphyllobothrium latum*, occurs as an adult in the small intestine of man, the dog, and certain wild carnivores. In the intestine of man this parasite may reach a size of up to 60 feet in length and about fourth-fifths of an inch in width.

The life cycle of the fish tapeworm involves two intermediate hosts. The first one is a copepod, or so-called water flea, of the genera *Diaptomus* and *Cyclops*, and the second is a fresh-water fish. In the United States the wall-eyed pike, the sand pike, the burbot, and the pickerel, among others, are common second intermediate hosts. The first intermediate host becomes infected by swallowing the free-swimming, microscopic larvae that hatch from the tapeworm eggs in water. The fish or second intermediate host becomes infected by swallowing parasitized copepods in which the tapeworm larvae have meanwhile undergone further development, or by eating smaller fish that have recently ingested parasitized copepods, or by ingesting smaller fish harboring the still more advanced tapeworm larvae, known as plerocercoids, in their viscera and muscles. Man and other definitive hosts become infected with the adult or strobilate tapeworm by eating raw, infected fish. Once the plerocercoid reaches the intestine of man or of another suitable definitive host, it grows rapidly. When mature, the tapeworm discharges enormous numbers of eggs which hatch in water, following a period of incubation therein, into the free-swimming, ciliated larvae.

For the propagation of the fish tapeworm lakes and streams have to be polluted by sewage containing the tapeworm eggs in order to

enable the larvae that hatch from these eggs to establish contact with the first intermediate host. Such pollution apparently has taken place in the Great Lakes region during the past few decades. Finlanders and other northern Europeans in that area who have retained their native fondness for raw or smoked or salted fish in which live plerocercoids may be present have contributed greatly to the pollution of lakes and streams to which infestations with this tapeworm have been traced in this country.

Although it was predicted in 1897 that the fish tapeworm would become endemic in various sections of the upper peninsula of Michigan, where immigrants from Finland, Sweden, and other Baltic countries were working as miners, it was not until 1906 that the first case of this tapeworm in a native American was reported from Minnesota. Before 1906 persons harboring this tapeworm in the United States were foreigners who either brought, or certainly could have brought, this parasite with them from their place of origin in Europe, especially the Baltic countries. In North America endemic areas are Minnesota and Michigan in the United States and Manitoba in Canada.

The beef and pork tapeworms.—The beef tapeworm, known to zoologists as *Taenia saginata*, and the related pork tapeworm, *Taenia solium*, are so-named because the larval or cysticercus stage (known also as a bladder worm) of these two parasites occurs in cattle and swine, respectively. The adult parasite occurs in the intestine of man.

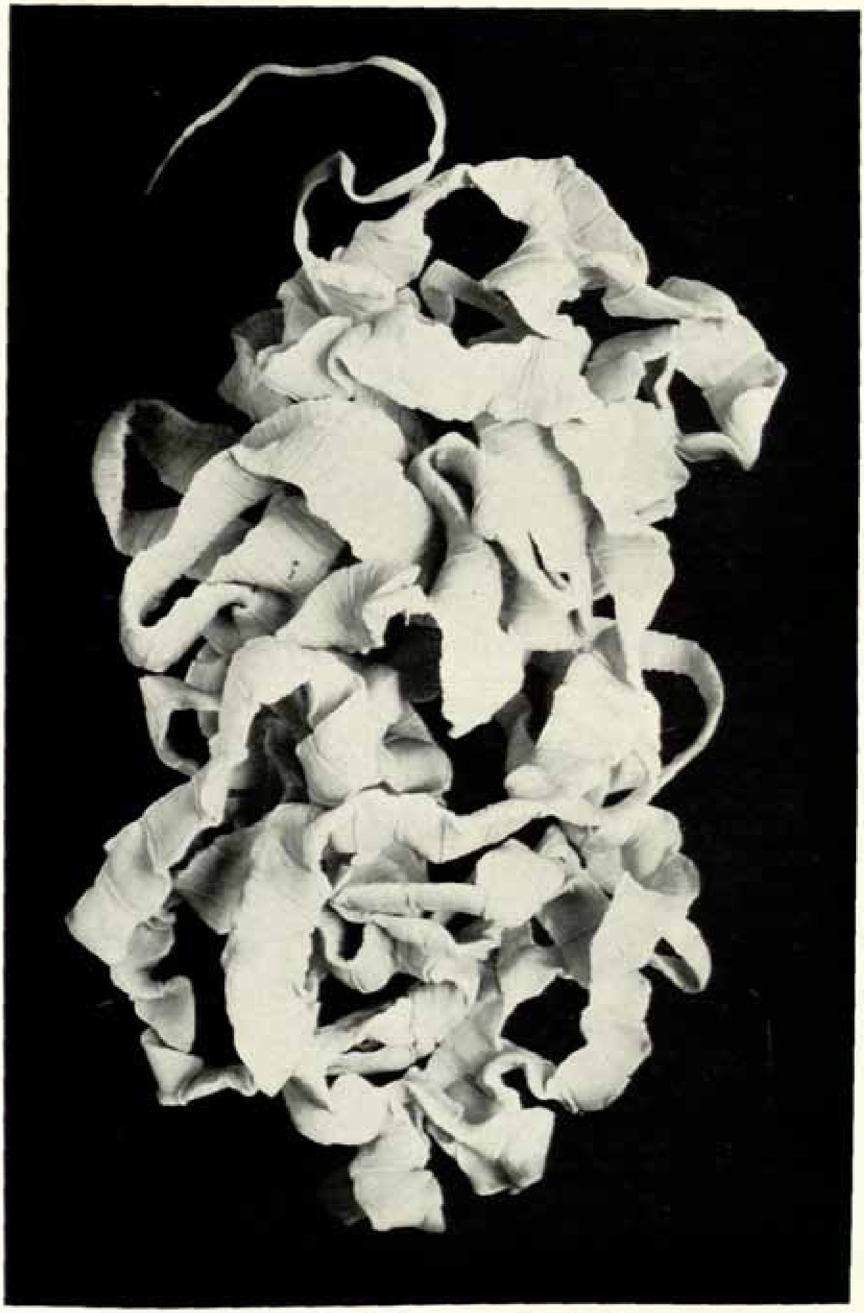
The adult beef tapeworm (pl. 1), which may attain a length of 40 feet or more, consists of a chain of proglottids or segments anchored to the intestinal wall by a so-called head which bears four cup-shaped suckers. It has been estimated that the entire tapeworm colony, or strobila, consists of between 1,000 and 2,000 proglottids. Those farthest from the head are gravid, those nearest to it are immature, and those between these extremes are sexually mature. The gravid proglottids filled with the tapeworm eggs become detached from the rest of the strobila either singly or in small chains and are voided to the outside with the bowel evacuations. If the proglottids reach pastures, barnyards, feed lots, or other places to which cattle have access, the segments disintegrate and liberate the eggs. Cattle are likely to swallow hundreds of eggs and become infected with the cystic stage of the tapeworm. The cysticerci, which sometimes occur in large numbers, localize principally in the muscles of the bovine intermediate host (pl. 2, fig. 1) and develop into bladder worms, ranging from about one-fifth to three-fifths of an inch in length by about half that in width. The thin-walled bladder worm contains a fluid into which the head of the future tapeworm is invaginated.

Nearly a century ago the relation between these bladder worms in cattle and the adult tapeworm in the intestine of man was first determined by rigid experiments carried out in Germany. Before that time bladder worms of all kinds were regarded as aberrant creatures of unknown relationship and were given distinct names by zoologists. The beef bladder worm was called *Cysticercus bovis*, a name that no longer has any scientific validity but is still retained more or less in the writings of parasitologists.

Man acquires the beef tapeworm by eating raw or rare beef infected with bladder worms. When the cysticercus reaches the human intestine, the head of the future tapeworm, already fully formed, becomes everted and attached to the intestine wall, but the bladder is digested. The tapeworm grows by budding off segments in the unsegmented region just below the head, known as the neck. The newly formed segments, which are immature, mature gradually by developing in each a set of male and female reproductive organs. Following fertilization of the eggs by the sperm the internal organs in each segment begin to disintegrate, the proglottid becoming filled with the developed tapeworm eggs each of which harbors a microscopic embryo. Meanwhile new segments are being budded off and this pushes the others down, so that ultimately the egg-filled or gravid segments come to be located in the lowest part of the strobila. It takes about three months for the tapeworm in the human intestine to reach the stage where it produces the gravid proglottids. These become detached from the rest of the strobila and voided to the outside. This continues throughout the life of the tapeworm which may extend for a year or longer.

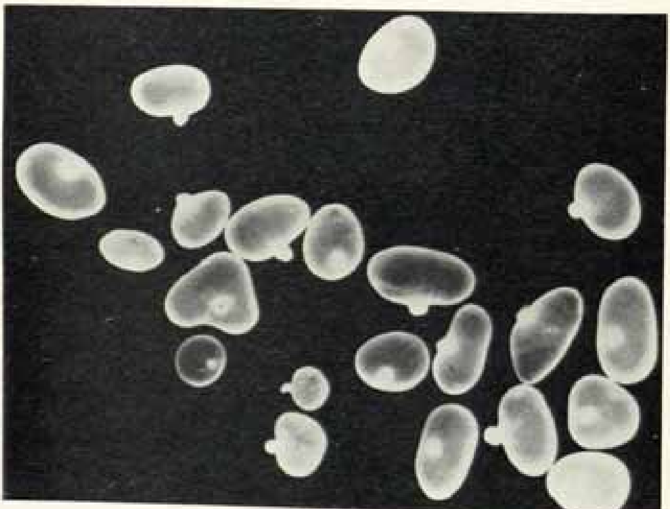
Considering the numerous eggs that a single tapeworm carrier may expel to the outside with the gravid proglottids every day, we can readily see that one such carrier, if he happens to live in a rural community where sanitary facilities are inadequate, can become a source of infection for the cattle that happen to graze, or consume dry feed, or drink water, in an area that has become contaminated with the tapeworm eggs. That contamination of this sort actually occurs in many places in the United States has been shown over and over again, especially where the infected individual happened to be the caretaker in a feed lot where cattle were being fattened.

In Europe the incidence of infestation of cattle, especially calves, with the beef tapeworm appears to be on the increase, according to recent information. In the United States this parasite is not very common in cattle but is present to a sufficient extent to cause more or less serious economic losses to the meat industry. During the years 1948–53 approximately 16,500 to 27,000 beef carcasses slaughtered annually under Federal inspection were found to be infected with

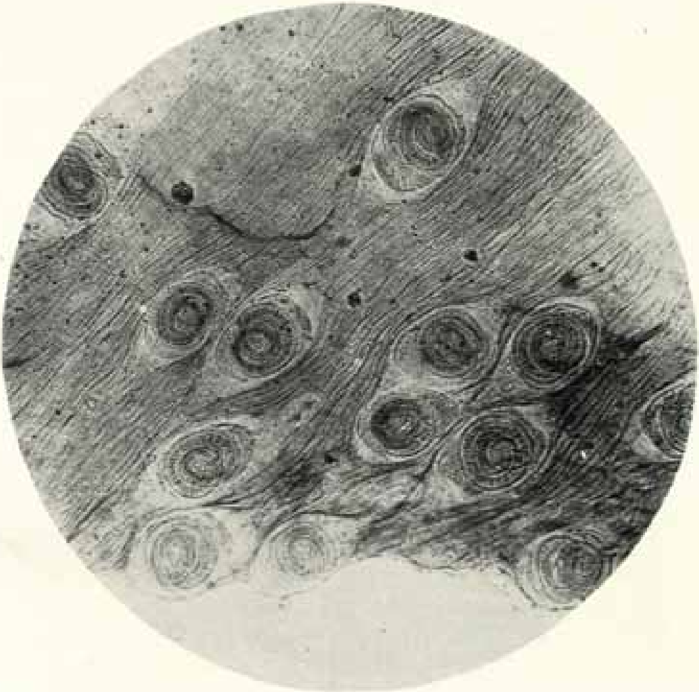


Photograph of the beef tapeworm, *Taenia saginata.*

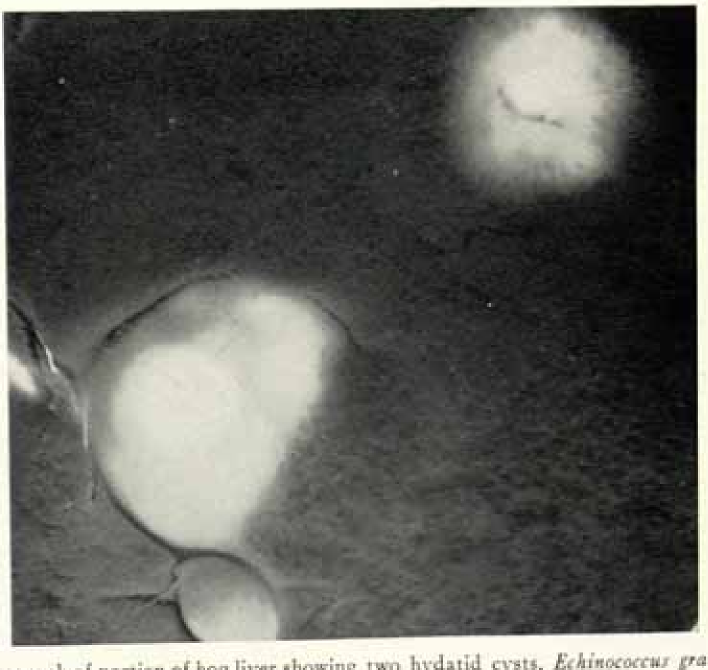
1. Photograph of beef muscle tissue showing several bladder worms of *Taenia saginata* embedded in it.



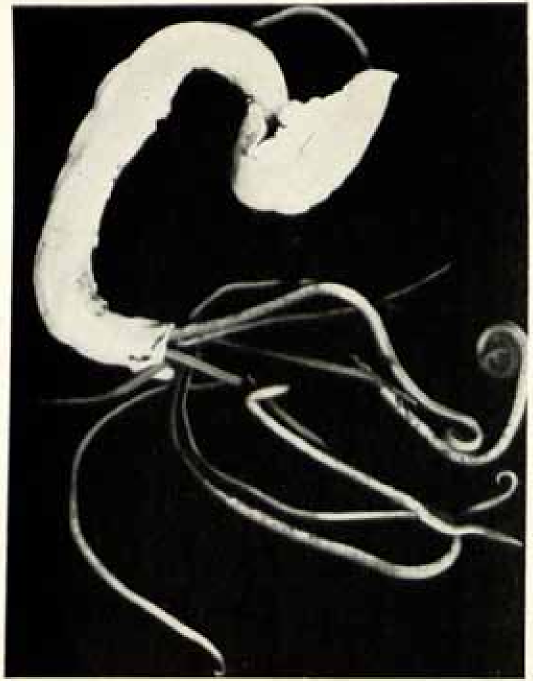
2. Photograph of bladder worms of *Taenia solium* isolated from hog muscle tissue. The heads of some of the bladder worms are extruded and those of others are invaginated.



1. Photograph of microscopic preparation of muscle tissue containing encysted trichinae *Trichinella spiralis.*



2. Photograph of portion of hog liver showing two hydatid cysts, *Echinococcus granulosus.*



1. Photograph of a small portion of a pig's intestine harboring roundworms, *Ascaris lumbricoides* var. *suis*, greatly reduced.

2. Photograph of microscopic preparation of lung containing an *Ascaris* larva in an alveolus or air space.

these parasites out of a total annual slaughter of about 20 million or more head. The latest available figure, for the fiscal year 1954, shows that 17,400 beef carcasses were found to be infected with these tapeworm cysts out of a total slaughter of approximately 26 million bovines inspected.

Inasmuch as the habit of eating rare beef is rather well established in this country and the tapeworm cysts in question are injurious to health, beef carcasses are regarded as unfit for human consumption under Federal meat inspection whenever these bladder worms are discovered in them. If only one dead or degenerated cysticercus is detected, and this often is the case when the parasite is located in the heart muscle, or when only one or a few live cysticerci are found, the carcass is not condemned. After removal with a knife of the cysts that are discovered, such carcass is retained by the inspectors, but before it is passed as fit for human food it must be refrigerated for periods and at temperatures known to be destructive to the cysticerci, or cooked at a temperature that is known to kill these parasites.

The life history of the pork tapeworm of man is essentially similar in most respects to that of the beef tapeworm, except that in this case the hog serves as the intermediate host. In man the pork tapeworm also localizes in the intestine and usually attains a length of only about 2½ to 5 feet or more. It follows the same pattern of development as already described for the beef tapeworm.

The bladder worm of the pork tapeworm (pl. 2, fig. 2) is very common in swine in countries to the south of us, especially Mexico, Peru, and Venezuela. In the last-named country its incidence reaches 20 percent of the hogs slaughtered. The incidence of the adult tapeworm in man in those countries is not known. In the United States this parasite, never very common in hogs as far as known, and consequently uncommon in man, has become exceedingly rare in recent years. During the fiscal year ended June 30, 1954, only 4 hogs out of a total of over 50 million slaughtered were found to be infected, and in the previous fiscal year only 11 infected swine carcasses were found by Federal inspectors out of over 57 million carcasses inspected. During the 4 fiscal years preceding 1953, the average number of infected carcasses was 19 out of a total annual slaughter under Federal meat inspection of about 50 million swine.

All infected swine carcasses discovered by Federal inspectors are condemned. The pork tapeworm is a more serious parasite than the beef tapeworm for the reason that human beings can serve as its intermediate as well as definitive host. An infested individual might accidentally contaminate his hands with the tapeworm eggs, transfer them to the mouth, and so become infected with cysticerci. In human beings

the cysticerci can localize in the heart, the brain, and the eyes. Cysticerci in the human brain can produce a condition resembling epilepsy. Fortunately, very few persons in this country harbor the pork tapeworm. In fact, this parasite is so rare in the United States that it is exceedingly difficult to find a specimen that has been removed from the intestine of man by medicinal treatment.

TRICHINAE AND TRICHINOSIS

Trichinae and the disease trichinosis which these parasites produce are acquired by human beings by eating the raw or insufficiently cooked meat of animals infected with these nematodes. Animals become infected with trichinae in the same way. Since hogs are the only animals slaughtered for human food in this country that are likely to eat scraps of meat, infected pork is the chief source of human trichinosis. The only other possible source of this disease in the Unitd States is jerked bear meat.

Once the infected meat has been ingested, the parasites it contains are freed from their cysts in the stomach by the digestion process. They pass into the small intestine where they develop to mature male and female worms from about 1.5 to 4 mm. long by 0.04 to 0.06 mm. wide, in two or three days. Following the mating of the sexes, the females become deeply embedded in the intestinal lining and begin to bring forth their young a few days later. The new-born larvae, which are about one-tenth of a millimeter long, make their way into the blood and are carried by the circulation to all parts of the body. They penetrate the individual muscle fibers in which they grow for about three weeks and then become encysted there (pl. 3, fig. 1). Unless the parasitized muscle or flesh of a trichina-infected animal is eaten by another susceptible animal or by a person, the encysted trichinae ultimately become calcified within their cysts and break up into crumbled masses, or die without undergoing calcification, and are gradually absorbed.

In their developmental cycle trichinae present a number of some rather unusual features. The same animal serves, first, as the definitive host by harboring the mature parasites in the intestine, and, later, as the intermediate host by harboring the next generation's infective larvae in the muscles. Moreover, the parasites invade not only the gastrointestinal tract, the body fluids, including the blood, and the muscles, but are carried also to the internal organs of the abdominal and thoracic cavities, the central nervous system, and even penetrate the heart muscle. There are a few records of their causing thrombosis in the arteries of the leg, which necessitated amputation of the limb.

Trichinosis is unquestionably the most serious parasitic disease of man in the United States. The wide prevalence of the causative nematode, *Trichinella spiralis*, in our human population, together with

the serious nature of the disease it can produce, has focused attention on trichinosis during the past two decades to such an extent that much of the valuable data brought to light by numerous survey studies sometimes has been misconstrued and misinterpreted. The evidence at hand indicates that one out of six persons, whose muscles were examined postmortem by special techniques that bring to light even very small numbers of trichinae, showed for the most part a light infection with this nematode. There was little or nothing, however, in the medical histories of individuals so infected to indicate that they had suffered from trichinosis during life, even including those in whose muscles relatively large numbers of worms were found. Such vague symptoms as muscular pain or rheumatism recorded in the medical histories of some of the affected persons also were found in those of individuals who were free of trichinae.

The wide prevalence of trichinae in our human population certainly affords evidence that pork is a popular item in our diet; that some of the hogs in this country contain trichinae; and that we sometimes, probably many times in the course of our lives, eat pork that has not been sufficiently processed by heat or in other ways to destroy the vitality of all the live trichinae it may have contained.

So far as known, about two-thirds of 1 percent of our farm-raised hogs are infected with trichinae, and the intensity of the infection apparently is very low. In very few of the infected hogs involved in studies in the Agricultural Research Service of the United States Department of Agriculture could the parasites be demonstrated by the direct examination of two or three microscopic preparations of muscle tissue taken from the pillars of the diaphragm. In garbage-fed hogs, on the other hand, the incidence of infection with trichinae varied considerably and reached in some cases nearly 12 percent of those examined. The numbers of trichinae present in about half of the hogs so affected were large enough to be readily demonstrable in microscopic preparations of muscle tissue. In the last two years, however, most of the States have passed legislation requiring the cooking of garbage to check the spread of a virus disease of swine known as vesicular exanthema. This cooking has already been reflected in a very sharp reduction in the incidence of trichinae in the hogs fed this garbage.

From the data at hand it may be concluded, therefore, that the more serious or clinical cases of trichinosis are acquired for the most part from infected pork obtained from hogs fed uncooked garbage. The nonclinical or zoological trichinosis in man, which has been so widely publicized, is acquired apparently from uncooked pork obtained from farm-raised hogs in which trichinae occur as a rule in very small numbers. When we consider the fact that pork is one of the com-

monest items in our diet, with an annual per capita consumption of about 65 pounds, and that the hurried preparation of food, especially in lunchrooms during the noon hour, is a common custom, it is not surprising that one out of six persons accumulates during his life a greater or lesser number of trichinae. It should be remembered that once they become encysted in the muscles, trichinae may remain there for some years.

Precise information on the number of clinical cases of human trichinosis in this country is unavailable. According to the data published by the U. S. Public Health Service, during the past 10 years the number of such cases reported to it by the States ranged from somewhat over 200 for 1943, when only some of the States reported this disease, up to about 450 in 1948. The average number per year since that time was approximately 350, with nearly all the States now reporting. The largest number of cases of clinical trichinosis have been found on the Atlantic and Pacific seaboards where the practice of feeding hogs on uncooked garbage developed to a sizable and profitable enterprise. It is probable that the recorded cases represented only part of the actual number of cases of clinical trichinosis that have occurred from year to year. Assuming, however, that they represented only 10 to 20 percent of the actual cases, there would still be a very wide gap between the incidence of infection with *T. spiralis* and that of the disease trichinosis. This is not surprising, since it is well known that the gravity of almost any helminthiasis, or worm-caused disease, in man and animals corresponds in most cases to the numbers of parasites that have invaded the body. The outstanding exceptions to this rule are the very large worms that by their size or location in vital organs produce serious injuries such as, for example, hydatid cysts in the liver and lungs of man, ascarids in the trachea or bronchi of children, and tapeworm cysts in the brain of man.

PARASITES NOT ACQUIRED THROUGH FOOD

Echinococcus.—Hydatids (pl. 3, fig. 2) are the intermediate or cystic stage of a very small carnivore tapeworm known as *Echinococcus granulosus.* The adult tapeworm occurs in the intestine of the dog or wild carnivore. It is only about 3 to 6 mm. long by 0.5 mm. or less wide, and consists of a head, neck, and three segments, one immature, one mature, and one gravid. The larval or cystic stage is the largest of its kind. It may attain a diameter of a few inches, and in man it sometimes attains the size of a child's head. Many mammals besides man, including cattle, sheep, goats, swine, horses, and species of wild animals, can serve as intermediate hosts of *Echinococcus.* In the intermediate host the larval stages, which consist of large bladders

filled with a watery liquid in which numerous tapeworm heads are present, become localized in the liver, lungs, spleen, kidney, brain, peritoneum, and elsewhere.

The intermediate host becomes infected with hydatid cysts by ingesting the tapeworm eggs eliminated by the definitive carnivore host. Human beings having close contact with infested dogs could readily soil their hands in one way or another with the dog's excreta and thereby contaminate the food that they eat. Petting an infected dog would be one way by which the hands could become so soiled, because dogs often roll on their own or other dog's excreta. If such excreta happens to contain the tapeworm eggs, the latter might adhere to the animal's haircoat and contaminate the hands of anyone petting the dog.

Echinococcus was of some concern to the medical services of our armed forces during the recent war because we had military personnel in Iceland, Australia, and New Zealand, where the parasites were known to be common. *Echinoccococus* infection and the hydatid disease which it produces in the intermediate host also are common in the Middle East, the Far East, and in South America.

The disease is rare in man in the United States though it is not so rare in our domestic stock. During the 5-year period 1937 through 1941 nearly 12,000 cattle livers out of over 50 million head slaughtered were condemned under Federal meat inspection because of echinococcosis; in calves, 1,133 livers were condemned out of over 5½ million inspected during the same period. The parasites are known to occur also in swine but precise data on their prevalence in hogs are unavailable. They were very common some years ago in hogs slaughtered in Richmond, Va., Chattanooga, Tenn., and in other meat-slaughtering centers.

The strobilate tapeworm, which can develop from each viable head in the hydatid cyst, has been found in dogs only rarely in this country. Perhaps this is because most dogs autopsied in laboratories where this parasite was looked for were obtained from pounds, where country dogs are seldom found. A vigilant Federal, State, or local meat inspection service certainly constitutes an effective barrier to the developmental cycle of *Echinococcus*. The condemnation and disposal of the affected organs break a link in the chain that constitutes the life cycle of a parasite dangerous to man and beast.

Rodent tapeworms.—Two rodent tapeworms of the genus *Hymenolepis* sometimes occur in the intestine of persons, mostly children. *H. nana* is from about two-fifths of an inch to nearly two inches long and less than one twenty-fifth of an inch wide. This parasite, common in rats and mice, is unusual among the tapeworms in that it has a direct life cycle. Rats and mice become infected by swallowing the

tapeworm eggs with feed and water. Children become infected in a similar manner by soiling their hands or contaminating their food in one way or another with the excreta of infested persons. There is reason to believe that there is a human strain of this parasite which passes from person to person. It is still problematical whether children acquire this parasite from rodents.

A related but larger tapeworm, *H. diminuta*, also occurs in rodents and, rarely, in human beings. This parasite has an indirect life cycle, fleas and other external parasites of rodents, and cereal-inhabiting insects serving as intermediate hosts. Children acquire this tapeworm by accidentally swallowing the infected intermediate host.

In studies made in the 1930's in Kentucky, Mississippi, North Carolina, and Tennessee, the incidence of infestation with *H. nana* ranged from a fraction of 1 percent to 2.7 percent, with a peak incidence of 3.6 percent in children 5 to 9 years old in Kentucky. *H. diminuta* was found only occasionally, and not in all the States surveyed.

The dog tapeworm.—*Dipylidium caninum*, which lives in the dog, cat, and in a number of wild carnivores, sometimes occurs also in children, localizing in them, as in its animal definitive host, in the small intestine. The dog louse, the dog flea, and the human flea serve as intermediate hosts. Dogs and cats become infected by gnawing at their fur to relieve the irritation produced by ectoparasites. Children acquire this tapeworm either by accidentally crushing the infected ectoparasites and then licking their hands, or by contaminating their food with the larval tapeworms, known as cysticercoids, or by being licked by a dog on the tongue of which these cysticercoids are present.

INTESTINAL ROUNDWORMS

Ascaris lumbricoides, an intestinal parasite of man known since ancient times, has a world-wide distribution and is undoubtedly one of the most common worms affecting human beings, especially persons living in rural areas and elsewhere where sanitation is inadequate. *Ascaris* is the parasite to which people everywhere usually refer when they speak of intestinal "worms." It has been estimated that about 30 percent of the world's population harbors this worm and that about 45 millions of those so parasitized live in the Western Hemisphere, mostly in the warm portions thereof. A closely related but morphologically indistinguishable worm, sometimes referred to as *Ascaris suum*, occurs in pigs the world over. The porcine worm, though considered by most parasitologists to be specifically identical with the human ascarid, is sometimes designated as a host variety thereof under the name *Ascaris lumbricoides* var. *suis* (pl. 4, fig. 1).

Like that of some other nematodes of the family Ascaridae, the early development of *Ascaris* involves a roundabout journey of the

newly hatched, microscopic larvae. In this case the journey is initiated in the intestine where the infective parasite eggs, which have been swallowed with contaminated food or water, hatch. The emerging larvae penetrate the intestinal wall and migrate to the liver by way of the blood stream, and thence to the lungs. Here the larval worms become free in the alveoli or air spaces (pl. 4, fig. 2) by rupturing and then escaping from the capillaries. The larvae get to the bronchi and trachea by upward migration in the lungs. They continue their migration to the pharynx and from there back to the intestine, after being swallowed. In the intestine they develop in about two months or less to egg-laying maturity, and ultimately reach a length up to about a foot or so and a thickness exceeding that of an ordinary lead pencil.

The migratory instincts of ascarids are by no means satisfied, however, even after their merry-go-round through the body during their early larval life. The grown worms, which are among the most injurious parasites of aimals and man, also exhibit a strong tendency to wander. Some pass into the stomach and are vomited up, and others continue their migration to the esophagus and from there into the trachea and bronchi where they can produce asphyxiation. Deaths of children in the Tropics by asphyxiation so produced is by no means rare. Some ascarids migrate to the pharynx and get into the nasal cavities. Ascarids have been known also to leave the body through the external ear after having perforated the middle ear. In fact, they have a tendency to push into narrow spaces and ducts within their migratory paths, and frequently get into the bile ducts and even the biliary canals and obstruct the flow of bile. In pigs this obstruction results in icterus or yellowish coloration of the flesh, a cause of condemnation of entire carcasses under Federal meat inspection. Moreover, a large number of worms can become so inextricably entangled with one another in the intestine that the resultant coiled mass can produce intestinal obstruction. These and other mechanical injuries produced by the large ascarids are in addition to those they produce by eliminating their metabolic products into the host's intestine. Some of these products, toxic in nature, have been extensively investigated by chemists and pharmacologists.

Whether the pig *Ascaris* can reach egg-laying maturity in the human intestine is still a moot question. The evidence at hand affords conclusive evidence that the pig *Ascaris* can undoubtedly infect man to the extent of undergoing its larval migrations through the liver and lungs, as it does in its porcine host. However, the worms are apparently eliminated from the human intestine before reaching maturity. The bulk of the experimental work involving the ingestion by human volunteers of *Ascaris* eggs of porcine origin points to these

conclusions, perhaps with one or more possible but questionable exceptions. The ability of pig ascarids to migrate to the liver and lungs of human beings and to produce hepatic and pulmonary symptoms and lesions places this parasite in the category of a human pathogen, even though it probably does not develop, or develops only rarely, to fertile maturity in the intestine of man.

MIGRATING LARVAL PARASITES

Visceral larval migrans.—Since many nematode parasites wander extensively through the body before getting to their ultimate location, it is not surprising that immature migrating worms are trapped from time to time in various organs and tissues through which they pass, without reaching their ultimate destination. It appears to be well established, moreover, that with repeated invasions of migrating larval nematodes the tissues through which they pass may become sensitized to them and the parasites tend to become arrested and trapped there. In fact, certain liver and lung lesions that are sometimes seen in animals and man appear to be due to a reaction to repeated assaults by certain nematode larvae. In the main, visceral larval migrans, as this condition is called, has been associated with the larvae of the zoological family Ascaridae, species of which occur in man, swine, and pet animals. The tissue reaction is characterized by small inflammatory foci, observed as a rule in the liver and lungs, in which the infiltrating cells are predominantly eosinophilic leucocytes. This reaction has been associated in man with larval *Ascaris lumbricoides* and also, more recently, with the larvae of carnivore ascarids accidentally acquired by man. Some of the earlier association of *Ascaris lumbricoides* larvae with visceral larval migrans in man is considered by some recent investigators to have been due perhaps to the larvae of one of the dog ascarids, *Toxacara canis*. Recent observations have shown that the larvae of these ascarids and probably also those of the closely related cat ascarid, *T. cati*, are involved in the production of the visceral lesions in man. It would appear, therefore, that migrating nematode larvae in a strange host, in this case carnivore ascarid larvae in man, can evoke liver and lung lesions that migrating larvae in a natural host apparently evoke as a result of a previous sensitization. At any rate, these studies, still in the early stage, have pointed up the danger to human beings, and especially children, from parasites of pet animals and probably also other animals, the eggs of which may contaminate food or water or be ingested in other ways.

Cutaneous larval migrans.—This condition involves the skin and is related to visceral invasion by strange parasites. In cutaneous larval migrans the causative parasites enter the body through the intact skin. The larvae are trapped there and produce by their movements under

the epithelial layer rather severe lesions, with accompanying irritation. In the United States a skin condition known as creeping eruption is caused by the penetration and subepithelial migration of dog and cat hookworm larvae of the species *Ancylostoma braziliense*. Creeping eruption is fairly common in the coastal regions of the South where *A. braziliense* also is common in the intestines of dogs and cats. In these carnivores the hookworm larvae develop to the adult stage, following their entrance into the body through the skin and their subsequent migration to the lungs via the blood stream. From the lungs the larvae reach the small intestine by upward migration in the respiratory system until they get to the pharynx and mouth, and go from there to the stomach and so on to the intestine. *A. braziliense* is a rare parasite of the intestine of man because the larvae cannot extricate themselves from the human skin or can do so only rarely.

On beaches and other places, where hookworm-infected dogs and cats have defecated and therefore contaminated the sand or soil with the worm eggs, the larvae that issue from the eggs and metamorphose by two successive molts to the infective stage, are attracted to the naked human skin and penetrate it. Their subsequent migrations under its subepithelial layer form the tortuous tunnels that characterize this cutaneous disease. The intense irritation that the larval migrations in the skin can cause leads to scratching of the affected areas. This, in turn, aggravates the condition by causing these areas to become inflamed.

Some Observations on the Functional Organization of the Human Brain

By Wilder Penfield
Director, Montreal Neurological Institute
Professor of Neurology and Neurosurgery
McGill University

[With 1 plate]

In Proverbs it is written: "For as he thinketh in his heart so is he," and again in the New Testament a thousand years later at the time of the birth of Christ, "Mary kept all these things and pondered them in her heart." It was only yesterday that Vannevar Bush slipped back into the same manner of speaking: "The seat of ethics," he said, "is in our hearts, not in our minds." (I'm sure he must be flattered by the succession in which he thus appears!)

But in the Elizabethan era even Shakespeare spoke otherwise, referring to the "brain which some suppose the soul's frail dwelling house." Medical men had by that time come to consider the brain to be the organ of the mind, believing that it functioned in some mysterious manner as a whole without localization and specialization of functions. Even today, although we are awed and even frightened by the intellectual achievement of man's mind, the mechanisms that make it possible are still unknown.

Knowledge of the outward form of the brain is well advanced. The pathways of sensation and of movement within the brain have been, and are being, charted. But what of the neurone mechanisms involved in consciousness, perception, memory. Far off, it seems to me, we hear the humming of the machinery of the mind and from time to time, we gain fleeting glimpses of its action. But still we stand in awe upon the threshold of understanding. I shall describe certain glimpses that have come to me by patience and by good luck.

But first I must make reference to what is common knowledge of the human brain (pl. 1). The mechanisms of reflex movement are well

[1] Reprinted by permission from Proceedings of the American Philosophical Society, vol. 98, No. 5, October 1954.

worked out. Voluntary action is produced by nerve impulses that originate within the brain and pass out along a succession of nerve-cell nerve-fiber connections into the peripheral nerves and so to the muscles which make movement by their contraction.

We know something about how the sense organs in the eye, the ear, the nose, and the skin transmute the stimuli of light, sound, floating particles, and touch into afferent streams of nerve impulses. These streams follow separate pathways into the brain to make possible the functions of vision, hearing, balance, smell, and touch. These streams of sensory impulses, which are like electrical currents, differ from each other in that they have separate goals in the central nervous system. The nerve cells in each goal, when activated, send on impulses into the

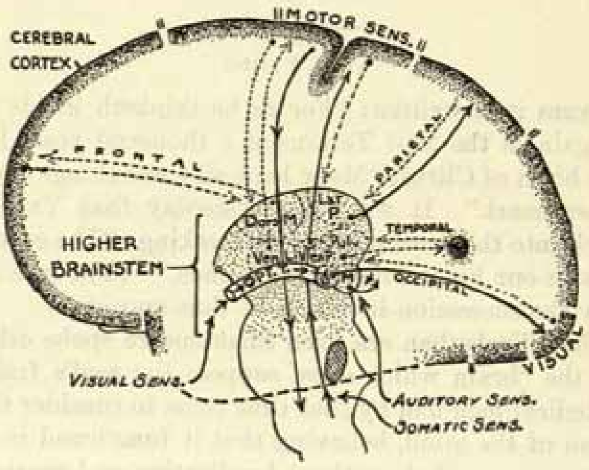


FIGURE 1.—A schematic representation of the interconnection of neurone circuits between the higher brain stem and the various functional areas of the cortex of both hemispheres. These converging connections and the integrating mechanisms within the brain stem make up the centrencephalic system. (From Penfield and Jasper, "Epilepsy and the Functional Anatomy of the Human Brain," Little, Brown and Co., 1954.)

neurone circuits which make possible conscious perception of things seen or heard or felt. For example (see fig. 1), the visual pathway leads from eye along optic tract (OPT. T.) to visual center in the occipital lobe of the cerebral cortex, but from there impulses pass onward to play a role in the more complicated mechanisms of integration.

But what of the neurone mechanisms of consciousness? What of thought, memory, behavior, and speech? Here the experimental physiologist stops. He can help us little. Here we must consider the brain and the mind of man himself. It is true that Pavlov and others have thrown some light upon the parts of the brain used in animal behavior, and in learning, by study of the conditioned reflexes. But this takes us such a short way toward the basic understanding that we seek.

Certain general principles of organization emerge. The area of final coordination and integration of neurone activity in the central nervous system is evidently situated in the higher brain stem. These coordinating circuits are essential to the very existence of consciousness. Almost any interference with this portion of the nervous system, either by compression or disease, produces unconsciousness. This is the portion that has symmetrical connections with the gray cortex of both hemispheres. It contains a converging and diverging system of nerve-fiber connections which we may call the centrencephalic system to indicate that it constitutes the functional center of the brain or encephalon.

The centrencephalic system occupies what may be called the old brain corresponding with the rudimentary head of the central nervous system of lower forms of life.

Higher mammals, and especially man, are provided with superimposed hemispheres covered by an ever more extensive mantle of gray matter, the cerebral cortex. This gray cortex is composed of millions of nerve cells, or ganglion cells, and, in the case of man, the cortex has so increased in extent that it is formed into deep folds or fissures that convert its surface into convolutions.

Each of the functional areas of this cortex is, in a sense, a separate projection from the brain stem so that each portion makes possible new and more complicated function (fig. 1). But no area of cortex is independent and none is capable of effective function without its corresponding portion of the old brain. Indeed it seems to be through the brain stem that the new capacities of each area of cortex are utilized.

Thus it is that the sensory areas of the cerebral hemispheres are no more than way stations in the several currents that carry different forms of sensation into the centrencephalic integrating system, and the cortical motor areas are way stations in the stream of outflowing impulses that produce motor activity. Large areas of cortex may be destroyed or removed without producing unconsciousness although this does interfere with the function to which the injured areas were devoted.

In order to treat certain conditions such as focal epilepsy, it is sometimes necessary to operate under local anesthesia and to stimulate the brain of conscious men and women with gentle electrical currents. When applied to the motor area of the cortex such stimulation produces crude movement because the current is conducted outward through the spinal cord and nerves to the muscles. This current does not enter the integrating area and the patient is surprised to discover that his hand, for example, has been caused to move.

If the surgeon's electrode is applied to one of the sensory areas (somatosensory, hearing, vision in fig. 2), the impulses do pass into

the centrencephalic system and the patient reports that he feels or hears or sees something, the nature of the sensation depending on the area selected. But the sensation that he experiences does not resemble things he sees or feels or hears in everyday life. Instead, it is a crude sensation such as simple lights and colors or a tingling of the fingers or a ringing sound.

But the sensory and motor elaborations of function are not the only uses of the cerebral cortex. There are large areas that are devoted to what may be called psychical function, particularly in the anterior frontal lobes and the temporal lobes. The most remarkable change in brain form, passing up the scale from dog through monkey to man, is the comparative enlargement of frontal and temporal lobes, and there can be little doubt that this is associated with man's supremacy in the intellectual sphere.

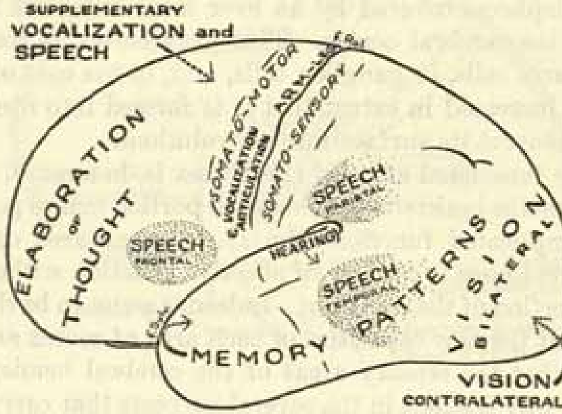


FIGURE 2.—Localization of some of the functional areas of the cortex. (From Penfield, W., Observations on cerebral localization of function. IV. Compt. Rend. Congrès Neurologique International, Paris, 1949, vol. 3, 1949.)

During the past 20 years it has been my good fortune to discover from time to time that similar stimulation of the temporal lobe cortex occasionally produced a psychical response, something of a different order from the motor or sensory effects previously described.

The patient might exclaim in sudden surprise that he heard music, or that he heard a well-known person speaking, or that he saw something he had seen before, or that he was himself taking part in a former experience in which he was himself an actor.

At such times the patient continued to be aware of the fact that he lay upon the operating-room table, and yet the recollection continued, in spite of himself, as long as the electrode was kept in place, to vanish instantly when the electrode was withdrawn. Brief examples may be given.

A young woman heard music when a certain point in the superior surface of the temporal cortex was stimulated. She said she heard an orchestra playing a song. The same song was forced into her consciousness over and over again by restimulation at the same spot. It progressed from verse to chorus at what must have been the tempo of the orchestra when she had heard it playing thus. She was quite sure each time that someone had turned on a gramophone in the operating room.

A South African who was being operated upon cried out in great surprise that he heard his cousins talking, and he explained that he seemed to be there laughing with them although he knew he was really in the operating room in Montreal.

There were many other examples of hearing music but always the patient heard a singing voice, or a piano, or an organ, or an orchestra, and sometimes he seemed to be present in the room or in church where he had heard it. What he heard and experienced was a single occasion recalled to him with a vividness that was much greater than anything he could summon voluntarily by effort of his will.

If the individual was asked later to recall the song he might be able to sing it, but he might not be able to recall the circumstances of any one previous hearing. His later memory of the song was a generalization. On the other hand, the electrode had reproduced for him one single previous experience when he had heard the music and it awakened in him the emotion which that particular situation had originally roused in him.

In summary it may be said that the electrode, applied to the temporal cortex, recalls specific occasions or events so that the individual is made aware of everything to which he was paying attention during a specific interval of time. Such responses have followed stimulation only in cases in which the cortex had been the site of previous habitual epileptic discharges. Although the content of the recollection thus evoked often bears no relationship to the psychical content of the seizure, it is possible that the cortex has been rendered more readily stimulable by the epileptic state.

These results were obtained in the temporal cortex only (fig. 2, memory patterns), an area of the brain to which no certain function has been previously ascribed. I must conclude that there are in this area permanent records of these experiences preserved somehow in the form of ganglionic patterns that can be reactivated by the electrical impulses delivered to the cortex by the operator's electrode.

It may be assumed then that in this area of cortex each successive conscious experience is laid down in a relatively permanent pattern of nerve-cell connections that records all those things of which a man is conscious at any given time. It is as though the cortex contained a

continuous strip of cinematographic film, a strip that includes the waking record from childhood onward.

One must assume that the right and the left temporal lobes give similar service in this regard and that the memory record is duplicated on the two sides since removal of a large part of one lobe does not usually interfere with a man's capacity to recollect or to recognize the things seen before.

Presumably these patterns are no more than pathways of permanent facilitation through preexisting connections of many branching nerve cells. When the electrode is applied the current seems to follow again this pathway, slowly, steadily, while all other neighboring pathways are somehow closed by the influence of some all-or-nothing principle.

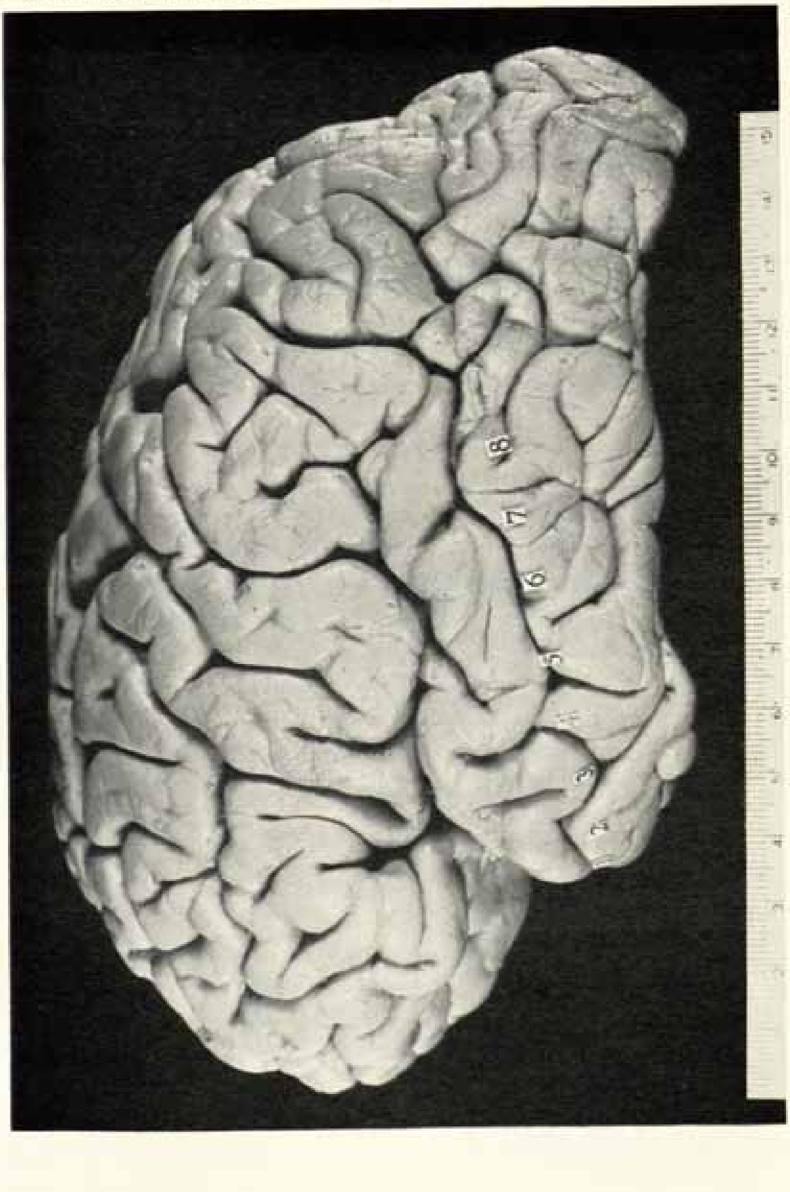
There is other evidence that such detailed patterns of previous experience are preserved within the brain. Take an example from what must be your own experience, as it has been mine. Let us assume that you have not seen a friend for many years. Once you knew him well, but now, after 10 or 20 years, you cannot picture him and certainly you could not paint his picture.

But suppose you come upon him unexpectedly. As he turns and looks at you and smiles there is a sense of familiarity. Suddenly you recognize your former friend. But even as you focus your attention upon him you realize he is altered in little ways. There is a difference between this moving, talking, laughing individual and the record of him that is preserved in great detail in your own brain, the record you could not have conjured up a moment before.

Now you see new lines in his face, an altered stoop to the shoulder, a strange slowness of movement. The voice is the same perhaps and the eye seems to twinkle with the same old understanding. You probably clap him on the back and tell him (for his own good) that he has "not changed a bit." But even as you shook his hand you had felt another alteration for you perceived that the joints had thickened.

You feel the necessity of calling him by name. That requires a separate physiological act, for the mechanism of speech and the whole process of summoning words that are appropriate to the content of new thought, bear only a distant relationship to those aspects of memory included in our present discussion.

It is obvious that you have preserved the records of the way your friend walked and talked and smiled during a long succession of interviews. When you met him again you reopened the old "file," rediscovering and reviving its contents. These are not portraits of still life; they are strips of action, each one as long as the periods of time during which you focused your attention upon him.



The left hemisphere of the human brain covered by cerebral cortex or gray matter. Only about 35 percent of the cortex is on the external surface of the convolutions. The rest is buried in the walls of the fissures. Scale in centimeters.

This must be the same sort of strip that the neurosurgeon had stumbled upon when he placed his exploring electrode at random upon the patient's hypersensitive cortex. A gentle electrical current, of 60 impulses per second for example, applied at a point on the temporal cortex activated one strip of experience and only one at a time. Thus, past experience was brought into the present, and the patient was aware of a doubling of his consciousness. An experience on a South African farm and present experience in a Montreal operating theater are presented to consciousness simultaneously. The man himself pointed out his awareness of the incongruity of the situation in his initial exclamation. He made his own decision as to which was the true present, and which must be the counterfeit. Patients often say, "this is not a memory, it is more vivid than that." The mechanism which the electrode has brought to light might well be considered an essential element in the very basis of consciousness by use of the following hypothesis:

The pattern of each successive experience is somehow projected from the centrencephalic system outward to the temporal cortex on the two sides (including hippocampal regions perhaps) in a continuous flow of patterned impulses, a flow that is interrupted only by deep sleep or by coma. It would seem that the projection could only come from this central integrating area, since it is there and only there that all sensory and psychical elaborative circuits converge. Each experience is made up of those elements of sensation of which a man is, for the moment, aware, together with his interpretation of each experience and the attendant emotion.

It must be that this outflow of nerve impulses creates a ganglionic pattern in the temporal cortex although perhaps not wholly there. Furthermore, it may be that a reprojection of impulses back from the temporal cortex to the centrencephalic system occurs invariably like a reflection in a mirror, a reflection of which the individual takes cognizance. That may seem an extraordinary hypothesis, and yet if stimulation with a simple electrical current can recreate a total experience, the reflection mechanism exists. The neurone record is there and the records of previous similar experiences are there also so that judgments of familiarity or strangeness may be made and other elaborative processes. I suggest that reflection or reverberation back into the centrencephalic or integrative circuits must occur normally.

I would surmise then that the neurone processes involved in the original creation of the record of present experience are those involved in the act of attention, and that the instantaneous reprojection or reflection of the record back again together with some sort of reflection of previous similar experience constitutes an essential neurone mechanism in consciousness.

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It is obvious that nerve impulse is somehow converted into thought and that thought can be converted into nerve impulse. And yet all this throws no light upon the nature of that strange conversion.

Before certain problems the scientist will always stand in awe. Perhaps he may be forced to make another approach—to what was called in old time "the heart." However far our successors in these studies may go, it is my belief that the machine will never fully explain the man, nor mechanisms the nature of the spirit.

Reprints of the various articles in this Report 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 Place of Tropical Soils in Feeding the World[1]

By Robert L. Pendleton
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What are the possibilities and limitations of humid, tropical, lowland soils? What can these soils contribute to the feeding of the world? Why can they *not* contribute so much as many persons think they can?

Now that the airways offer more facilities and ease for travel, hundreds of passengers are flying over the enormous and magnificent equatorial forests of the Congo and Amazon Basins. Literally from an armchair, high above these forests, the layman who has enough interest to look out of the plane window, down upon the lush vegetation, easily gets the idea that the potentialities of the Tropics are unlimited.[2]

Before it was possible to travel so easily above these vast and magnificent forests, the relatively few travelers who saw the humid, tropical river valleys such as the Amazon did so from the vantage point of the small river steamer or dugout canoe. Usually gallery or fringing forests stand along the river banks; and not so far back from the river are open, worse than useless grasslands. Before the age of air travel, the occasional traveler on the rivers undoubtedly obtained an exaggerated idea of the extent of the tropical forests. But such travelers did have, from time to time, opportunities to go ashore, and perhaps to get something of a worm's-eye view of the forest. A United States agricultural attaché in Venezuela, planning a trip up the Orinoco River, was being dissuaded by a river boatman with the remark, "Why

[1] Substance of a lecture delivered before "Friends of the Land" in Chicago, July 1, 1953. Reprinted by permission from Ceiba, vol. 4, No. 4, November 1954.

[2] For a more extended discussion of man's relations to humid tropical regions, see Pierre Gourou, The Tropical World, 153 pp., 1953, London. For the best and most recent discussion of the nature, origin, and classification of tropical soils, see E. C. Jul. Mohr and F. A. van Baren, Tropical Soils, 498 pp., 1954, New York.

do you want to go up this river? There's nothing up the river but the banks."

It is also true that a traveler on foot through humid tropical lowland forests gets the idea of lush vegetation, and the impression that the ability of the soils to produce plants is unlimited. Often these forests are so thick and dense overhead that seldom can he see the sky. If standing on the forest floor, he does not know whether it is raining or whether the sun is shining up above the forest, until the raindrops begin to fall to the ground. Where he must keep to the trail, or cut his way through the vines and ground cover, and where he is continually oppressed by the denseness and gloom of the forest, to say nothing of the leeches reaching out for him from the shrubbery along the path, he finds travel in these forests extremely unpleasant. The difficulties of traveling through the equatorial rain forest of the Congo basin are described, with great restraint, by Stanley in his "Darkest Africa," though the woodcuts are totally inadequate to represent conditions within an equatorial forest. Yet after many failures to get an adequate photographic record of conditions in the forest, the cameraman is not inclined to be so critical of woodcuts!

DIFFERENCES BETWEEN TEMPERATE AND TROPICAL REGIONS

The differences between temperate and tropical regions and the vast and rich, almost unexploited, timber and soil resources especially of the Tropics continually appeal to the stranger.[3] He cannot rid himself of the idea that there are vast fortunes to be made in tropical regions, or, at least, that unlimited quantities of raw materials needed in temperate zones can be obtained in such areas. An outstanding example of this is the so-called groundnut scheme of Great Britain which was undertaken in British East Africa. This resulted in a shocking loss of capital, and the final results in oil produced were disappointing, to put it mildly. Then there have been the efforts of others to produce food in South America. Recent eyewitness reports are to the effect that these schemes are producing most meager results, considering the investment of capital.

The history of agriculture in Malaya, Ceylon, and elsewhere in the humid low latitudes in the production of rubber and tea is scarcely known in the States, but 50 years ago the soil erosion in the orchard-like tea and rubber plantations in those regions was appalling. Tea and rubber seem to be able to get along on soils with only modest amounts of plant nutrients, though for profitable production on exposed subsoils (for the surface soil has often long since been lost) both these crops respond well to appropriate applications of commercial fertilizers.

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[3] For a graphically illustrated account of the selva, or tropical rain forest, see Life magazine, September 20, 1954, p. 76 ff.

Too often, however, particularly in the vast interiors of equatorial Africa and equatorial South America, there has been too little erosion. The residual products of weathering have accumulated, after the principal nutrient materials have long since been leached from the soils: iron has accumulated as laterite, less often aluminum as bauxite, or more often as kaolinitic clays, and silica as quartz sand. It may seem rank heresy to emphasize the fact that any region can suffer from too little erosion, but this certainly is the case in considerable portions of the one tropical region which I know best, Thailand (Siam).

THE SOIL-FOREST COMPLEX

It is likely that these magnificent forests in humid equatorial lowland regions started when the soil was not so poor, when rocks had not yet weathered so deeply, so that there was not such a scarcity of plant nutrients in the surface soil within the reach of the roots of the forest trees and other plants. The forest developed great luxuriance, while the tree roots went deeper and deeper. As long as there was no general destruction of the forest vegetation, there was very little loss of plant nutrients within the reach of the tree roots, for as soon as one tree died and fell to the ground, it was quickly attacked by termites, mold, fungi, etc., and within a year or two, practically all the plant nutrients were liberated in the mineralization of the plant materials. Roots of the surrounding trees and plants immediately took up these nutrients. They were taken back into the forest vegetation without any considerable proportion being lost to the deeper percolating waters. In other words, the plant nutrients were being cycled—used in the forest vegetation over and over again. But the soil itself was changing. Weathering had been progressing deeper and deeper. While most of the plant nutrient substances were being held by the roots of the vegetation, small portions were lost by too rapid percolation and perhaps some by erosion. The mineral soil itself was becoming poorer and poorer.

Felisberto de Camargo has described one of the most striking examples of a magnificent dense and tall equatorial forest (selva) which had developed on a soil that has proved a serious disappointment for annual agricultural crop production. This is the country through which runs the railway from Belém to Bragança, state of Pará, Brazil.[4] South of the mouth of the Amazon River is an enormous region of low, rolling country on which once stood a magnificent high tropical rain forest. Some 70 years ago the government under-

[4] Felisberto C. de Camargo, Terra en colonização no antigo e novo Quaternario da zona da estrada de Ferro de Braganca, Estado de Pará, Brasil. Bol. Mus. Paraense E. Goeldi, vol. 10, pp. 123–147, 1948. (In English *in* Dept. State Publ. 3382, International Organization and Conference Series 2, American Republics 4, sect. 3, pp. 213–220.)

took to develop this region. There was great need for development of the selva to the east because a few hundred miles to the southeast, in northeastern Brazil, is an area where droughts are chronic. Even during recent years thousands of villagers from this drought-stricken region have been going some hundreds of miles by road to São Paulo for work because of the too rigorous conditions in the northeast. When in São Paulo in 1949 I remember clearly seeing the truckloads of peasants coming in after a week or more of dusty travel by road from the northeast, where they could no longer find any way to make a living because of the drought in their arid and too often rainless country.

As a start in developing this Bragança region, the government built a railroad east from Belém and assisted villagers to come in from the dry regions of northeastern Brazil. Settlers came in, the land was cleared, and crops were grown. The first crop following the clearing of the forest was often very encouraging, but thereafter the crops were extremely poor. It soon became evident that it was futile to cultivate these very poor sandy upland soils continuously in an effort to develop a permanent agriculture on them.

Before his most untimely death in 1942, Geoffry Milne, soil chemist to Tanganyika Territory, British East Africa, contributed greatly to a better understanding of tropical soil-plant relationships. As a result of his field studies in Trinidad and British Guiana [5] he pointed out that "It is true that in better known floras there are always a few 'indicator' plants, but all plants must indicate something, and what most of them could tell about the soil is quite insufficiently known." Milne continues that—

> the difficulties due to the nature of the soil-plant relationship may be stated briefly thus:
>
> (1) However faithfully a natural vegetation may reflect the soil conditions that have promoted it, we usually propose to change or remove that vegetation for the purpose of our uses of the land, and we shall thereby change the conditions, perhaps fundamentally. A soil and its plant cover have interlocking identities; and what we have thought of as forest soils or prairie soils cease to be such within a short period after the trees have been cut or the sod turned.
>
> (2) The soil properties that are significant to a natural vegetation and receive expression in it are not necessarily those that will be of most significance to the crop proposed for replacing it. Crop plants will usually have a more urgent demand for nutrients and may have a different range of tolerances.

Milne visited a project on the island of Trinidad where natural forest of mediocre value had been cleared and the land used for annual crops. The settlers of East Indian stock had not been able to continue cropping the land for more than a few years because the productivity

[5] G. Milne, A report on a journey to parts of the West Indies and the United States for the study of soils, February to August 1938, East African Agr. Res. Stat., Amani, Tanganyika Territory, 78 pp., 1940, Government Press.

had dropped very rapidly. Milne was convinced that neither the peasants' lack of skill nor soil erosion in any form could be blamed for the almost complete abandonment of the holdings when he visited the area.

Milne also describes conditions in a forest reserve in Trinidad, where temporary settlers for one year only had cut the forest, made charcoal, and raised one crop of food in lieu of wages. He stated that the Forest Department had, however, experienced the greatest difficulty in establishing the desired stand of valuable (indigenous) trees on land that had been cleared and cropped in this manner. On the occasion of Milne's visit the Conservator of Forests expressed the opinion that giving over the ground to the cultivator for even one year had been an expensive mistake. The replanting operations had been handicapped thereby to the point of defeat. The only hope of replacing natural forest by commercial forest lay in *preserving the continuity of forest conditions through the transition* as far as possible. In other words, the forest soil must be maintained as an entity, without changing it first into something else by alien processes of tillage and exposure.

Milne concludes that—

> both these Trinidad soils had, in fact, a fertility quite sufficient to maintain mixed forest, or to grow satisfactory forests of commercial timbers, but they had this fertility *only so long as the reactions of forest upon soil properties were maintained without interruption.* It was not expressable through field crops, because the clear felling, burning and tillage necessary in preparation for such crops has, as it were, dismembered the soil as a working system, and the "scrap" that was left did not provide the makings of an agricultural soil. Not even a good forest soil could be rebuilt from it; there had been loss of essential parts and the mechanisms of a year or two before could not be restored to working order.

Once a tropical forest is cut and burned and the land cleared, most of the mineral nutrients from the forest growth are dissipated. Of course, in the ashes the minerals are freely soluble, but the young crop being grown can take in only a small part of the liberated nutrients, and the rest are washed deep into the soil by the heavy rains of the summer. Certainly at least 90 percent of all the plant nutrients are quicky washed below the limited range of the roots of any crop or annual plant growth. A second year's crop is almost impossible to raise because the sandy soil is so poor; the farmers leave it and clear more forest land. The abandoned land is gradually occupied by herbs, wild bushes, and small trees. It is obviously uneconomical to use commercial fertilizers on the soils for the production of subsistence crops for they do not, and cannot, justify the expense. As Milne emphasized, once the soil-forest system is broken, the cycle interrupted, it is quite impossible to restore the forest-soil relationships.

The Brazilian agricultural scientists who have been studying this problem are convinced that it is not economically possible to raise crop plants on these sandy upland soils. Therefore, they are urging the settlers to go down and dike the lowlands along the rivers and use them for rice and pasture, and use the uplands only for building sites for their farmsteads. The effectiveness of this system is being demonstrated on their governmental experimental farms near Belém, and it is promising. It should be remembered, however, that these river lowlands are along branches of the local streams which discharge into the Amazon estuary so that their levels are not greatly affected by the changes in level of the Amazon River proper.

THE AMAZON VALLEY

The Amazon Valley has been more often described by popular writers than almost any other tropical region,[6] and its imagined possibilities for food production have been enlarged upon at great length.[7] Unfortunately, the potentialities seem to be very limited, even more limited than the experiments near Bragança would suggest. As Marbut and Manifold pointed out more than a quarter of a century ago, the alluvial plain of the Amazon Valley is relatively very narrow, often only a few miles in width.

> The alluvial soils constitute a sixth group. They are in general of two kinds. (1) Well-drained loams and very fine sandy loams occupy the immediate banks of the rivers in a narrow belt ranging from a few feet to a few hundred yards in width. They lie on the natural levee and are moderately well drained, subject to flooding for a short period each year, but highly productive. (2) Heavy, imperfectly drained to poorly drained "back swamp" soils are often dark in color and heavy throughout the whole section. They are subject to long periods of inundation. Considerable areas are treeless. The belts in which they lie contain many shallow lakes and swamps.[8]

The reports are that during the high-water season of 1953 the Amazon River levels were 15 to 20 feet *above* the street level at Manaos. Higher up the Amazon, as at Iquitos, the usual variations in the level of the river in different seasons of the year are from 50 to 60 feet or more. Obviously, it would be quite impossible to keep out floodwaters by raising dikes high enough along the mid-Amazon which would be needed in order to plant rice or other lowland crops in the remaining portion of the alluvium.

The largest-scale experiments in the development of the Amazon Valley were certainly those of the Ford Motor Company. The engineers planned first to exploit the forest timber and, by clear felling

[6] Michael Scully, Amazing Amazon, The Rotarian, August 1952, pp. 35–36.

[7] Earl Parker Hanson, Mankind need not starve, The Nation, vol. 169, No. 20, pp. 464–467, Nov. 12, 1954; New Worlds Emerging, 373 pp., 1949, New York.

[8] C. F. Marbut and C. B. Manifold, The soils of the Amazon Basin in relation to agricultural possibilities, Geogr. Rev., vol. 16, pp. 414–442, 1926.

the forest, to make clearings in which to plant Hevea rubber. They built the largest modern sawmill in South America to cut the forest trees into timber for export to temperate regions. Undoubtedly one of the most serious difficulties was to market the large number of different kinds of tropical timbers. This has always been a problem in the Philippines where there are over 400 different kinds of commercial timber trees that can be used but there is seldom enough of any one of these to make exploitation of most sorts economical; nor do commercial firms care to experiment as to how to utilize new and untried kinds of timber.

It is not well understood how very diversified all forms of life are in tropical countries—not only trees, but insects, birds, fishes, etc. As an example of diversity there is Mount Makiling in the Philippines on whose slopes we made our home for about 12 years. On this one small extinct volcano less than 4,000 feet high, and perhaps 10 miles in diameter at the base, a botanical survey showed that there were more different species of woody plants on this one small mountain than in the entire United States.

Returning to Ford's experiments in the central Amazon, it should be mentioned that at the start this project was in the hands of engineers, not agriculturists. The first timber mill and plantation, Fordlandia, was well up the Tapajós River. The site was found unsuitable for the growing of rubber. A second site, called Belterra, was found nearer the Amazon River. In 1949 I visited this plantation, and was much impressed with the growth of the trees and with the general layout of the plantation on a plateau well above the river. It should be mentioned that the *Hevea brasiliensis* (Pará rubber trees) do not require a very fertile soil. It is native on the poor upland forest soils of the Amazon Valley, for it does not thrive where the drainage is very poor, as Hevea trees should have reasonably good drainage. The development of the Belterra plantation had been expensive, in part, because of the South American leaf disease, so that double budding is necessary in order to get the highest yielding types of trunk panels to grow disease-resistant crowns. To retard the spread of the leaf disease actually three different kinds of tops had been budded onto clonal trunks. When I visited this plantation in 1949 it was under control of the Brazilian Government; the management was tapping as many of the trees as possible with the available labor. In spite of inducements to labor there were never enough workers to tap the trees already large enough for tapping. The Brazilian Government bought Ford's 11-million-dollar investment for a mere quarter of a million dollars, but even on this basis, and without any capital charges to meet and with a protected market in Brazil for all the rubber they produced, we were told that the plantation was barely making ends meet.

However, in the Amazon Valley there are more serious difficulties than even the poor soil. Some of these are described very vividly by Vicki Baum in her novel "The Weeping Wood."[9] It is impossible here to discuss the social and economic relationships and the motives back of the conquistadores from Europe who explored the New World about 400 years ago, setting the pattern for development of the governmental, economic, and social relationships, but as Vicki Baum describes them, certainly the feudal pattern imposed by the Portuguese has persisted with amazingly little change. I have elsewhere referred to this as the "Iberian curse" which has affected so many of the tropical regions. A typical town of the lower reaches of the Amazon River has been meticulously described by Dr. Charles Wagley.[10]

Central Brazil is a vast region of old plateaus and eroded uplands but with only a very moderate relative relief. One might say that there has been really too little erosion in this country where the laterite capping of the uplands has further retarded geological erosion.[11]

José Setzer is one of those Brazilian students of tropical soils who believe that coffee soils, particularly, suffer an irreversible degradation as they are used. The exposure to sun and rain, plus the clean cultivation from the excessive tillage, help to destroy the organic matter and so the structure. The lack of shade trees for the coffee in most of Brazil is another factor.

It is certain that the abuse of the coffee gardens during the economic crisis of the '30's was serious. The gardens were used for cattle pasture. The grass that grew abundantly on the red clay loam did protect the soil from sun and rain, but the trampling of the cattle ruined the soil structure. At the same time, the cattle did great damage to the coffee bushes.

Much of the original organic matter had already been oxidized out of the soil, but pasture grasses should restore at least some of it. But whether or not the deterioration was permanent and irreversible, 20 years later new coffee gardens were being developed on freshly cleared forest land farther west and north. The irreversible nature of soil deterioration had been accepted, though not yet conclusively proven.

THE PHILIPPINES

The Philippine Islands are a region of diversified rocks, relief, soils, and climate. There are humid lowland rain forests, and in

[9] 508 pp., 1945, published by Michael Joseph, Ltd., London.

[10] Amazon Town, 298 pp., 1953, New York.

[11] Robert L. Pendleton, Potentialities of the Tropics. A lecture before the Graduate School, United States Department of Agriculture, Apr. 18, 1949; in Chronica Botanica (in press).

the northern two-thirds of the archipelago typhoons are frequent. In Mindanao, by contrast, typhoons practically never occur. The Philippines have many volcanoes, some of them recently active. Fertile soils have developed from the volcanic ash. These volcanic soils are outstanding in their productive capacity. The relatively rough relief of the Philippines has maintained geological erosion on a considerable scale; as a result, almost no laterite has developed.[12] In other words, normal erosion and good drainage have prevented the development of the iron hardpan (laterite) characteristic of considerable areas of older peneplains of India, southeast Asia, tropical America, and tropical Africa.

Unfortunately the Philippines, too, suffered from the "Iberian curse." During the early years of this century, when the United States of America was in control of the Philippines and had the power to change conditions and to do away with the majority of the evils of the imposed feudalism, the opportunity was largely missed and such progress of this kind that the American Government did make had been quite emasculated after 1916 by the activities of the Philippine Government, as Karl Pelzer has shown in his chapter "Landless Filipinos."[13]

The failure of the Americans to keep in mind the desperate situation of the Philippine peasants compelled the latter to try to find some other solution, one of which included the activities of the communist inspired and aided Hukbalahaps.

BORNEO COMPARED WITH JAVA

For several centuries the two islands of Borneo and Java were under European control and direction. During the past century the Dutch made great progress in developing tropical agriculture and applying science to the development of the country. At the moment, for the purposes of this discussion let us limit the comparisons. Borneo is an island of very old rocks worn down by erosion and weathering to a relatively low relief. The soils, as a whole, are typical of humid tropical lowland regions,[14] where a heavy rain forest stood on the land. In places along the coast are extensive swamps. During recent decades

[12] There is evidence that ancient vesicular laterite overlies extensive earthy iron-ore deposits in Surigao Province, Mindanao. The laterite must have been formed when the sea stand was much higher and peneplain conditions prevailed. G. H. Kemmer and R. L. Pendleton, Journ. Amer. Soc. Agron., vol. 36, p. 1025 (abstract), 1944.

[13] Pioneer settlement of the Asiatic Tropics, chap. 4, Amer. Geogr. Soc. Spec. Publ. 29, pp. 81–114, 1945.

[14] E. C. Jul. Mohr, Soil of equatorial regions, with special reference to the Netherlands East Indies, pp. 383–403. Tr. by Robert L. Pendleton, Ann Arbor, Mich.

some of these swampy lowlands have been diked, and the development of paddy (lowland rice) agriculture has been under way.[15] Not far away to the south, across the Java Sea is Java, a much smaller island than Borneo but with at least 50 volcanoes, many of which are magnificent mountains. A considerable number of these volcanoes have been active in modern times, some within the last few years, spreading rock powder over the countryside, so that many of the soils are still very young and have physically good conditions, as well as abundant amounts of plant nutrients. Moreover, the natural or geologic erosion and creep have been considerable and have gradually helped the surface soil to move on down into the lowlands and toward the sea before it becomes senile and devoid of most of the plant nutrient substances that had weathered out from the parent rock minerals. Thus the nonvolcanic rocks are also, for the most part, covered with soils that are at least reasonably productive. The population on Java is overwhelmingly agricultural and where irrigation is available the farmers follow very intensive methods of plant production. The population on Java per square mile is at least a hundred times as great as on Borneo. This is possible because the soil resources of Java are such that even a denser population than this can certainly be supported on the land. By contrast, the crop-producing potentialities of the soils of Borneo are very limited.

THAILAND (SIAM)

Thailand, a relatively small country in southeast Asia, lies between Burma and Cambodia, Laos and Viet Nam. The area of Thailand is somewhat greater than that of California but less than that of Texas. Much of Siam is too poor to grow upland crops, that is, nonirrigated crops. Where the forest has been reasonably good, the general practice has been to kaingin the land and grow a crop of sugarcane, corn (maize), cucurbits, or similar crops on the land so cleared. Where the forest is poorer, upland crops are grown only on the larger termite heaps, which may be as much as 10 feet high and 20 feet across at the base. In some cases, the termitaria are truncated somewhat to give a larger, flattish garden plot on which can be grown sugarcane for chewing, tomatoes, tobacco, pineapple, papaya, and other upland crops. It should be noted that the wise Thai farmer never levels the mound completely.[16]

Where the land can be flooded and the water held on it, at least during the rainy season, the soil is stirred, puddled, and seedling lowland

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[15] C. L. van Wijk, Soil survey of the tidal swamps of South Borneo in connection with the agricultural possibilities, Contr. Gen. Agr. Res. Stat., No. 123, pp. 1–49, June 1951, Bogor.

[16] Pendleton, Robert L., Some results of termite activity in Thailand soils, Thai Sci. Bull., vol. 3, pp. 29–53, 12 figs., map, 1941; Importance of termites in modifying certain Thailand soils, Journ. Amer. Soc. Agron., vol. 34, pp. 340–344, 3 figs., 1942.

rice plants transplanted into the standing water and underlying mud. Unfortunately, over much of the kingdom the rainfall is inadequate to raise a crop of rice without some additional water either from streams or from higher slopes nearby.

Where the forest soils are too poor to be worth planting, and only the termite heaps are cleared, the farmers may go some miles to the steep slopes of the few hills in the region, kaingin the slopes (cut down the trees, burn them) and plant the cotton or upland rice among the stones on the shallow soil, where there are still sufficient plant nutrients in the surface soil from the weathering rocks to grow a crop. Because of the soil limitations rice is produced on about 90 percent of the cultivated land of the kingdom. By assisting inundation, irrigation in a large way has been applied to some of the soils of the Bangkok plain, but as a whole, conventional effective irrigation by direct flow from large canals is only now being developed. In the northern valleys, farmers cooperatively dig local irrigation ditches to bring onto their fields the water from mountain creeks.

In some portions of the Bangkok plain the water naturally floods very deeply. These areas require a special type of agriculture using the so-called floating rice. In this case the fields are plowed early, the seed broadcast before the heavy rains and the later deep floods, so that the water as it rises over the plain from the rain and the overflow of the rivers gradually raises the level of the water on the lower land between the rivers. The only danger is that when heavier rains fall earlier in the season the water in the lower portions of the plain may rise so rapidly that the plants cannot keep their heads above the water surface, in which case the rice may drown, but where the rice plants survive they may grow to a height of 10 feet or more and produce a fairly good crop. If the flood has not subsided, such a crop may have to be gathered from boats.

TROPICAL AGRICULTURE

There are two or three main divisions of this subject that should be considered separately. In the first place, there are the upland subsistence crops, that is, crops that are not grown like paddy on flooded fields. The average inhabitant of the Tropics produces most, if not all, of his food by a process called "kaingining," a method that under different names is employed in practically all the humid tropical lowland regions of the world.[17] On the usually poor soils of the humid tropical lowlands the forests are practically the cover crops,

[17] This method was described by Cook under the unfortunate name of "milpa." It is often called "shifting cultivation," but this term is not desirable because it implies, and has been described as a means of, food production by nomadic tribes, when in most cases the people who produce food in kaingins live in settled villages and only go out during the crop season to their kaingins.

and are the common property of the village they surround. Usually a village will have a settled existence and location and if possible permanent fields close by for certain crops, as in Asia for lowland rice.

When a villager wants to make a kaingin he blazes his claim in the forest early in the dry season. Then he cuts the underbrush and usually most of the big trees, felling them and allowing the slash to dry. Shortly before the rains begin the slash is fired and all the brush and branches and more of the big trunks of the trees are completely burned. Seldom does the standing forest catch fire, though the frequent burnings do scorch the edge of it and gradually force it back.

The ashes remain scattered over the ground. After the beginning of the rainy season the seeds of the crop desired are dibbled into the surface soil with a sharpened planting stick of some sort, often having a flat iron bit. A few seeds are dropped into each shallow hole; then a little earth is pushed over the seed, usually with the toe. Aside from a weeding or two, and the cutting of some sprouts from stumps, there is seldom need for any particular care of the crop plants, for following the years under forest the soil is sufficiently loose so that no cultivation or other stirring of the surface soil is necessary. Of course, if the crop is edible, it is necessary to protect it as it ripens against wild hogs, birds, and other pests. No livestock is needed in this type of agriculture for no plows or similar implements are used. Usually several kinds of crops are planted mixed in the kaingin. The labor required for production of food by this method is high, but even on relatively poor soil a crop can be raised in the kaingin. After one or two crops, or at the most, perhaps three, the field is left fallow; the villager hopes it will grow up again to forest trees. Whether it does, depends upon local conditions, particularly upon the need for land and upon the character of the soil.

Unfortunately, in some humid tropical lowlands there are some very serious grass pests, especially the Asian *Imperata cylindrica*, often known as cogon, lalang, or alang alang. This grass has deep underground rootstocks and small seeds with a feathery down, which are disseminated by the wind. If the soil is not too poor, and there are sources of seed, cogon may spread rapidly. The most serious objection to cogon is that it burns readily even when quite green, so that fire is apt to sweep across the old kaingin, burning the grass, and at the same time killing most of the seedling forest trees which, in a few years, might otherwise reforest the land. Only the so-called asbestos or fireproof trees survive the annual fires. It is probably this grass burning annually that is causing most of the extension of savannas in low latitudes.[18] Incidentally and most unfortunately, cogon grass is now getting a strong hold in the southeastern United

[18] Cf. Proc. Conf. Africaine des Sols, Coma, Kivu, Congo Belge, November 1948.

States. Not only has it been introduced and distributed in Florida, but recent reports are that in Alabama[19] it is also well under way. Though it does involve severe forest destruction, kaingining makes it possible for the farmers to obtain something to eat and some fiber for clothing from a relatively poor soil with little else but very simple hand tools and plenty of hard work. If the forest returns to the land within a reasonable time, perhaps after 5, 10, or 15 years, the same plot of land may be kaingined again. The main difficulty with this method of crop production is that it requires five to fifteen times as much land to produce the same amount of crop as can be obtained from a plot of reasonably fertile land year after year.

In regions such as the western Belgian Congo, where *Imperata* already dominates the landscape and there is no chance for the forest to come back naturally, the natives employ a laborious system of hoeing the surface soil up into little heaps, perhaps 18 inches high and 3 feet across, and planting cuttings of cassava in the heap. In this way the plant seems to be able to survive and produce food without too much competition by cogon grass, especially if some dry grass or roots are collected and burned on the heaps before planting the crop.

But even if the forest does come back on the land within a reasonable time, when it can be kaingined again, crops from these kaingins will do little more than maintain the family during the year. It is, definitely, a subsistence agriculture. Little can be produced for sale, even if there are buyers for any considerable quantity. Perhaps a neighboring village will use some of the produce, but only at a low price, and usually only in trade for something else. There is practically no money for fertilizers, and they are rarely used even though they may be bought at a reasonable price. The transport of fertilizer to the fields where it is applied is, in itself, a difficult problem, for roads are few. Good roads in tropical regions are usually costly. In humid tropical lowlands, profoundly weathered rocks, deep plastic clay subsoils, and the often torrential rainfall are serious and expensive obstacles to contend with and overcome in highway construction and maintenance.

PLANTATION CROPS

In humid tropical regions, both at low altitudes and at higher ones, there can be grown certain agricultural crops that the world wants and will pay for. Moreover, there are practicable ways of handling or processing the materials so that the products can be shipped overseas. These plantation crops may require a considerable amount of capital for developing the land, for building, operating, and maintain-

[19] Reported by Dr. Mark Baldwin in a personal communication.

ing the processing plant, and transporting the product to tidewater ports for export to temperate regions. Sugar, fruits, coffee, tea, rubber, and fibers are the usual plantation crops. These and others have usually been developed by foreign corporations with a competent technical staff and with adequate capital to invest in plant and equipment, as well as for research on control of pests and diseases, development of better and higher yielding varieties, and increase of effectiveness and economy of the processing plants.

Europeans who led in the development of plantation crops in the Tropics made some terrible mistakes, particularly in the earlier periods, when they attempted to raise rubber as an orchard crop, clearing the land of wild trees, terracing it, and keeping the land clean and well cultivated. This was not only expensive but was worse than useless; it led to serious soil erosion. Now it is realized that even in temperate regions it is not only necessary but preferable not to maintain the plantations in a "shipshape" condition. It is not difficult to understand that Hevea rubber, which is a wild forest tree not long or far removed from its native habitat, can grow more effectively and produce rubber more economically if it is maintained under forest conditions. Moreover, rubber does not require much processing, and can be produced by a peasant with simple equipment. Even before the last World War about three-fourths of all the rubber coming out of the Netherlands Indies was produced by peasants from their own small plantings of Hevea.

Sugarcane is a different type of crop. High-yielding cane of good milling quality responds significantly to cultivation and appropriate fertilization. The fertilizer can usually be delivered economically to the cane fields, for the need for rapid transportation of the cane to the mill necessitates an adequate transportation system, usually a light railway. To prevent serious deterioration of the cane and loss of sugar, the cane should be milled within 24 hours of the time of cutting. For effective, economical management of a sugar mill it is necessary to maintain chemical control, and this requires a sufficiently large mill to employ a chemist, and sufficient cane to maintain operation continuously, night and day. As a consequence, sugarcane growing for "plantation white" sugar production or for "centrifugal" or 96-percent sugar for export is not adapted to peasant farming to the same degree as Hevea rubber.

For Occidental consumption tea must be processed in a relatively large and expensive factory so that satisfactory quality can be maintained. To an increasing degree the tea gardens are owned and operated by peasants, and the fresh tea leaves delivered to the central factory every morning for processing. This gives a satisfactory quality of tea but, unfortunately, the peasant seldom seems to pay

adequate attention to the maintenance of soil fertility of his garden; he seems to be indifferent to the erosion of his soils. As a consequence native tea gardens are often in a shocking condition as, for example, in Ceylon. The deterioration of these valuable lands is sad to behold.

Coffee raising, too, requires considerable investment for proper processing of the berries in order to produce a good-quality bean, and coffee plantations are often extensive, so it is still mainly a capitalistic enterprise. The one important tropical crop that is produced mostly by peasant farmers is cacao. This crop is grown extensively along the Gold Coast, British West Africa, and in the American Tropics. European agriculturists have not yet made significant progress in producing cacao under plantation conditions and on a large scale; probably an important reason is the lack of any need for elaborate machinery for processing the "beans."

One of the outstanding tropical plantation crops is bananas. It is obvious that rapid transportation and effective cold storage are necessary if bananas are to be marketed in quantity in the temperate regions. Before the general incidence of sigatoka and Panama diseases in Central America, there were banana-shipping companies that marketed peasant-grown bananas in temperate regions. Now, with the need for rigorous control of diseases, and with the proven benefits of spray irrigation in even rainy regions, plantation growing of bananas has become the usual practice. The companies interested in producing and marketing them in quantity are careful in their selection of soils. Notably they did *not* settle in or utilize any of the vast areas of the Amazon Valley. Rather, they have gone to Central America, Jamaica, and now to the Pacific coast of Ecuador. Where possible they have selected volcanic soils. In general, banana soils must be well drained, nearly neutral in reaction, and located near a seaport. All planting, spraying, and irrigation must be carefully taken care of. In some cases the banana rhizomes are planted before the tropical forest trees are felled. After felling, but without burning, the banana plants grow up through the slash with relatively little help in cutting of branches that are smothering some of the plants. By the time the banana plants are ready to bear, the slash has decayed or been eaten by termites.

THE BELGIAN CONGO

The Congo River basin of central Africa is another vast region where the rainfall is heavy and well distributed, and where the relief is relatively low. The Belgians have spent a vast amount of time and effort in trying to rationalize kaingining and other agricultural practices that can be carried out in that region without the utilization of fertilizers.

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To give some idea of the magnitude of their experiments, it might be mentioned that the Central Agricultural Experiment Station at Yangambi has an area of 50,000 acres of tropical high forests where such experiments can be and are being carried out. In the Congo, it is particularly important to try to rationalize kaingining because of the severe transportation limitations on the importation of fertilizers. In central Africa it is out of the question to obtain fertilizers at prices that peasants can pay. Transportation of products out and of fertilizer in are both difficult and expensive. Africa does not have good waterways permitting oceangoing vessels access to the interior. Limited and expensive railway facilities must be used. Moreover, these involve repeated transshipment of freight.

In the Belgian Congo studies of the factors of plant growth under humid tropical conditions are being made. One of the things discovered is that it makes a big difference what kind of crops were last raised on the soil before the abandonment of the kaingin. It is also important to keep the soil as continuously covered with crop vegetation as possible to prevent loss of plant nutrients and other types of soil deterioration.

Belgian agronomists have been devoting much time and effort in an endeavor to rationalize the kaingin or shifting cultivation system of utilizing the tropical high forest and the secondary growth throughout a rotation lasting 15 or 20 years. This is called the corridor system because the separate but parallel plots of forest for each family are usually 100 meters wide and perhaps a mile long. To direct the peasant farmers most effectively, careful adherence to a regular rotation is insisted upon. In 1949 I visited one such colony in the equatorial forest of the Bambesa district in which over 19,000 peasant families had been settled according to such a plan. Kellogg and Davol [20] have described and figured the corridor system and the results obtained.

In the "educative" agriculture which has been worked out for the Congo peasants, production in quick succession of upland rice and corn is followed, where the climate is appropriate, by peanuts, cotton, then manioc (cassava), the main food crop, with which bananas are important as a secondary food crop. After the cassava is dug, the banana plants remain. Natural regeneration of forest trees occurs particularly well in the microclimate under the abandoned banana plants. Recently Kellogg has published a description of a newer form.[21]

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[20] Charles E. Kellogg and Fidelia D. Davol, An exploratory study of soil groups in the Belgian Congo, Publ. Inst. Nat. Étude Agron. Congo Belge, sci. ser., No. 46, p. 66 ff., 1949.

[21] Charles E. Kellogg, The Fifth International Congress of Soil Science, Leopoldville, Belgian Congo, August 1954, Proc. Soil Sci. Amer., p. 117, April 1955.

AGRONOMIC PRACTICES IN HUMID TROPICAL LOWLANDS

As the Belgians and others have found, the most effective methods of managing agricultural soils in the humid tropical lowlands are not the most effective under humid temperate zone conditions. It is always difficult to differentiate between what is traditional and what is empirical, and which will be the most effective soil-management practices in the long run. The Belgian agricultural scientists in the Congo, for example, insist that it is not possible to build up organic matter to any considerable degree in the soil, and that leguminous green manure crops are even less effective than grasses. They have found that the perennial grasses are much better for rejuvenating agricultural soils than legumes. They also emphasize mulches and as nearly continuous a succession of crops on the soil as possible, to keep the soil protected from scorching sun and beating rain. Greene reports [22] that in recent African experiments burning the leguminous cover crops and applying the ashes gives as good stimulation to the following crop as plowing under the green cover.

Tropical soils thus are, in general, low in plant nutrients, except the very small percentage of recent alluvial and recent volcanic soils which are usually really fertile. There are various reasons for this. In the first place, in the vast basins of the Amazon and the Congo, and in Borneo, the relief of the terrain is low. There is too little erosion to wash away the worn-out surface soil and so expose the less fully weathered-out soil material in deeper portions of the profile. This weathering is hastened by both the heavy rainfall and the constantly high temperatures. The result is that phosphorus, particularly, is strongly fixed in the soil because of the weathering processes which have liberated iron and aluminum; these accumulate in the soil and all too easily combine with phosphorus in forms that the crop plant cannot utilize. Without phosphorus, plants will not grow. Consequently, experimental work with fertilizers in central Africa, in humid tropical America, and in southeastern Asia indicates that phosphorus is usually markedly deficient for good crop production. For certain crops, such as sugarcane, nitrogen is an important limiting factor, but for many other crops nitrogen, relatively, is much less deficient than phosphorus, and in only a relatively few cases is potassium needed, as for tobacco and certain legumes. In Malaya there seem to be other plant nutrients which limit paddy growth but just what these are, and how they can be made good in plant nutrient, is not yet clear.

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[22] Dr. Herbert Greene, Adviser on Tropical Soils, Rothamsted, England, in a personal communication.

PADDY OR LOWLAND RICE

As has been suggested above, lowland rice is a unique crop. Most of the principles of agronomy that apply to the usual grain crops do not seem to apply to paddy. Just why this is so cannot yet be satisfactorily explained. The fact remains that rice, if it is grown on a soil that is well puddled and can have a few inches of water standing on it throughout the growing season, will produce some to eat when this soil is too infertile to produce any other grain crop. The puddling of the land eliminates most of the weeds, or at least so reduces their competition that the young transplanted rice seedlings can get a good start and grow well. It is obvious that the puddling materially reduces soil aeration around the roots of the rice plants; nevertheless the paddy seems to get along without aeration of the soil in the usual sense. The transplanting of the young rice seedlings into the fields is a laborious process, but it does insure a considerably greater yield of rice per acre every year than the use of any other method. Soils that are not so poor, but that can produce reasonable yields of upland grain crops, if planted to lowland rice, flooded, irrigated, and weeded, can produce about a quarter more rice grain than other grain crops.[23]

CONCLUSION

Humid tropical lowland soils can be used for crop production, and will have to be used more and more as the number of mouths to be fed increases. Lowland rice is undoubtedly the most effective food crop that can be grown on many of these soils, both because it is adapted to wet soils and also because on even very poor soils it will still produce something to eat. But the utilization of rice on an ever-increasing scale in feeding the world calls to our attention serious nutritional problems. No people who eat rice habitually will willingly eat it unmilled or even only partly milled (polished). The flavor of less than fully milled rice is not appreciated. Where increased milling by mechanical means, as power becomes increasingly available, replaces hand milling, beriberi and similar diseases also increase. There is the possibility of utilizing the parboiling system of rice processing before milling to reduce the loss of minerals and vitamins from the processed grain. This is worthy of more serious consideration. It is, moreover, a method that has been introduced in the United States for making the so-called "converted" rice.

This is, indeed, not an optimistic picture, but after 35 years of study of the possibilities and limitations of humid tropical lowland soils and their allied agricultural problems, it seems to me the realistic point of view, namely, that more and more of the people of the world, and especially of the Tropics, will subsist on rice . . . and like it.

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[23] J. Lossing Buck, in a personal communication.

Tree Rings and History in the Western United States[1]

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[With 4 plates]

INTRODUCTION[2]

The common opinion that the rings so obvious on cross sections of most trees may be counted to give the age of the tree, and that the succession of wide and narrow rings may be interpreted as reflecting the history of favorable and unfavorable growth years, is indeed old—surely the statement by Leonardo da Vinci near A.D. 1500 to this effect is the earliest only because far earlier ones were not recorded or have been lost, perhaps in the disappearance of the Alexandrian Library!

Despite this ancient recognition of tree rings as a historical index, modern scientific research on ring growth at first quite properly emphasized botanical and ecological aspects. By the end of the nineteenth century a truly vast amount of work had been done on the nature of such growth layers and their complex relationships to climatic and other factors.

In recent decades, however, many investigators in this country and abroad have sampled various forest stands and have measured several millions of annual rings in an effort to develop long chronologies which might represent, to some extent, histories of past rainfall, temperature, river flow, and other climatic variables. The stimulus for this activity arose, in good part, in an astronomical objective! Quite independently, it occurred to a Dutch astronomer, later renowned for his contributions on stellar statistics, and to an American astronomer,

[1] Reprinted by permission from Economic Botany, vol. 8, No. 3, July-September 1954.

[2] Literature citations have been almost completely omitted from this article; see research reports in the Tree-Ring Bulletin from 1934 on, and an outline bibliography in the Compendium of Meteorology, Amer. Meteorol. Soc., 1951, p. 1029.

studying variations such as those of the markings on Mars, that the rings of trees might directly or indirectly record year-by-year changes in the sun.

Julius C. Kapteyn, about 1880, examined oak sections from western Germany and Holland and derived a 240-year ring chronology. The later decades of this history corresponded well with rainfall data, and a strong, but quite unexplainable, cyclic variation of 12.4 years was present throughout. Fortunately for astronomy, Kapteyn evidently felt this work to be strictly extracurricular, for he carried it no further. But his single paper on the subject, a published lecture in Pasadena in 1908, is a delight to read for its simple presentation of essentials and its humility.

In contrast to this somewhat abortive effort, the program of research initiated by A. E. Douglass at Flagstaff, Ariz., in 1904, has been carried on for almost half a century at the University of Arizona, at Tucson, and has led to important developments in quite unexpected directions. The most spectacular development was a method which made it possible to precisely date many ruins and thus provide a time scale for the pre-Spanish cultures of the Southwest. This method is based on detailed matching or cross-dating of the patterns in tree rings—an application of the operation of forecast-and-verification, which is such an integral part of the scientific method. It proved to have far-reaching implications in climatic studies as well, for it was the essential key to the development of highly significant tree-ring histories of rainfall and other climatic variables.

We thus see that modern techniques in dendrochronology find their principal application in two fields of research: (*a*) dendroclimatology, that is, historical climatology based on fluctuations in ring growth, and (*b*) dendroarcheology, the dating of prehistoric structures and activities by the precise dating of ancient wood. Before we consider the contributions in these two fields, however, it may be illuminating to directly examine some tree rings of the sensitive type useful in dendrochronology.

The photographed outer rings in radial increment cores from the lower stem of selected living Douglas-fir trees are shown in plate 1. These represent the ring chronologies in recent decades in three localities of the Colorado River basin—the isolated and arid Nine Mile Canyon of northeastern Utah, the archeologically rich Mesa Verde of southwestern Colorado, and the Tucson area of southern Arizona—a range of over 500 miles north-south.

In the outermost ring at the extreme right in the upper photograph of plate 1, the band of light-colored earlywood must have been laid down largely during June and early July, as is characteristic of mountain conifers near the lower forest border throughout the western United States. The growth of dark latewood cells, which complete

the year's ring, is commonly found to be essentially over by the end of July. Since the tree was sampled June 6, 1950, the ring for 1949 is complete; that for 1950 had not yet started on this core. Similarly the Tucson core (lower), taken May 22, 1951, ends with the 1950 ring. The Mesa Verde core (center), on the other hand, was cut later in the season, October 2, 1951, and therefore has the 1951 ring complete.

That the same general pattern of thick and thin rings may be found in selected trees over a fairly large area is also illustrated in the photographs. These ring series represent not only the succession of good and poor growth years, but also, as will be pointed out below, a significant record of excessive rainfall or drought for the entire year preceding the end of the growth season. Anticipating these conclusions, we note some interesting details of climatic history in plate 1. Although the ring growth in individual trees must, even at best, be subject, to a considerable extent, to purely local or random influences, certain outstanding climatic events in the Southwest are well shown. The unusually snowy "haylift" winter of 1948–49 in northern Utah-Nevada resulted in the very thick 1949 ring in the Nine Mile tree (upper); the rainfall excess was less pronounced to the south, as the Tucson core suggests (lower). The widespread drought of the "dustbowl" year 1934 is represented by a very narrow ring in all three areas. The general deficiency in growth in the outer two decades or so in the more northerly areas of the Colorado River basin, and since 1920 in the Gila River tributary basin, represents a rainfall fluctuation of major economic importance.

Further, 1904 is generally represented by a narrower ring than 1902 in southern Arizona, in correct relation to the rainfall; but in northeastern Utah the trees, like the rain-gage records, show the July 1901–June 1902 interval to be the drier year. The flow of the Colorado River at the Grand Canyon is largely subject to the rainfall in northern Colorado and Utah; the water year 1902 (ending September 30) had the minimum flow of record preceding 1931.

Occasionally, as in 1931, ring growth in a year of over-all drought may not be correspondingly small, even in the most sensitive trees. Further, the low rainfall of the 1898–99 season and the correspondingly narrow ring which is observed over most of the Colorado River basin are in great contrast to the very heavy main-stream runoff for 1899, the result of an unusual concentration of heavy snows in the headwaters area. The importance of a sufficiently dense and widespread sampling network is thus obvious.

DENDROARCHEOLOGY

The method of overlapping patterns by means of which prehistoric beams may be dated is illustrated in highly idealized form in figure 1.

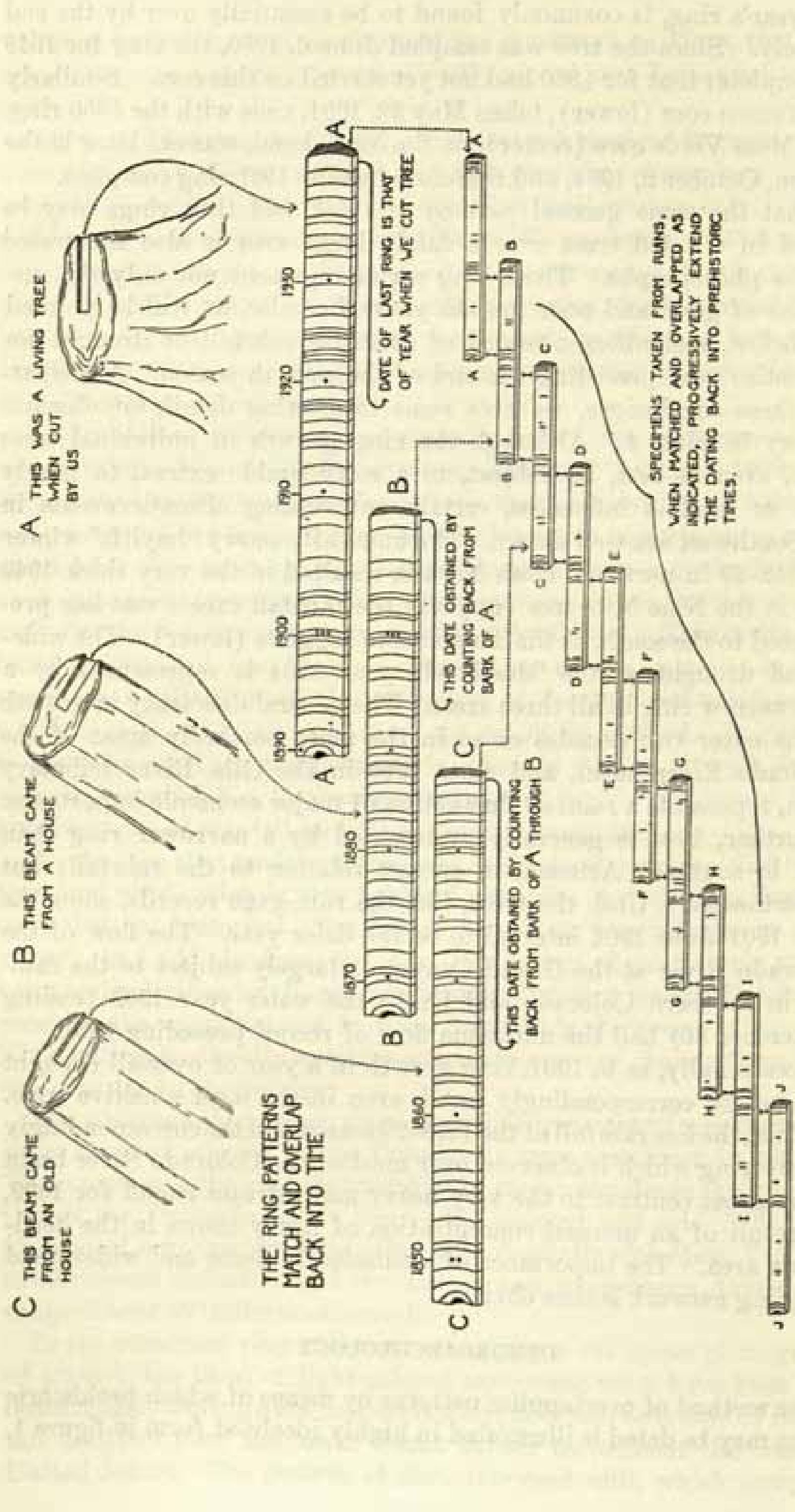


FIGURE 1.—The matching of ring spectra may not only show when a beam from an archeological site was felled, but may also lead to a long backward extension of the ring history of climate in living trees. (From Stallings, Dating prehistoric ruins.)

It is evident that matching the outer rings of an old beam with the inner rings in a living tree serves two purposes, namely, to date the old beam and to extend into earlier times the potential climatic chronology in the living tree.

Those acquainted with the great range of variability, which seems to be one of the universal properties of biologic elements, will recognize that such simple growth and perfect synchroneity from tree to tree as shown in the figure is quite unlikely to be found, even in trees of one species and within a small locality.

In many species and individual trees, the rings are so complex and variable that cross-referencing with other rings is not possible. Indeed, the botanist is familiar with so many reasons for such ring irregularity—specific characteristics, environmental influences, accidental events, and so on—that close parallelism in ring fluctuations among different trees might well seem the rare exception. It was fortunate for the pioneer work in dendroarcheology that it was applied in the Southwest, where species, climate, site, and wood collecting by the ancients all so happily favored the research. It should not be supposed, however, from the foregoing that such cross-dating is a characteristic only of certain Southwestern trees. This property has now been found present in many other regions, though nowhere in such good form in so many trees.

The tendency of the ring widths in dominant conifers of the Southwest—*Pseudotsuga menziesii*, *Pinus ponderosa*, *P. edulis*—to show approximately the same patterns over a large area made it significant to take broad-scale averages of many trees and thus derive a so-called master chronology. In this way local peculiarities in growth were minimized and the master chronology served as a general standard, against which beams from widely separated localities could be dated.

The development from living trees and relatively recent house beams of a master chronology which extended back into the time of the prehistoric Pueblos was not accomplished at once—the dating of the Cliff Dweller ruins, announced by Douglass in the National Geographic Magazine in December 1929, was preceded by over a decade of collection and analysis of archeological wood. A number of floating chronologies were developed, built up of ancient beams which cross-dated with each other but which could not be joined to the dated rings of the living-tree master record; a gap of unknown length had to be bridged. At last beams were obtained which did overlap the inner part of the master chronology, and immediately dates could be assigned to several scores of ruins in the Southwest. The most magnificent of these, the apartment houses of the "cliff dwellers," as at Mesa Verde National Park, were among the most recent, principally in the 1200's A. D.

The 1929 "Crossing of the Gap" initiated a period of intense activity in dendroarcheology. Earlier and still earlier ruins were dated in the Central Pueblo area; independent master chronologies were developed for the Rio Grande by W. S. Stallings and for northeastern Utah by Schulman; and now the dates of several hundred ruins and a chronology for the Southwest reaching back 2,000 years have been established. By similar methods dates have been obtained by various investigators for less ancient works of man in Norway, Sweden, Germany, and, particularly, by J. L. Giddings in Alaska.

As an example, we may note a recent application (1952) of this method, namely, the extension of the Puebloan chronology into B. C. times. The ring sequence in a very sensitive and consistent ancient beam of Douglas fir from Mummy Cave, northeastern Arizona, was definitively dated by comparison with master chronologies and with individual specimens long dated and available for several localities in that area. The inner part of a portion of the Mummy Cave beam is illustrated in plate 2.

This extension of the known chronology then made possible the dating of a number of short charcoal fragments from an early archeological site near Durango, Colo. Among these fragments was one with attached bark, the outer ring of A. D. 46 providing the earliest precise culture date presently available for the Southwest. Some of the evidence on which this extension of the Southwestern chronology is based is shown in figure 2.

It will be evident from the foregoing that, in general, the successful application of tree-ring analysis to archeological dating requires two principal favoring factors which are, unfortunately, by no means widely found:

1. One or more living species must exist in which, on at least some type of site, the annual rings are sharply defined, show fairly high year-to-year changes in ring width, vary in essentially parallel fashion along different radii and from tree to tree, and provide centuries-long sequences.

2. Available archeological beams must be of the datable species and from the datable types of sites, in general must overlap the time range of the master chronology for at least 50 years, and must have sufficiently high ring sensitivity to provide unqualified dating. (Since the ring chronologies in any region tend to be much alike over broad areas, the preceding restriction is not so severe as it might otherwise be.)

For specially favored localities of the Pueblo area, ring chronologies in some species are so simple and consistent that reliable archeological beam dating, given a sufficiently long master chronology, is an absurdly simple matter. But this is far from true in general. Definitive beam dating requires, first, a professionally secure solution of all

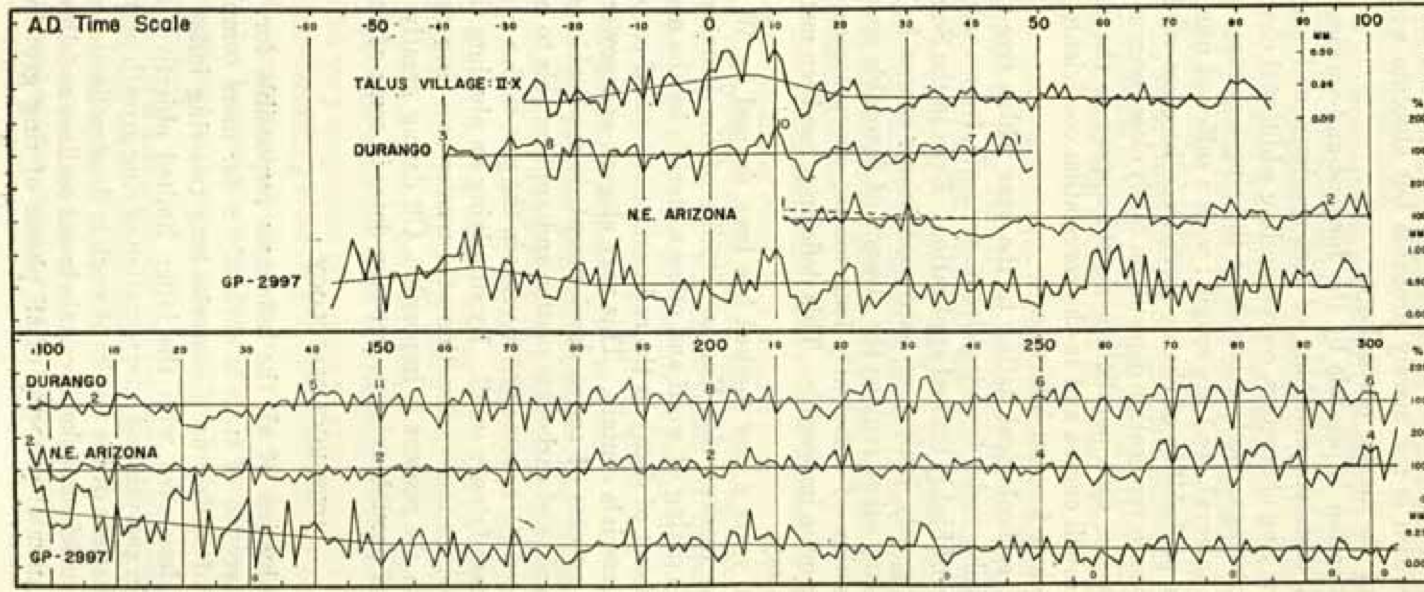


FIGURE 2.—The established mean growth records from A. D. 97 to 304 for the Durango, Colo., area, and from A. D. 11 to 304 for northeastern Arizona are paralleled and extended by the ring widths in beam GP-2997, cut by an early Arizonan shortly after the growth ring for A. D. 304 was completed. A previously undated set of charcoal fragments from the Durango Rock Shelters and one specimen from another ruin nearby were then tied into the extended record. Trend lines are superposed on the growth curves, and then number of component trees noted along the group curves. A zero year has been introduced for graphical continuity, so that earlier dates are displaced one year with respect to the B. C. scale; thus −49 A. D. corresponds to the narrow ring 50 B. C. in plate 2. (From Tree-Ring Bulletin.)

problems, such as those presented by false annual rings, and, second, an identification which is not merely probable but absolute with a selected segment of the master chronology.

Absolute identification is possible by the forecast-and-verification method. Given a tentative matching of test specimen and master chronology by some ring characters, corresponding additional characters (locally absent rings, check segments of the ring sequences outside the test-dated interval, etc.) are sought; with a sufficient number of verifications the probability of chance correlation becomes vanishingly small. Since such verification depends on fairly close congruence of both ring sequences, such parallelism should appear in the compared measured growth curves and in the correlation coefficients, especially of the check or forecast intervals.

The unqualified archeological dating to the year which tree-ring analysis makes possible under favoring circumstances is, from a worldwide point of view, of highly limited application. Even in the Southwest, ruins yielding only juniper or hardwood beams cannot be directly dated; in many other regions the absence of favorable species makes the construction of sufficiently long master chronologies extremely difficult or quite impossible. This deficiency has been met in a most unexpected way.

In the past few years a new method has been devised by W. F. Libby, then of the Institute for Nuclear Studies of the University of Chicago, for the dating of wood and other materials by the measurement of the amount of decay in the radioactive isotope of carbon, C^{14}, which these materials contain. This very elegant and powerful technique, now in process of active development, is applicable to a wide range of organic and carbonate matter and appears able to provide dates from about 300 to some 30,000 years in the past with a probable error that is satisfyingly small. By supplying an absolute time scale for regions where the construction of a master tree-ring chronology anchored in the present is impossible, C^{14} dating greatly increases the value of possible relative tree-ring dates in some of these regions.

DENDROCLIMATOLOGY

Principles.—Evaluation of all the influences responsible for the observed absolute growth of trees is obviously a far more complex matter than that of setting up a centuries-long tree-ring index of climate. Nevertheless, even with the latter limited objective, the numerous pitfalls in analysis and interpretation of ring growth permit no simple generalizations of the results of work in dendroclimatology. It will perhaps be sufficient to sketch certain broad outlines as follows:

1. A most fundamental property of all phases of ring growth is

variability; no conclusions based on one species or stand are necessarily generally applicable.

2. Coniferous species are usually preferable to hardwoods as sources of climatic chronologies because of longevity and ease of sampling and analysis[3]; however, their dominance in the most "sensitive" belts thus far studied may unduly determine this view.

3. As a single meteorological element becomes severely limiting in tree growth—e. g., temperature near the Arctic tree line or moisture near the lower forest border on mountain slopes of semiarid regions—the door seems to close to the entry of numerous random factors which in part control the fluctuations in radial tree growth in mesophytic areas.

4. A powerful tool for the solution of uncertainties and elimination of errors in ring identity is provided by the cross-dating technique already emphasized, in which the sequences of widths are matched ring by ring; only when a general tendency exists for parallelism among the various sequences, whether from a tree, locality, or large but climatically homogeneous area, are absolute dating and a significant index possible.

5. The dendroclimatic history of a region, if derivable at all, is an approximation which it is usually possible to replace with a better one. By repeated sampling of trees, selected according to improved field criteria, and by the construction of indices having a wider statistical base, it may be possible to go far toward avoiding or canceling out the innumerable biotic, climatic, and other factors which tend to distort the climatic index in trees.

Over-age conifers and chronology.—The spectacular achievement in archeological application of a botanical variable was not the only unexpected offshoot of dendrochronologic research. An intensive field search by the writer during the past 14 years for suitable tree sources of climatic data has brought to light a remarkable category of long-lived growth-stunted trees of high index value. These not only provide a unique kind of tree-gage record of past rainfall but exhibit very suggestive properties of growth under extreme adversity.

Rain-recording trees of great longevity are of specially high value in dendroclimatic studies, not only because they provide long histories but also because they make possible a greatly improved estimate, as compared with young trees, of the absolute values of past rainfall.

[3] Sampling is done principally with the Swedish increment borer. This permits a widespread survey without damage to the trees. The cores, about 4 mm. in diameter and up to 15 inches long, may be quickly surfaced with a razor blade by use of a sliding cut with the grain and at a low angle to it. On the resultant undamaged cellular surfaces, rings 2 to 3 cells thick, that is, less than 0.10 mm. wide, may be readily seen with a low-power hand lens and proper lighting, and several cores may be examined simultaneously.

Since the actual amount of annual radial growth of the stem is a function of the tree's age, species, environment, and other factors, the growth must be expressed in departures from the mean trend, preferably as percentages, in order to derive climatic indices. Obviously the position of the trend line fitted to the data may be raised or lowered if the series is extended; this so-called end effect is usually of little importance in the outer part of the growth curve of a mature tree, where the mean growth rate has usually approached a nearly constant value, but may be critical in the early part of the record, where the rate is usually changing fairly rapidly. Since the age trend in over-age chronology trees is especially shallow except in the earliest decades of growth, these trees can provide indices which represent a good approximation to absolute values. On the other hand, it is evident that any small secular trend in climate would be completely hidden in the fitted trend line and thus would not be determinable even in these trees.

A typical site on which such trees may be found is illustrated in plate 3. For many miles bordering the upper Colorado River, as in this area just west of Eagle, Colo., stunted Douglas firs and pinyon pines (*P. edulis* Engelm.) dot the steep slopes and are readily accessible from the highway. Standing dead poles are common. That this site happens to be a gypsum formation may have no great significance, since trees of comparable age, sensitivity, and slow growth have been found on sandstone or limestone slopes nearby; however, the number of extremely old Douglas firs per unit area is greater here than at any other site in the Rockies thus far sampled by the writer. A closer view of one of the trees in plate 3 is shown in plate 4, left. The dead snag above a small cluster of live limbs is characteristic of many over-age Douglas firs.

Another excellent source for drought-chronology trees is the Bryce Canyon National Park area. The stunted Douglas fir in plate 4, center, photographed in its dying years, has for some seven centuries been overlooking what is now called Bryce Point. In plate 4, right, the roots of this tree, exposed for hundreds of years, show a 2-foot loss of soil during the tree's life. The increment borer, which makes available 15-inch cores, provides a scale.

On the basis of several hundred sampled trees which were suitable for chronology studies and which exceeded the commonly assumed maximum age of about 500 years for Rocky Mountain conifers, certain characteristics of these drought-site trees emerge as probably very general in nature: (*a*) The absolute maximum ages of Douglas fir, ponderosa pine and pinyon pine in the Rocky Mountains area of the order of 1,000 years, and for *P. flexilis* (limber pine) in excess of

1,650 years [4]; (*b*) in addition to the observed tendency for maximum longevity on the most adverse sites, there seems to be a systematic though probably only indirect relation to latitude in the age limits of various stands of a given species; (*c*) the median ring width in the lower stem is about 0.30 mm.[5]; (*d*) this growth rate is often approached by early maturity—two or three centuries—after which the mean growth rate decreases very slowly; (*e*) the absolute minimum in total mean radial growth of the lower stem for an entire century is about 6 mm.; (*f*) the number of sapwood rings in over-age Douglas fir does not seem to be significantly related to either the number of heartwood rings or thickness of heartwood (for relatively young trees a systematic relation has been found by Stallings when groups of five or more trees are averaged); (*g*) false rings are almost completely absent in these over-age trees of all species except the scopulorum juniper, and there is a marked tendency to decreased incidence of locally absent rings in higher latitudes.

The asymmetric age distribution is most clearly noted in drought-type Douglas fir, which has been sampled on many sites throughout its range of some 30° of latitude in the inland western cordillera from central Mexico to Jasper National Park in Alberta. In a belt roughly defined by latitudes 30° and 40° N. in the Colorado River basin of eastern Utah and western Colorado literally thousands of trees may be found from 700 to 900 years old. Curiously, Douglas fir east of the Continental Divide in these latitudes and also in the Great Basin ranges to the west of the Colorado River basin shows much lower maximum ages. Although the distribution of such trees is, as already noted, highly dependent on local site conditions and therefore very spotty, there is a decided tendency to generally decreased maximum ages both northward and southward. Douglas firs in the 600-year age class may be found in considerable numbers on careful search in southern Utah and southwestern Colorado, but are, in contrast, quite rare in the forests of northern Arizona and New Mexico, and in the writer's knowledge are unreported in the southern areas of these States or in Mexico, where the average maximum age seems to be about

[4] The extraordinary longevity in certain stands of the high-altitude pines *P. flexilis* and *P. artistata*, observed in very recent field sampling by the writer, is being reported in detail elsewhere; the chronologies in the oldest known *Juniperus scopulorum* (the Jardine juniper of Logan Canyon, Utah, about 1,500 years) and in *J. osteosperma* or *utahensis* (about 1,650 years) are of doubtful climatic significance.

[5] It may be noted that Douglas fir on locally moist sites in this generally dry region may attain growth rates comparable to those in wet-climate regions: the "Hitchcock Douglas fir", over 125 feet in height and 7-foot base diameter, a recent windfall in the Santa Catalina Mountains near Tucson, Ariz., had an average ring width of 2.53 mm. for the 281 years of growth at the 12-foot level (5.06 mm. for the inner 50 years).

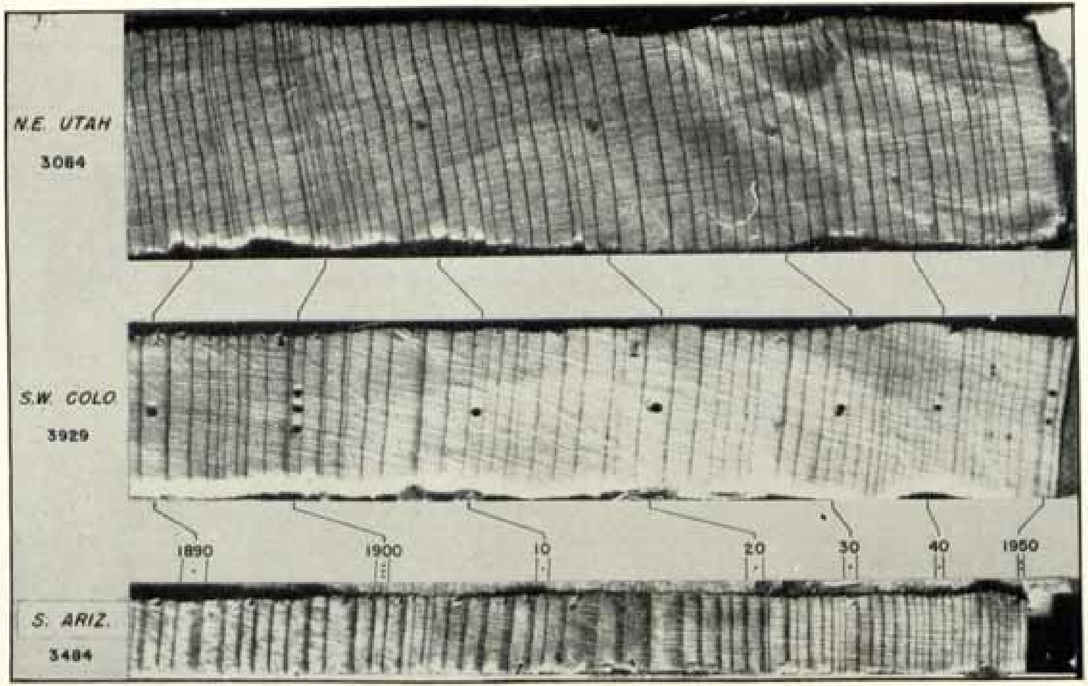
350 years. Maximum ages are generally less than 600 years northward from the 39°–40° belt to the Canadian border, are less than 500 years in southern British Columbia and at Banff, and may be no more than about 400 years near the northern limits for the species in central British Columbia and at Jasper Park.

Much less complete sampling of species other than Douglas fir does not allow more than a suggestion of the age distribution pattern. One limber pine maximum seems to occur near 44° in eastern Idaho, the pinyon pine in the 39°–40° belt, like the Douglas fir maximum, and the ponderosa pine in the 37°–38° belt in southern Utah; all species seem to show a marked decline in maximum ages southward and to a lesser degree northward of the respective belts of maxima.

Climatic histories.—In the Scandinavian Arctic, ring indices up to five centuries in length and with correlation coefficients of the order of +0.7 against observed growing-season temperature are obtainable, particularly at or near the northern tree limit; in the drier areas of the western United States and southwestern Canada, ring indices up to 1,000 years in length and with coefficients of +0.7 to +0.8 against total yearly rainfall ending in June or July are obtainable, particularly at the lower, or dry, forest margin. The significance of the ring record in upper timberline trees of midlatitudes is not yet entirely clear. For more stress-free areas, such as the eastern United States and central Europe, variant conclusions have been reported as to the climatic significance of ring growth—e. g., no relation, fair relation to the annual number of rainy days, pronounced effects in years of physiological drought, and moderate relation to rainfall of certain months. However, C. J. Lyon and others have shown that in such mesophytic areas the basis for significant ring histories does exist in the fair degree of cross-dating which may be found in selected species and trees.

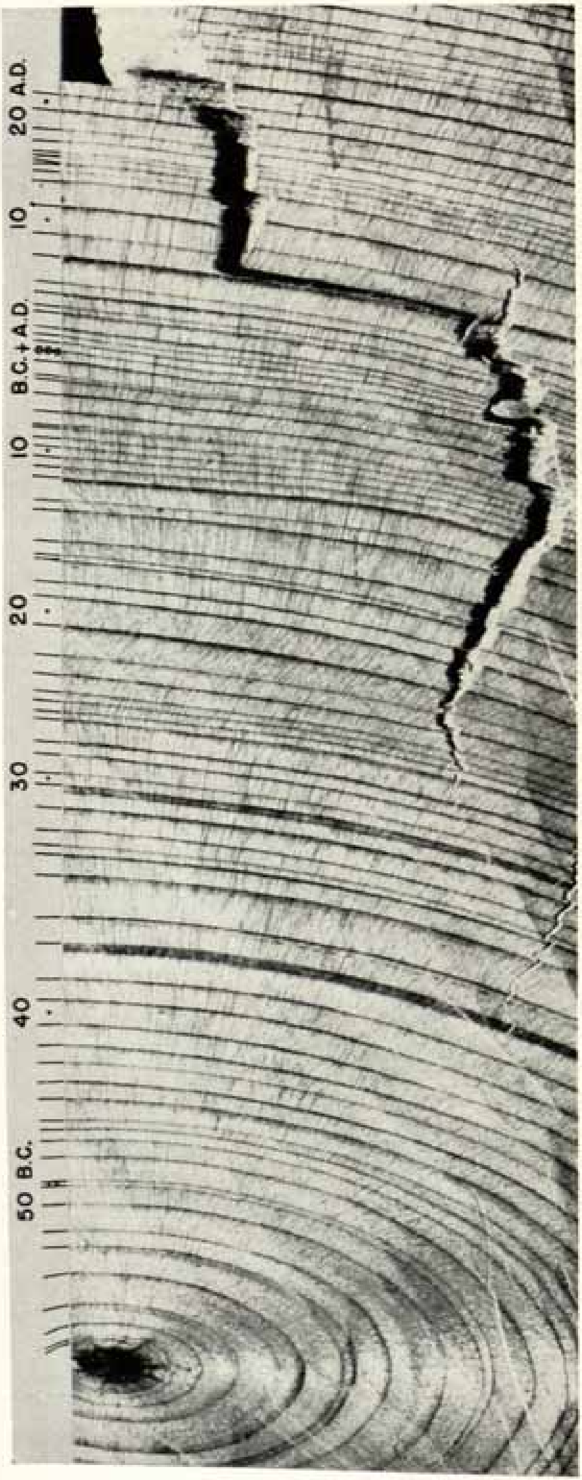
When properly analyzed, the sequences of ring width in over-age drought conifers may provide long and highly significant extensions into the past of the gage records of rainfall and runoff.

It must be emphasized, however, that the correlation observed for recent decades between growth and rainfall may be applied only with diminishing assurance to successively earlier centuries of growth index. It has already been noted that the effect of hypothetical secular trends in climate, such as a steady decrease in mean rainfall by as much as 5 percent during the life of a tree many centuries old, cannot at present be separated from the tree's decreased radial growth as a function of age. Other centuries-long, nonclimatic effects on growth rate, such as might conceivably result from radical long-term fluctuations in the activity of the soil micro-organisms, must remain as a source of uncertainty which only the most widespread sampling can in part reduce.

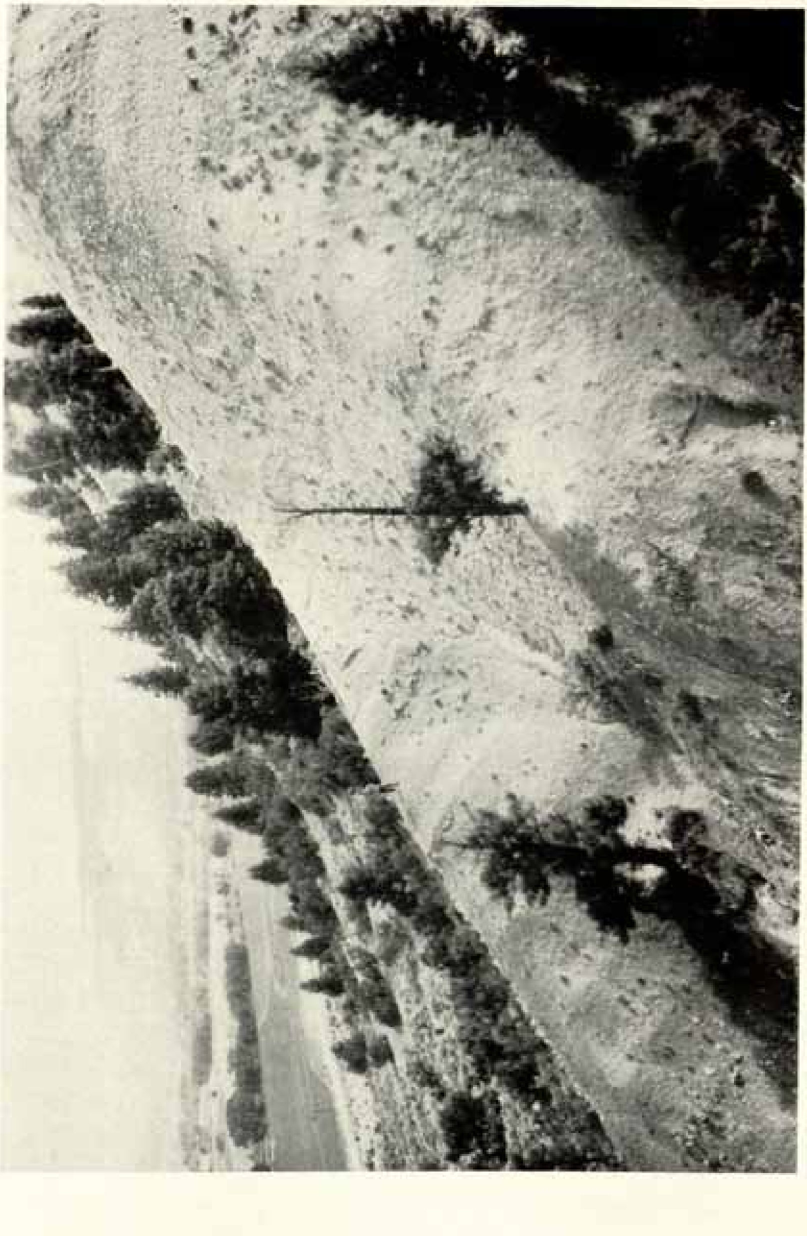


Cross sections, obtained as increment cores with a borer, of Douglas fir trees in three localities of the Colorado River Basin. The center of the trees was at the left of the photos, the bark at right edge. Each annual ring consists of a wider, light-colored, less dense portion of wood, formed in late spring and summer, and a much narrower, denser portion, formed later and represented in the photos by the perpendicular dark line to the right of each of the lighter-colored bands. The circular dark spots are decade date marks.

The ring widths in these particular dry-site and sensitive Douglas firs are closely proportional to the local rainfall. Most of the specially narrow or wide rings in any of these series may be recognized in the others, in accord with the generally widespread nature of drought or wetness in the Colorado River basin. Magnification: upper, ×7.0; middle, ×5.7; lower, ×2.4.



The first information about Southwestern rainfall in specific years during B. C. times was given by these annual rings in a recently dated Douglas fir beam, GP-2997, from Mummy Cave, in the Navajo Reservation, Arizona. Magnification: ×3.2.



Methuselah Douglas firs, growing very slowly, are characteristic on these arid slopes near Eagle, Colo.

Left, One of the 700-year trees shown on plate 3. *Center*, On the upper slopes and ridge tops in Bryce Canyon National Park many centuries-old trees like this one may be found, adding only an inch or so of radius per century yet providing a good year-by-year ring index of changes in rainfall. *Right*, A 4-mm. core from bark to pith may be readily obtained with the Swedish increment borer. Even the oldest resinous conifers quickly seal off the slight wound. Bit length above handle, 15¾ inches.

These considerations do not, of course, apply to fluctuations from decade to decade.

Three critical regional indices for the western United States, based on the ring growth of dry-site conifers of the type just discussed, are compared with appropriate water-year flow data in figure 3. The strong parallelism to be noted in this figure suggests that variations from year to year in the pattern of climate—distribution and intensity of storms, anomalous temperatures, the varying ratio in different years of runoff to rainfall, etc.—introduce only a relatively small error in such regional indices. It is highly probable that local biotic and other factors are to a substantial degree canceled out in these large-scale means.

Pronounced differences in some years in the march of the compared variables will undoubtedly be corrected somewhat with more representative tree indices which await development; minor errors in the river-gage data no doubt also exist and may be found and corrected. For example, reexamination of the early gage measurements at Fort Benton, Mont., recently led to somewhat reduced annual totals for the flow of the Missouri River at this station from 1891 to 1918, as shown in the figure. Despite such improvements in the data, however, it cannot be hoped that the observed correlation between river flow and the best regional tree indices will ever substantially exceed about +0.85, the presently observed value for some of the comparisons.

Certain features of the probable past rainfall in the western United States suggested by figure 3 may be specially noted. A strong though by no means perfect parallelism is evident between the Colorado River basin and southern California. The final 25 or 30 years of the 1500's in these regions seem to have been characterized in general by deficient growth, rainfall, and river flow of severity substantially greater than that in the recorded "dry spells" near 1900 and 1934; data based on the oldest trees appear to show, in fact, that this was the worst drought since the century-long dryness of the 1200's. The pronounced deficiency of the late 1500's seems to have affected the Missouri River basin also. The occurrence of two extremely deficient years in succession, however, is apparently quite rare, except during the major general minima. The bearing of inferences of this nature on water and power reserves, such as those at Hoover Dam on the Colorado, is perhaps obvious.

The minimum near 1900 in water supply in the Southwest, evident in the figure, is less severe in the upper Missouri River basin and, in fact, is replaced still farther north by what appears to be the greatest maximum in three centuries, at latitude 51° N. in Banff National Park.

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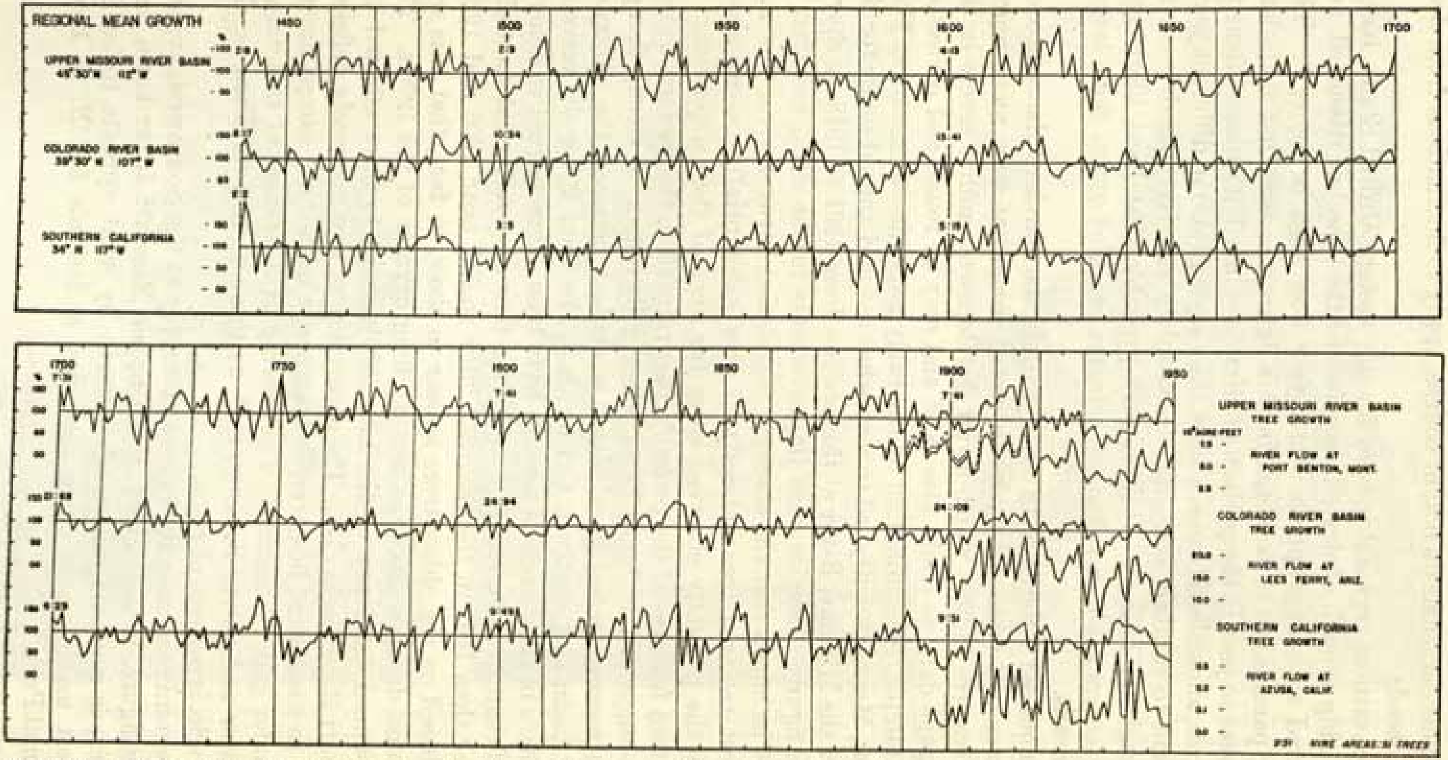

FIGURE 3.—Regional growth indices based on drought-sensitive trees of the western United States parallel the major and most of the minor fluctuations in measured river flow at appropriate stations and thus provide a view of the approximate march of this variable in earlier centuries.

It is of no little interest to find, in the over-age conifers, a strong suggestion that a century of great drought in the Southwest was followed during the 1300's by a century of seldom-interrupted rainy years. This very wet interval was perhaps the greatest in two thousand years in this region, as the supplementary evidence in the archeological chronologies suggests.

A great deal of attention has been devoted to the attractive hypothesis that tree-ring series contain a history of solar or other extraterrestrial variations, especially cyclic ones. Some instances of direct parallelism which have been noted between sunspot variation and the ring growth of certain trees are often cited and indeed may not be entirely due to chance. In general, however, extraterrestrial variations, if they are recorded by trees, must be in very complex form and are largely obscured by what seem to be random cyclic variations, for no aid toward the solution of the problem of long-range climatic forecasting is as yet established in growth cycles. Nevertheless, the very great importance of the problem and the strong evidence that real, if hidden, nonterrestrial effects are, in fact, present in such growth cycles, would seem to justify continued scientific inquiry.

Geographic distribution of drought conifers.—Do over-age conifers providing significant rainfall chronologies exist on other continents? It now seems quite certain that they do.

Along the foothills of the Patagonian Andes of Argentina, between latitudes 38° S. and about 43° S., dry sites comparable to the semiarid Rocky Mountain margins were sampled in early 1950 by the writer. In two coniferous species, *Araucaria imbricata* Prav. and *Libocedrus chilensis* Endl., the ring records showed the characters of sensitivity and cross-dating which are essential for the derivation of climatic chronologies. Since these conifers are developed only in scattered stands in a very thin and short belt between the line of the Andes and the plains, little area is available for development of long-lived strains. Yet the same inverse relation between mean growth rate and age was found for the two Patagonian species as for the conifers of the Rockies. When the analysis of these collections and others in southern Chile is completed, some hundreds of years of climatic chronology for Patagonia should be available.

Xerophytic conifers, and possibly some hardwood species, exist in apparently suitable environments in a number of other regions, particularly in Asia, and will probably be found to provide significant rainfall chronologies; little exploration seems yet to have been made of the extensive Siberian forests as sources of temperature chronologies. In the light of present knowledge, however, it appears that the combination of factors which makes possible long tree-ring histories of climate is particularly favorable and widespread in western North America.

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Geographic extensions of drought analyses.—How wide are districts providing significant rainfall chronologies such as those established? It now seems quite certain that they do.

Along the foothills of the Patagonian Andes of Argentina, between latitudes 38° S. and about 43° S., dry sites comparable to the western Rocky Mountain canyons were sampled in early 1950 by the writer. In two coniferous species, [illegible] and [illegible], the ring records showed the characters of sensitivity and cross-dating which are essential for the derivation of climatic chronologies. Since these conifers are localized only in scattered stands in a very thin arc about [illegible] between the line of the Andes and the plains, little area is available for development of long-lived stands. Yet the same inverse relation between mean growth rate and age was found for the two Patagonian species as for the conifers of the Rockies. When the analysis of these specimens and others in southern Chile is completed, some hundreds of years of climatic chronology for Patagonia should be available.

[illegible] conifers, and possibly some hardwood species, grow in apparently suitable environments in a number of other regions, particularly in Asia, and will probably be found to provide significant rainfall chronologies; but little exploration seems yet to have been made of the extensive Siberian [illegible] sources of temperature chronologies. In the light of present knowledge, however, it appears that the combination of factors which make possible long tree-ring histories of climate is particularly favorable and widespread in western North America.

New Light on the Dodo and Its Illustrators

By Herbert Friedmann
Curator, Division of Birds
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[With 5 plates]

Among the strange birds that have become extinct within historic times none was stranger, more unusual in appearance, than the dodo, a cumbersome, flightless, huge-bodied, heavy-billed bird, allied more nearly to the pigeons than to any other group of living birds. Furthermore, although but little is, or ever was, known of it, few birds became known by name to so many people otherwise not especially interested in natural history. "As dead as a dodo" has become a common expression of extinction, while the term "dodo" has also come to be used as a connotation of stupidity, based partly on the ridiculous appearance of the bird, made widely known by Tenniel's illustrations of it in Lewis Carroll's ever-popular "Alice in Wonderland."

As a living creature the dodo was known to civilized Europeans for barely a century, being first seen and described by the early Dutch mariners in 1598, and last recorded in life in 1681. Its extermination in its homeland of Mauritius was probably largely due to, and certainly expedited by, the introduction of hogs into that island. Fortunately, a few (a very few) dodos were brought to Europe, where they were depicted by several artists, the chief and most important of whom was Roelandt Savery. Two and three hundred years later numerous dodo bones were collected and brought to Europe for study. These, and the scant notes and sketches of the early voyagers to the remote Mascarene Islands where the dodos lived, still constitute the source of the little we know of these remarkable birds.

In the spring of 1954 the Museum of Fine Arts at Ghent, Belgium, held an important exhibition of the work of Roelandt Savery (1596–1639), an artist remembered chiefly for his picturesque landscapes literally crowded with animal life. It so happens that Savery, by virtue of his being the chief delineator of the dodo from life, has become important to the ornithologists as well as to students of European art. In the absence of other comparable observations of this

unusual fowl, Savery's renditions of it come close to being the main source of our concept of its appearance in life.

Among the items assembled at Ghent was a drawing belonging to the E. B. Crocker Art Gallery, at Sacramento, Calif. (Pl. 1.) This drawing, in black crayon, 140 x 210 mm., signed in gauche at the bottom: "Savery," is listed as "Deux . . . Dodo . . .," number 107 (p. 36) in the excellent catalog issued for the exhibition under the supervision of Paul Eeckhaut. In the discussion of a painting, "Landscape with Birds," signed and dated 1628, loaned by the Kunsthistorisches Museum, Vienna, number 75 of the Ghent exhibition, the dodo in it (pl. 3, fig. 2) is singled out for brief comment, with a reference to the Crocker Gallery's drawing, ". . . qui prouve que Savery a du exécuter son tableau d'après un spécimen vivant . . . ."

The Crocker Gallery drawing had remained unstudied and even unrecorded for many years. It was one of a number of old master drawings, formerly in the possession of Rudolf Weigel, of Leipzig, Germany, purchased in Europe by Judge and Mrs. Crocker in the early 1870's. According to the 1954 Ghent catalog it had at one time been number 448 of the "Ancienne Collection Rosey," a collection concerning which I have been unable to learn anything further.

For the next 80 years it remained, virtually unnoticed, in the Crocker files, labeled simply "Exotic Birds," under which title it was once included in a temporary exhibition in the late 1930's. Because it was unpublished and unknown, it was not mentioned in Strickland and Melville's monograph "The Dodo and Its Kindred" (1848) or in Rothschild's "Extinct Birds" (1907), and not even in Hachisuka's recent book "The Dodo and Kindred Birds" (1954).

It was first brought prominently into public notice in 1950 when the great assemblage of art treasures from Vienna was touring the United States. Among the paintings was the one by Savery mentioned earlier in this note. It came to the attention of John B. Matthew, then director of the Crocker Gallery, who recalled the Savery drawing in that museum and was stimulated to study it more carefully. He noticed that the drawing contained no less than three dodos and that they were depicted with webbed feet, whereas the painting included a single one, with no webs between the toes.

Savery's Vienna painting had long been well known and was often reproduced but was suspected more than once of not being wholly accurate inasmuch as the artist had apparently given the dodo two right feet. Because of this inaccuracy Matthews was inclined to suggest that where the artist had gone astray in one particular he might have done so in another, and that the error perpetrated therein was even greater than previously supposed and the bird's feet should have been shown with webs between the toes. Inasmuch as the drawing

was more probably done from life than was the painting, which contained so many kinds of birds as to be obviously a studio résumé of many original studies, it seemed as if the treatment of the feet could presumably be considered more realistic in the drawing than in the oil painting. The drawing was then put on display together with the Vienna picture when the Hapsburg treasures were exhibited at the M. H. De Young Museum in San Francisco, when it received its first publicity, first in the columns of the San Francisco Chronicle, and then shortly thereafter in Life magazine, for December 11, 1950 (pp. 171–172), under the unacademic title "New-Fangled Dodo." This brought it to the attention of the wide-reading art authorities in Belgium and resulted in a request for its loan to the Ghent show in 1954. When studied in connection with the other Savery materials assembled there, the authenticity of the Crocker drawing was apparently unquestioningly accepted.

The drawing definitely posed a problem: Was the dodo provided with webbed feet or was it not? All the delineations of the bird described and illustrated by Rothschild (1907) and by Hachisuka (1954) show no definite webs. However, there is one picture, which was unknown to these authors, that does agree with the Crocker drawing. Both Rothschild and Hachisuka list an oil painting containing a dodo by Savery, known to have been in the possession of a Dr. Otto Seiffer, in Stuttgart, Germany, in the 1870's, but which had disappeared without a trace some time before 1900. Fortunately for us, we do know something of the appearance of the dodo in this painting, as it was copied in pencil by the great naturalist Theodor von Heuglin, whose drawing was then used as the basis for an engraving by M. Toller, which, in turn, served as a frontispiece for Gustav Hartlaub's book "Die Vögel Madagascars und der benachbarten Inselgruppen," published in 1877. In this rendition the dodo is clearly shown to have webs between the three front toes. It follows, then, that Savery depicted the bird with webbed feet at least twice and that in all his other known pictures he gave it unwebbed toes.

It may be recalled at this point that many years ago George Clark, a resident of Mauritius (1866, pp. 141–146), discovered quantities of dodo bones in the mud in a marsh near Mahébourg, on that island. Associated with them he found many bones of flamingoes, gallinules, whimbrels, and egrets, all marsh-dwelling birds. Clark noted that all the dodo bones appeared "to have belonged to adult birds; and none bear any marks of having been cut or gnawed, or of the action of fire. This leads me to believe that all the Dodos of which the relics were found here were denizens either of this marsh or its immediate neighborhood, that they all died a natural death." Recently, Hachisuka (1954, p. 85) has commented that the observations of several earlier

writers that the dodo "was a shore bird are probably based upon conclusions drawn from most of the oil-paintings, which represent the bird standing near, or even in, water. Artists who painted the Dodo from life doubtless found them kept, not in cages, since they could not fly, but in enclosures along with other ornamental birds, such as Ducks, Geese, Storks, etc., i. e., near a body of water . . . He possessed no power to swim, as Peter Mundy clearly states." In fact, Peter Mundy (Journal, 1914) who was in Mauritius from 1628 to 1634, writes of "Dodoes, a strange kind of fowle, twice as big as a Goose, that can neither flye nor swimm beinge Cloven footed."

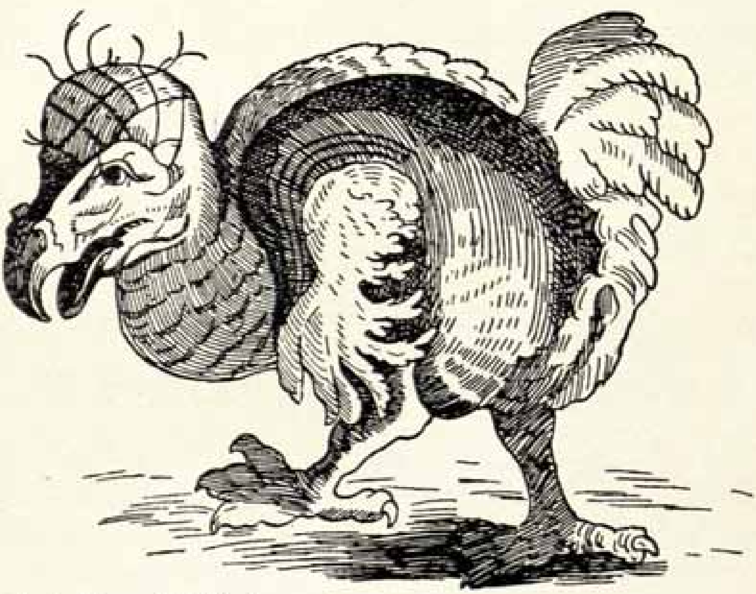
In response to my request, R. E. Moreau kindly made a careful examination of the actual foot of a dodo (pl. 4) preserved in the University Museum at Oxford, and he reports that there is no trace of webbing between the toes, agreeing in this respect with the bulk of the illustrations and with the literature. Moreau suggests that it is conceivable that the heavy phalangial pads under the toes might have flattened out somewhat in a captive bird walking on a hard surface. This might have suggested webs, but not more than that.

Apparently Savery himself was not too certain of the foot structure, as he did not endow the dodo with webs in most of his pictures; the fact that he did so twice may be attributed to carelessness, but it does suggest that he, our main first-hand observer of the bird in life, probably saw it but seldom, or only casually. His renditions of other kinds of birds are more consistently alike than are his dodos. It is a sad thing that the results of further study of this remarkable bird and its literature and iconography should reduce rather than enhance the little we know of it, but we cannot avoid the conclusion that our primary source of information about its appearance did not know it very well.

If we accept the Crocker Gallery drawing as an original by Roelandt Savery, as is done by the compiler of the Ghent catalog (who was in a better position to decide this than anyone else), it becomes possible to point out the sources of two better-known renditions of the dodo. The first of these is a painting by Jan Goeimare (pl. 2, fig. 1), done in 1627, now in Sion House, the seat of the Duke of Northumberland. It shows a dodo bending down over a smew. The painting is obviously a studio invention, as these two birds would not occur together in nature, and from this it follows that the painting was probably done from sketches made separately of the two birds. The dodo in it seems to be merely a poor version of the dodo to the right in the Crocker Gallery sheet. The body has become formless, the wings obviously wrong and made to conform with those of ordinary birds although reduced in size, the tail greatly minimized, and the pattern of the head altered, giving it a double frontal band and eliminating the peculiar cross-net lines on the cranium. Similarly, we find that Bontekoe's

Drawing of three dodos by Roelandt Savery. E. B. Crocker Art Gallery, Sacramento, Calif.

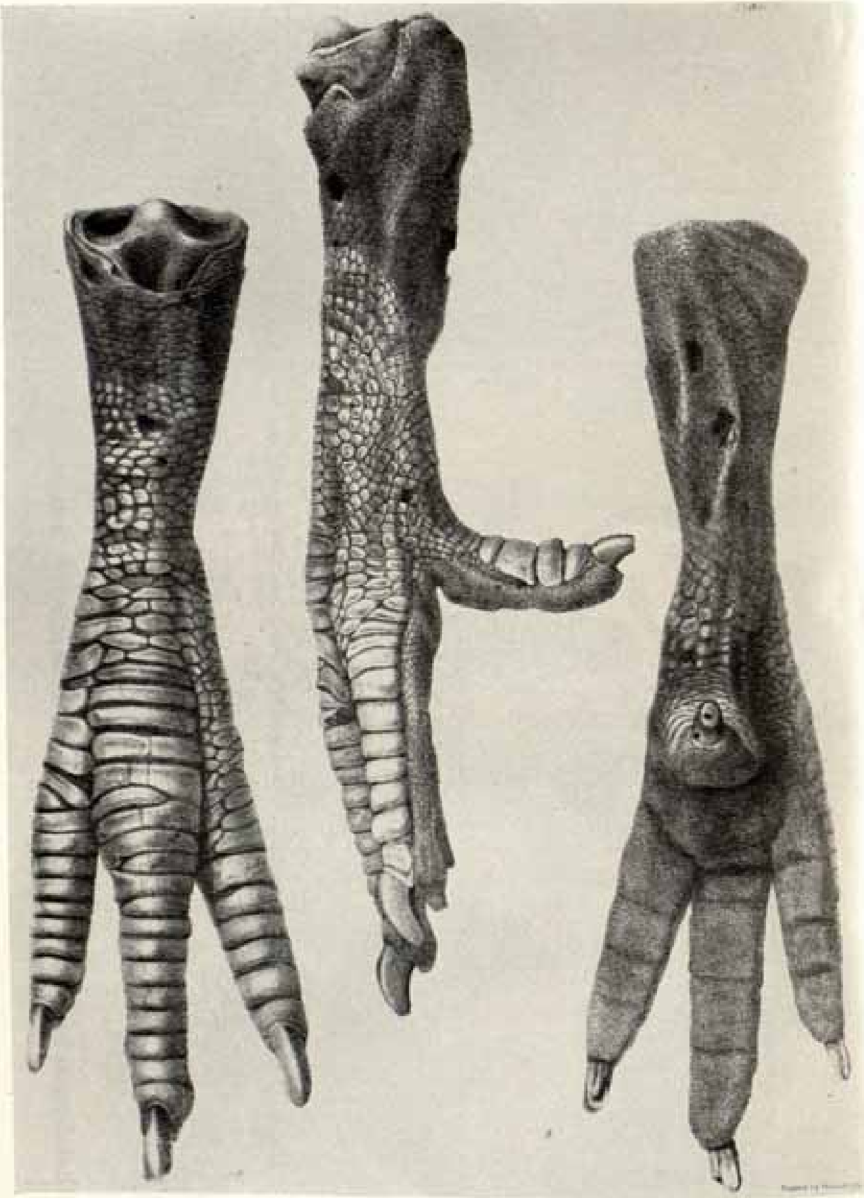
1. Jan Goeimare's dodo with a smew. Sion House; Duke of Northumberland. This dodo is a poor version of the one at the right of the Crocker Gallery drawing. (pl. 1)



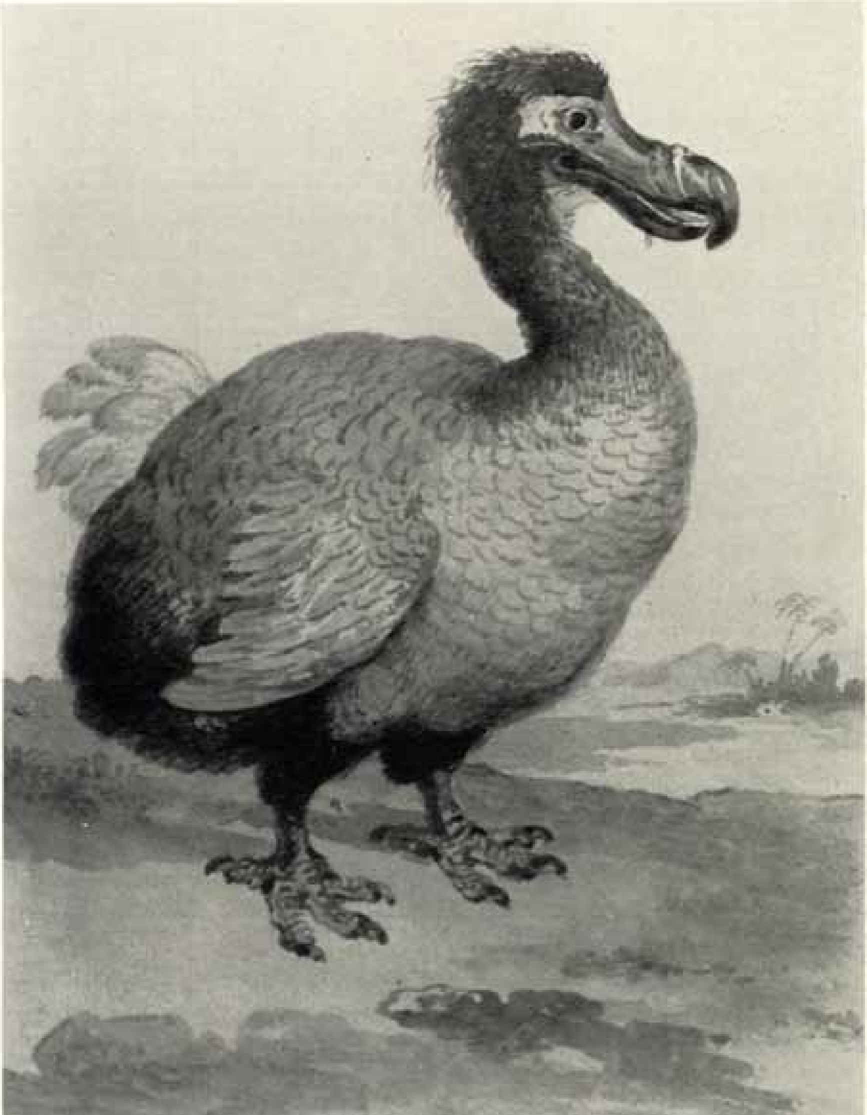
2. Bontekoe's dodo, published in Amsterdam about 1646. It is now preserved in the Bodleian Library at Oxford. This is a reversed or mirror image of the one at the left of the Crocker Gallery drawing. (pl. 1)

1. Web-footed dodo from the lost Savery painting, formerly in the Seiffer collection, Stuttgart. (From Hartlaub, 1877.)

2. Dodo from Savery's painting in the Kunsthistorisches Museum, Vienna. (Reproduced from Strickland and Melville, 1848.)



The preserved foot of a dodo showing absence of webs. (From Strickland and Melville, 1848.)



Drawing of a dodo by Aert Schouman. K. J. Hewitt Collection, London.

figure of a dodo (pl. 2, fig. 2), first published in 1646 and preserved in the Bodleian Library at Oxford, generally assumed by recent authors to be the white dodo of Réunion, is merely a reversed or mirror image of the one at the left of the Crocker Gallery's Savery, which is ostensibly based on the gray dodo of Mauritius! Credit should be given to Strickland who long ago thought Bontekoe's figure was based on the Mauritius bird. The fact that the Bontekoe figure is a mirror image suggests the possibility that the Savery drawing had been engraved at some time and that Bontekoe may have used a copy of the engraving. The feet in his drawing are rendered in a somewhat unclear manner as if he was not certain whether the toes should be webbed. Now that we have some inkling of his source, it is understandable that he should have been puzzled and uncertain, and it is possible to interpret the very broadened, almost coherent, toes in his picture as being webbed.

Years ago Newton (1876, p. 334) suggested that the figure of a dodo in A. de Wees's amplified Dutch version of Pliny's Natural History (many editions, 1650 to 1776), "is unquestionably of cognate origin with that given in . . . Bontekoe's Voyage . . . I think . . . the copper plate of the Pliny has not been copied from the woodcut of the Bontekoe, but the woodcut from the copper plate . . ." Later, Oudemans (1917, esp. pp. 56–64) brought together the variations of this figure, credited to Salomon Savery, in the different editions of de Wees's compilation. Most of them (Oudemans, figs. 13–18, 20) show the webs very clearly, while one (fig. 19) is similar to the Bontekoe one with very widened, almost coherent toes. According to Henkel (1935), Salomon Savery, like his uncle Roelandt, was an etcher as well as a painter and thus might have produced an etching from the drawing, which, in turn, may have been used by Bontekoe. Were it not for the fact that the drawing must have been done not later than 1627 (the date of Goeimare's derived painting), and also the fact that the Belgian art authorities apparently have accepted the Crocker sheet as an original by Roelandt, and not as a work of his nephew Salomon, I would have been inclined to suggest that the latter might have been the author of the sketch. Additional support for the drawing's being by Roelandt may be derived from the fact that the lost Seiffer painting (pl. 3, fig. 1), reported to be by him, also showed a web-footed dodo.

I am indebted to Ernest van Harlingen, director of the E. B. Crocker Art Gallery, for a photograph of the Savery drawing here discussed, and for the loan of a copy of the Ghent exhibition catalog.

Even though it has no bearing on the Crocker Gallery's drawing, the fact that another unrecorded painting of the dodo has come to my attention may be added to this discussion of early illustrations and illus-

trators of this fabulous fowl. This is a painting by van Kessel, done about 1660, now in the Prado, the great art gallery of Madrid. The dodo is included among a very large number of birds in a many-segmented triptych representing the Animal Kingdom. Hachisuka (p. 56) notes an oil painting of a dodo, "gaunt, but not moulting," done about 1655 by Johannes van Kessel. This picture, said to be in Munich, has been assumed by Killermann to be a copy of one done in 1605 by Clusius, whereas Oudemans considers it to have been done from a living bird. Hachisuka argues for the latter view, stating that "since it is improbable that a painter like Johannes van Kessel of Amsterdam would use the old picture of Clusius as a model for his painting of a Dodo, as Killermann thinks, it may be assumed that there was a living specimen in Amsterdam at the time . . ." This is supported by the fact that van Kessel did a second version of the dodo, in the picture now in Madrid. This later version, apparently overlooked by all previous writers on the subject, is clearly not based on the old, crude one by Clusius, a fact that is in complete agreement with the presumed independence of van Kessel from Clusius, his predecessor by half a century.

Still another unpublished, fairly early, although definitely posthumous portrayal of a dodo may be mentioned here. It is a small drawing on a sheet measuring only 8 by 6 inches, by Aert Schouman, a Dutch painter and engraver. Inasmuch as the artist was not born until 1710, nearly 30 years after the dodo was last seen alive, it is obvious that this sketch could not have been done from a living model. In fact, the uncertain, rather hesitant treatment of the tail, which is depicted almost as if it were something behind, on the far side of the bird and merely projecting beyond it, rather than an outgrowth from the posterior end of the body, bears this out. This drawing was included in an exhibition at Agnews, in London, in November 1955, and is now the property of K. J. Hewitt, of that city. I am indebted to both the dealer and the present owner not only for the photograph of this interesting sketch but also for permission to publish it here for the first time (pl. 5).

Schouman was born in Dordrecht in 1710 and died in The Hague in 1792. He painted numerous pictures in which birds played a conspicuous part and worked, on the whole, somewhat in the manner of the better known bird painter Melchior Hondecoeter, but he also did work in portraiture and genre. His drawing of a dodo shows the top of the head covered with rather ruffled, frowzy dark feathers, agreeing in this respect with van Kessell's Madrid version. It is not unlikely that he may have seen van Kessell's picture and partly derived his from it.

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George Catlin, Painter of Indians and the West

By John C. Ewers
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[With 20 plates]

George Catlin holds a unique position in the history of American art. No other artist painted as many pictures in the trans-Mississippi West in the days before the development of photography as did Catlin. No other painter of the early West is so well represented in museum collections today. Yet during his lifetime and for many decades thereafter Catlin remained a minor figure in American art. As recently as the 1930's his paintings were rarely exhibited in art museums or seriouly studied by historians.

In recent years, however, there has been a marked revival of interest in George Catlin's works. This has been due in part to a widespread and growing popular interest in the history of the romantic and always colorful American West. Historians and museum directors seeking pictorial interpretations of the real wild West before the advance of white settlement into the Great Plains have rediscovered George Catlin. He was never really lost. For generations he has been known to (if not entirely appreciated by) anthropologists, who have had primary responsibility for preserving the larger collections of his paintings in museum study collections. Yet the resurgence of popular interest in Catlin's paintings is a recent thing. Within the past decade the U. S. National Museum has received scores of requests from other museums for the loan of original oil paintings from its Catlin collection for temporary exhibition. These paintings have been shown to hundreds of thousands of interested viewers in museums of history, of science, and especially of art in all sections of the United States, in Canada, and in western Europe. Today, a century and a quarter after vigorous, restless George Catlin braved the dangers and discomforts of the Indian country beyond the Mississippi to record on

canvas the appearance of the land and its people, scholars and the public are gaining an understanding of the true significance of his paintings as pictorial documents of the old West.

THE MAKING OF A PAINTBRUSH PIONEER

George Catlin was born in Wilkes-Barre, Pa., on July 26, 1796. As a boy his interest in American Indians was aroused by Indian legends and stories of Indian captivities which were current in his neighborhood. His own mother, as a girl, had been taken prisoner by Indians in the bloody Wyoming Massacre of 1778. Young George loved the outdoors and cared much more for the world of nature than that of schoolbooks. He was fond of hunting and fishing. He also collected flint arrowheads and other Indian relics.

At the request of his lawyer father, George Catlin entered the law school of Reeves and Gould at Litchfield, Conn., in 1817. Next year he passed his bar examinations and began the practice of law in Lucerne, Pa. But his heart was not in the courtroom. Rather he was becoming more and more interested in art. Finally he sold his law books, abandoned his legal career, and moved to Philadelphia to devote full time to painting.

As a painter Catlin was entirely self-taught. With characteristic enthusiasm and industry he worked at his art until he developed skill both as a miniature painter in watercolors and as a portrait painter in oils. In 1824 he was elected an academician of the Pennsylvania Academy of Fine Arts, a select company that numbered among its members such masters of the period as Charles Willson Peale, Rembrandt Peale, and Thomas Sully. In 1828, 12 of Catlin's works (including both drawings and paintings) were exhibited by the American Academy of Fine Arts. One of these was a full-length portrait of the late Gov. De Witt Clinton of New York State, which Catlin had painted for the Corporation of the City of New York.

The fame of some of his sitters and the acceptance of his paintings in important exhibitions indicate that Catlin early achieved a degree of success as a portraitist. Yet he was restless, dissatisfied. As he himself later explained it, he was "continually reaching for some branch or enterprise of the arts on which to devote a whole life-time of enthusiasm." (Catlin, 1841, vol. 1. p. 2.)

While he was trying to find himself, Catlin saw some 10 or 15 Indian members of a delegation from the wilds of the "Far West" who were passing through Philadelphia on their way to visit the Great White Father in Washington. Sight of their handsome features and picturesque costumes rekindled Catlin's youthful enthusiasm for Indians. It changed the course of his career and provided him with a goal for his life's work. In later years he worded his new resolve thus:

> Man, in the simplicity and loftiness of his nature, unrestrained and unfettered by the disguises of art, is surely the most beautiful model for the painter, and the country from which he hails is unquestionably the best study or school of the arts in the world; such I am sure, from the models I have seen, is the wilderness of North America. And the history and customs of such a people, preserved by pictorial illustrations are themes worthy the life-time of one man, and nothing short of the loss of my life, shall prevent me from visiting their country, and of becoming their historian. (Catlin, 1841, vol. 1, p. 2.)

No missionary answering a call to service among a heathen people ever dedicated himself to a cause more steadfastly or energetically than did George Catlin to his self-determined task of "rescuing from oblivion the looks and customs of the vanishing races of native men in America." To this single purpose he devoted the best years of an amazingly active life.

TRAVELS IN THE INDIAN COUNTRY

George Catlin gained his initial experience as a painter of Indians among the acculturated, reservation Iroquois of western New York. His earliest known Indian subject is an unfinished portrait of the Seneca orator, Red Jacket, signed and dated "Buffalo, 1826." (It is reproduced in Haberly, 1948, pl. 2.) This work may have been the one exhibited in the American Academy of Fine Arts show in 1828 as "No. 68. Red Jacket, a sketch." In 1829 Catlin returned to western New York to paint portraits of other Seneca, Oneida, and Tuscarora Indians. That winter (1829–30) he painted an Ottawa Indian visitor to Niagara Falls and two Mohegan Indians. One of the latter was frock-coated John W. Quinney, noted as a missionary preacher among his own people (pl. 2, fig. 1).

In the spring of 1830, Catlin started on his great western adventure by traveling to St. Louis. There he gained the friendship of William Clark, best remembered as coleader with Meriwether Lewis of the overland expedition to the Pacific Ocean a quarter-century earlier, and then Superintendent of Indian Affairs for the western tribes. No one was in a better position to introduce Catlin to the Indians west of the Mississippi. In July of that year Catlin accompanied General Clark to Prairie du Chien and Fort Crawford to make treaties with the Iowa, Missouri, Sioux, Omaha, and Sauk and Fox. Early that fall he was at Cantonment Leavenworth on the Missouri painting Iowa Indians and members of tribes removed from the Eastern Woodlands—Delaware, Kaskaskia, Kickapoo, Peoria, Potawatomi, Shawnee, and Weah. Later that fall he accompanied General Clark to Kansa Indian villages on Kansas River where he executed a series of portraits of tribal leaders.

In the spring of 1831 Catlin accompanied Indian Agent (Major) John Dougherty up the Missouri and Platte Rivers to visit his charges,

the horticultural Pawnee, Omaha, Oto, and Missouri. The rough-and-ready appearance of Horse Chief, Grand Pawnee head chief (pl. 2, fig. 2), contrasts sharply with that of mild Mohegan pastor Quinney. Late that fall Catlin met the members of a small delegation of magnificent savages from the Upper Missouri, 2,000 miles upriver from St. Louis, who were passing through St. Louis en route to Washington in charge of their agent. Catlin obtained permission to make their portraits. Among them were The Light, powerful son of an Assiniboin chief (pl. 11, fig. 2), and Broken Arm (No. 176), a handsome Cree.

The year 1832 marked another turning point in Catlin's career. Prior to that time he had been content to paint only portraits. Nor is there evidence that he had taken extensive field notes describing his previous experiences among the redmen. In 1832, in taking advantage of a unique opportunity to visit the wild tribes of the Upper Missouri as a guest of the American Fur Co., Catlin expanded his activities. On this (and later) trips he would paint landscapes, Indian villages, and scenes illustrative of Indian life. He would also write extensive ethnological descriptions of the Indians he encountered. Catlin's expedition from St. Louis up the river Missouri to the mouth of the Yellowstone and return in the spring and summer of 1832 proved to be "the most fruitful journey in artistic and ethnographic material that he ever made." (Mathews, 1891, p. 597.)

Catlin was a passenger on the *Yellowstone*, which in that year was the first steamboat to ascend the Missouri 2,000 miles to Fort Union at the mouth of the Yellowstone. From the deck of the steamer he painted landscapes on the lower river. At Fort Pierre (mouth of Teton River) he painted a large series of Western (Teton) Sioux portraits and scenes in Sioux life. He also portrayed a visiting Cheyenne chief and his attractive wife (Nos. 143, 144). Continuing upriver he recorded more landscapes and the appearance of the Arikara village as seen from the passing ship (pl. 12, fig. 1). At Fort Union he met and painted leading men and women of those tribes who came in to trade—Assiniboin, Blackfoot (individuals of both Blood and Piegan tribes), Crow, Plains Cree, and Plains Ojibwa. He also painted a landscape indicating the natural setting of that fort (pl. 19, fig. 1) and a number of wildlife and hunting scenes on the neighboring plains.

From Fort Union Catlin returned downriver by skiff in company with two French-Canadian trappers who regaled him with tall tales of the Upper Missouri. They stopped at the American Fur Company's post, Fort Clark, near the Mandan and Hidatsa villages. There Catlin exploited his remarkable opportunity to record with pen and brush the appearance of those Indians, their villages, games, dances, and ceremonies. Catlin's little party then continued down the Missouri to St. Louis. Soon after his arrival Catlin learned that

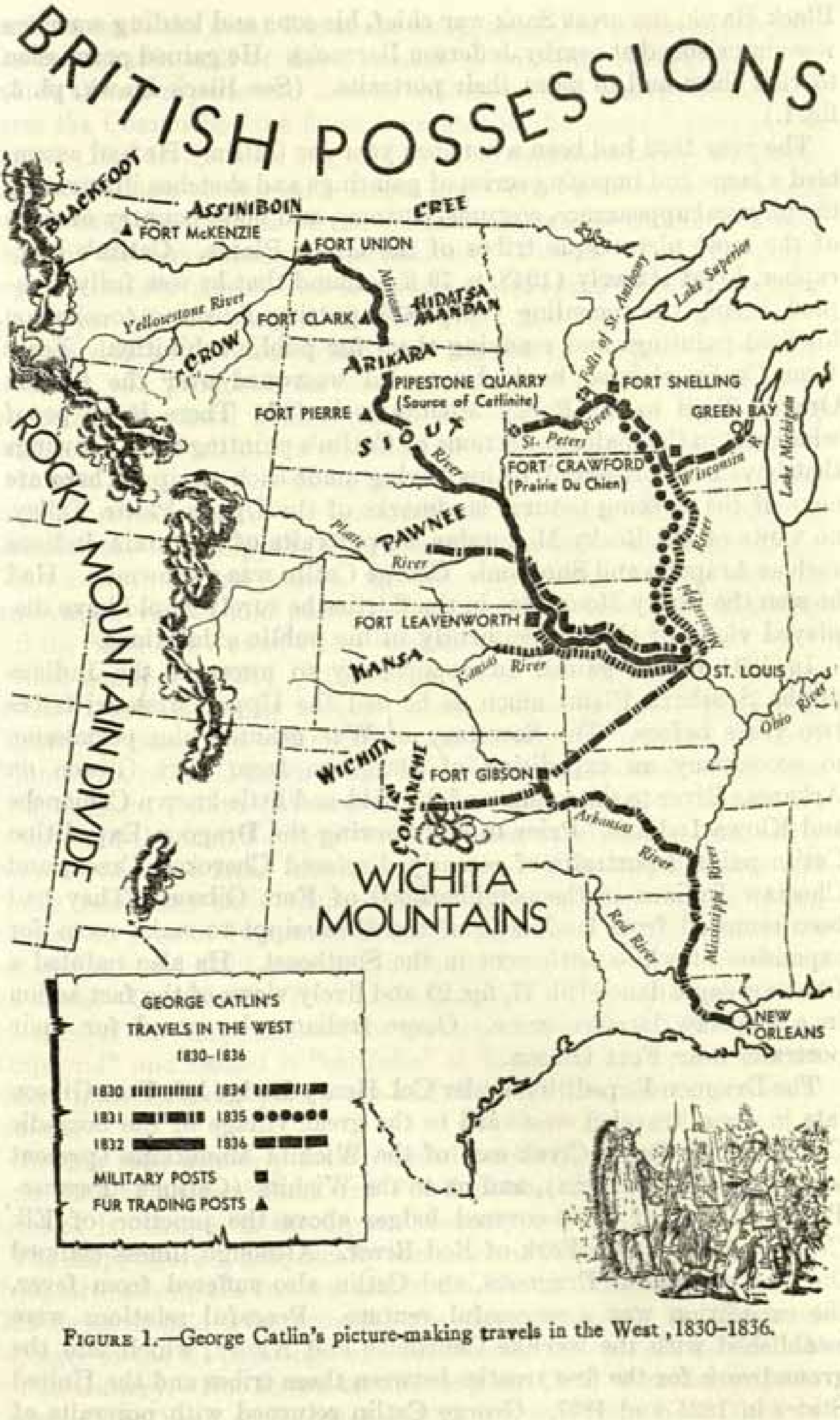

FIGURE 1.—George Catlin's picture-making travels in the West, 1830–1836.

Black Hawk, the great Sauk war chief, his sons and leading warriors were imprisoned at nearby Jefferson Barracks. He gained permission to visit them and to paint their portraits. (See Black Hawk, pl. 3, fig. 1.)

The year 1832 had been a bonanza year for Catlin. He had assembled a large and imposing series of paintings and sketches illustrating the physical appearance, costume, customs, and home country of some of the most picturesque tribes of the Great Plains. Catlin's biographer, Loyd Haberly (1948, p. 79 ff.), found that he was fully occupied during the suceeding year, 1833, putting finishing touches on his field paintings and readying them for public exhibition. Years later Catlin claimed he had traveled westward over the famous Oregon Trail to the Rocky Mountains in '33. There is no proof whatever, in the major collections of Catlin's paintings and drawings that have been preserved, of his having made such a trip. There are none of the striking natural landmarks of the Upper Platte Valley, no views of the Rocky Mountains, no portraits of mountain Indians such as Arapaho and Shoshoni. George Catlin was a showman. Had he seen the Rocky Mountains in the thirties he surely would have displayed views of them prominently in his public exhibitions.

In 1834 Catlin gained an opportunity to interpret the Indians of the Southern Plains much as he had the Upper Missouri tribes two years before. The Secretary of War granted him permission to accompany an expedition of Dragoons from Fort Gibson on Arkansas River to the country of the wild and little-known Comanche and Kiowa Indians. Prior to or following the Dragoon Expedition Catlin painted portraits of recently displaced Cherokee, Creek, and Choctaw Indians in the neighborhood of Fort Gibson. They had been removed from lands east of the Mississippi to make room for expansion of white settlement in the Southeast. He also painted a Choctaw eagle dance (pl. 17, fig. 2) and lively views of the fast action in a Choctaw lacrosse game. Osage Indians also posed for their portraits near Fort Gibson.

The Dragoon Expedition under Col. Henry Dodge left Fort Gibson late in June, traveled westward to the great village of the nomadic Comanche on Cache Creek east of the Wichita Mountains (present southwestern Oklahoma), and on to the Wichita (Catlin's "Pawnee-Pict") village of grass-covered lodges above the junction of Elk Creek and the North Fork of Red River. Although illness claimed the lives of several Dragoons, and Catlin also suffered from fever, the expedition was a successful venture. Peaceful relations were established with the warlike Comanche and Kiowa, which laid the groundwork for the first treaties between those tribes and the United States in 1835 and 1837. George Catlin returned with portraits of Comanche, Kiowa, Waco, and Wichita Indians. He also brought

back scenes in the great Comanche camp, several of which emphasized the remarkable skill of those Indians in handling horses, an ability which caused experienced cavalry officers on the western frontier to term the Comanche "the finest horsemen in the world." (See pl. 17, fig. 1.) Had Catlin been in good health throughout this trip he doubtless would have completed a larger and more varied series of scenes contrasting the customs of the nomadic Comanche and Kiowa with those of the semisedentary, horticultural Wichita. His 1834 paintings then might have rivaled in historical and ethnological importance his Upper Missouri series. Nevertheless, the 1834 expedition must be regarded as Catlin's second most significant venture in western painting. It produced the first known pictorial interpretation of important Southern Plains tribes. It also furnished some of the earliest views of wildlife and scenery in the Arkansas River Valley.

In 1835 Catlin shifted the scene of his travels and artistic endeavors to the forested country of the Upper Mississippi. That spring he ascended the Mississippi to the Falls of St. Anthony where he painted Ojibwa portraits and scenes. On the way downstream he recorded landscapes, visited and painted Eastern Sioux near Fort Snelling, and the Sauk and Fox of Chief Keokuk's village.

Next summer (1836) Catlin approached the Mississippi by way of the Great Lakes—by steamer from Buffalo to Green Bay, Wis. Thence by canoe via river, lake, and portage he traveled to Fort Winnebago, paddled down the Wisconsin to the Mississippi, up that river to Saint Peter's (Minnesota) River, and ascended that stream in search of the famed quarry where Indians cut the handsome, easily worked red stone from which many tribes of the Great Lakes and Plains fashioned their tobacco pipes. He found it in the rising country of present Pipestone County, Minnesota. Catlin painted a panoramic view of the quarry (pl. 19, fig. 2) and collected samples of the stone. Dr. Charles Thomas Jackson, of Boston, a leading mineralogist of the time, examined the stone, pronounced it "a new mineral compound" and named it "catlinite" in honor of the man who first widely publicized the quarry site and the importance of this stone to Indians.

On this 1836 field trip Catlin added portraits of Ojibwa, Winnebago, Menominee, and Sauk and Fox Indians. He also extended his series of landscapes in the Upper Mississippi Valley.

The map, figure 1, graphically summarizes Catlin's travels in quest of pictures among the Indians and in the West in the years 1830–1836. This series of field trips provided the source materials for the great majority of the oil paintings in what later became known as Catlin's Indian Gallery. Not shown on this map are Catlin's earlier trips to western New York or his later (1837) journey from New York to

Charleston, S. C., to obtain portraits of Osceola (pl. 6) and those other Seminole and Yuchi Indian prisoners held at Fort Moultrie.

INTERPRETING INDIANS TO THE PUBLIC

George Catlin made a virtual second career of interpreting his art to the public. He began exhibiting his Indian paintings in Pittsburgh in 1833 and thereafter showed them in other midwestern river towns. It was not until after he enlarged the collection through his field trips of 1834 to the Southern Plains and of 1835–36 to the Upper Mississippi that he was ready to present his Indians on canvas to the critical eyes of New Yorkers. Catlin's Indian Gallery opened at Clinton Hall late in 1837. It was such a hit with sophisticated New Yorkers that the artist had to move his vast one-man show to Stuyvesant Institute on Broadway. Later he exhibited it in Washington, Philadelphia, and Boston to large and appreciative crowds.

At Faneuil Hall in Boston the English phrenologist George Combe saw Catlin's Indian Gallery. It was one of the sights really worth remembering on his visit to this country. He said of it—

> The pictures, as works of art, are deficient in drawing, perspective, and finish; but they convey a vivid impression of the objects, and impress the mind of the spectator with a conviction of their fidelity to nature which gives them an inexpressible charm. (Combe, 1841, vol. 1, p. 70.)

Many other critics as well as the public succumbed to the charm of Catlin's show. They were willing to overlook the artist's technical limitations in view of his obvious sincerity and the tremendous interest of his subject matter. No one had brought the Wild West to civilization in pictorial form for everyone to see before.

In the fall of 1839 Catlin packed his Indian Gallery and sailed for Europe. He opened in London's Egyptian Hall. The published catalog of this exhibition of Catlin's Indian Gallery listed 507 numbered paintings, 310 of them portraits. In the same hall he exhibited a fine collection of Indian artifacts—costumes and ornaments, weapons, musical instrument, tools, and ceremonial objects, even a full-sized Crow Indian tipi with a cover of 25 buffalo skins.

For nearly five years Catlin's Indian Gallery was exhibited in England. Meanwhile Catlin the artist gained a reputation as an author. In 1841 his first and most popular book appeared, a 2-volume work entitled "Letters and Notes on the Manners, Customs and Condition of the North American Indians." In it Catlin combined the tall tales of an adventure book with sound ethnological information. Reprinted many times, this has remained a classic description of the Indians and the West. It was illustrated by 312 plates of little line drawings (some less than 2½″ x 3¼″, none larger than 5″ x 7″). The great majority of these pictures were simplifications of original

oil paintings exhibited in Catlin's Indian Gallery and executed prior to 1840. In 1844 he published "Catlin's North American Indian Portfolio," a handsome collection of 25 large (18″ x 12¼″) lithographic reproductions of his most popular paintings. Although the crude linecuts in his first book failed to do Catlin's work justice, the carefully drawn and colored lithographs in the Portfolio improved upon some of the originals. (Compare Catlin's painting of the Sioux scalp dance with the colored lithograph of the same subject, pl. 14.) In the lithograph the figures are more realistic, the details more sharply defined, the action more intense.

In the summer of 1845 Catlin moved his exhibition to Paris and exhibited there until the following spring. Even before that time Catlin began to employ live Indians to give dances and demonstrations in his exhibition hall, adding the attractions of sound and action to the static picture gallery and museum. Thus Catlin anticipated the appeal of the Wild West Show the year before Buffalo Bill was born. In 1848, after the fall of his French patron, King Louis Philippe, Catlin returned to London. "A Descriptive Catalogue of Catlin's Indian Collection" (1848a) listed 607 paintings. This was 100 more than he had shown in London previously. Among them were 35 portraits of Iowa and Chippewa Indians who had performed for him in 1845–46. The other new pictures were primarily wildlife and hunting scenes developed from old field sketches and from memory of his western travels more than a decade earlier. But the new pictures were not enough to insure success for the exhibition. Catlin's Indian Collection was no longer a novelty to the English public. Catlin ran heavily into debt.

PRESERVATION OF CATLIN'S INDIAN COLLECTION

Catlin's impatient creditors were beginning to auction off his belongings when a wealthy fellow American appeared in the person of Joseph Harrison. Mr. Harrison paid off Catlin's indebtedness, took over the greater part of his collection as security and shipped it to his home town of Philadelphia.

Years passed. George Catlin, the artist, after a vain effort to sell to the Government his Cartoon Collection, comprising revised replicas of his earlier works and paintings based upon later travels in South America and the Far West, died in Jersey City, N. J., on December 23, 1872. Joseph Harrison also passed away. Then one day in 1879 Thomas Donaldson, a lawyer from Idaho Territory who was interested in Indian affairs, learned that the original Catlin collection was in Philadelphia in the possession of the Harrison estate. The collection was said to have been through two fires since its arrival in Philadelphia from Europe. It was also believed to be in a dilapidated

condition. Spencer F. Baird, then Secretary of the Smithsonian Institution, and Mr. Donaldson were eager to see that as much of the collection as possible should be salvaged and preserved. Donaldson's suggestion that the collection be made a part of the national collection was received with favor by Mr. Harrison's widow. On May 15, 1879, the George Catlin collection was given to the Nation by Mrs. Joseph Harrison of Philadelphia.

Examination of the valuable ethnological specimens revealed that many of them were destroyed by the actions of fire, water, and insect pests. There is no record of paintings in the collections which may have been destroyed. But it is remarkable that by far the greater part of Catlin's original collection of oil paintings was salvaged. No fewer than 80 percent of the 507 paintings listed in Catlin's Indian Gallery on its London opening in 1840 are preserved in the Division of Ethnology of the U. S. National Museum. One-third (33) of the additional 100 paintings which he executed in Europe between 1840 and 1848 are also preserved there.

CATLIN'S PAINTING METHODS

George Catlin rarely mentioned his painting methods in his own writings. His pictures, however, reveal two distinct styles. One of these may be termed his studio-portrait style. Its outstanding example is his portrait of Osceola executed in 1838 (pl. 6). Osceola was then a Seminole War hero for whose portrait there was a popular demand. Catlin visited him in prison and slowly and realistically rendered Osceola's physical appearance and the details of his costume. Osceola's grandfather was a Scotchman and the Caucasian strain is apparent in the features and complexion of Catlin's portrait. Few other half-length portraits by Catlin approach this one as finished works of art.

Catlin's second style we may term his impressionistic or field-sketching style. He achieved it through a remarkably disciplined coordination of eye and hand, quick observation, and rapid execution. If his subject was a person, Catlin tried to catch a likeness in a few deft strokes of his brush. If it was an Indian activity, he merely suggested the position and actions of the figures with a like economy of time and paint. If it was a landscape, he indicated the general character of the country without dwelling on the details. This bold simplification of man and nature is typical of the great majority of paintings in the Catlin Collection in the U. S. National Museum. Only by employing a sort of pictorial shorthand could even the energetic Catlin have performed the amazing feats he accomplished on some of his field trips.

In the summer of 1832, for example, George Catlin spent exactly 86 days on the Upper Missouri from Fort Pierre northward (May 23 through August 16). During that period he traveled upriver to Fort Union at the mouth of the Yellowstone by steamboat and back downstream by skiff. This travel averaged 18 miles per day. In addition he participated in buffalo hunts, watched prolonged and complicated ceremonials (including the 4-day Okipa of the Mandan), talked with officials and employees of the American Fur Co., and gathered material for a series of popular travel letters for the *Commercial Advertiser* which he later expanded into the greater portion of his 2-volume book of 1841. At the same time he created more than 135 pictures—some 66 Indian portraits, 36 scenes in Indian life, 25 landscapes and at least 8 hunting scenes. Only a man of boundless energy, roused to a feverish pitch of creativity, could have performed all these tasks in so short a period. Holger Cahill, the art critic, who has examined the entire collection with me, expressed the opinion that Catlin may have painted some of these Upper Missouri pictures in a matter of minutes. Yet the series of paintings resulting from this 1832 expedition comprise the most important part of his oeuvre.

In addition to his oils, Catlin apparently made rapid full-length pencil or pen-and-ink sketches of many of his costumed Indian subjects and sketchbook renderings of some of his scenes of Indian activities. He described his method of preparing the most controversial of all his paintings, those illustrating the Okipa ceremony which he was permitted to observe among the Mandan that summer, as follows:

> I took my sketch-book with me, and have made many and faithful drawings of what we saw, and full notes of everything as translated to me by the interpreter; and since the close of that horrid and frightful scene, which was a week ago or more, I have been closely ensconced in an earth-covered wigwam, with a fine sky-light over my head, with my palette and brushes, endeavouring faithfully to put the whole of what we saw upon canvas. . . . I have made four paintings of these strange scenes, containing several hundred figures, representing the transactions of each day. (Catlin, 1841, vol. 1, p. 155.)

Add to this at least 20 portraits of Mandan, Hidatsa, and Arikara Indians and a score or more of landscapes and scenes in Indian villages and we have the production of Catlin's short stopover in the neighborhood of Fort Clark. Surely, there must have been days during this stay when Catlin created more than a half-dozen pictures.

Recent cleaning of a number of paintings in this collection has revealed some of the tricks Catlin used to save time and shortcut his field studies. He commonly painted the backgrounds of his landscapes and scenes first. Then he drew his figures *over* the backgrounds. In some pictures the figures are so thinly painted that the backgrounds

under them show through. Catlin quickly roughed in the figures in brown outline. If he had time he filled in the outlines. Catlin's field portraits were started in this same technique of rapid outlining in brown. Sometimes he never bothered to develop any part of the painting but the head. (See pls. 2 and 7.) At other times he added or refined details after his return to civilization. An article in the *Pittsburgh Gazette* of April 23, 1833, the spring following his busy summer on the Upper Missouri, refers to his practice of touching up his fieldwork in the studio:

> The total number (of paintings) which he commenced during his expedition is very large, most of them are yet in an unfinished state, he only having had sufficient leisure to secure correct likenesses of the various living subjects of his pencil and the general features of the scenery which he had selected, the backgrounds and details being reserved for the labours of a future time.

Probably Catlin paid much more attention to his portraits in the studio—adding backgrounds and finishing touches—than to his scenes in Indian life. He was content to let some of his oil paintings of Indian activities remain as rough suggestions, little more refined than the crude pictographs drawn by Indians themselves. Years later (in the 1850's) he redrew some of these subjects in greater detail in pencil retaining the basic composition but sharpening the individual figures. Compare Catlin's painting of Sioux moving camp (1832) with his pencil rendering of the same subject 20 years later (pl. 13).

UNUSUAL HISTORICAL SIGNIFICANCE OF CATLIN'S WORKS

As historical documents George Catlin's paintings offer a broad panorama of the Wild West as it appeared a century and a quarter ago. Indians were then as independent as their aboriginal ancestors had been when they met the first white explorers. The Great Plains were still Indian country. The few white men who entered it were mostly traders and trappers. Cowboys, prospectors, land surveyors, and homesteaders were unknown there in the 1830's. The buffalo was the Indians' staff of life. The bitter Plains Indian Wars that followed settlers' disturbances of native hunting grounds were yet far away. Indeed Catlin traveled almost alone through the country of the warlike Sioux before either Sitting Bull or Custer were born.

Catlin journeyed up the Missouri 28 years after Lewis and Clark ascended that river on their trek to the Pacific. The country and its native cultures had changed little in the intervening years. Three of Catlin's works are especially reminiscent of the Lewis and Clark Expedition. One is a portrait of the aged Hidatsa chief Black Moccasin (pl. 4), who was a virile leader well known to Lewis and Clark. Another is a panoramic view of the double village of the Arikara (pl. 12, fig. 1), 4 miles above the mouth of Grand River. Lewis and Clark

visited this village in 1804. Although still occupied when Catlin painted it, this site was abandoned soon thereafter (Wedel, 1955, pp. 80–81). A third is Catlin's distant view of the grave of Sergeant Floyd, sole fatality of the Lewis and Clark Expedition, atop a lonely hill beside the Missouri (No. 376).

The Mandan Indians near whom Lewis and Clark wintered in 1804–5 had intrigued the explorers and the readers of their journals. In Catlin's time they were still the most remarkable tribe on the Missouri. He painted their proud leaders in their beautifully decorated dress costumes, their villages, their traditional recreations and sacred ceremonies—something no member of the Lewis and Clark party had had the skill to do. (See pls. 8, 10, 12, 16.) Five years later an epidemic of smallpox decimated the Mandan. The remnant of that tribe found residence with other farming Indians on the Missouri but never regained prominence among the tribes of the region.

Less spectacular but no less historically significant are Catlin's paintings executed in the Southern Plains in 1834. Removal of Southeastern tribes to land west of the Mississippi was already underway and Catlin was the first artist to portray the Creek, Cherokee, and Choctaw Indian leaders in their strange new homeland. These pictures of gun-carrying, calico-clad civilized Indians contrast sharply with the wild Comanche and neighboring natives of the plains farther west—Indians who had yet to sign their first treaty with the United States. (Compare the portrait of Creek chief "Ben Perryman" with that of the Comanche warrior, Little Spaniard, in pl. 5.)

CATLIN'S PORTRAITS OF INDIANS

Catlin was at his best as a painter of portraits. His early experience and reputation as an artist were achieved as a painter of portraits of white men and women. His bust or half-length portraits are the best of his Indian work. Catlin never was content to portray generalized or idealized Indian types. He was a realist who tried to produce recognizable likenesses of real people. He possessed an uncommon genius for seizing upon those features of a sitter's face that defined its individuality. Catlin's Indians are sympathetically presented. They have a proud bearing and an expression of dignity which should be familiar to anyone who has photographed Indians on western reservations.

Catlin was less successful in his full-length portraits. He never quite mastered the human body. His attempts to solve problems of foreshortening sometimes led to the representation of huge hands and feet thrust forward as if projected in three-dimensional motion pictures. Some of his well-proportioned heads sit like peanuts upon gigantic bodies.

Indian portraits comprise more than half of the paintings in the George Catlin Collection in the U. S. National Museum. Some of these Indians were men famous in American history—such men as Black Hawk (pl. 3, fig. 1), The Open Door, brother of Tecumseh (pl. 3, fig. 2), and Osceola (pl. 6). Others played roles of some importance in regional or local history. Many were men of prominence in their tribes who have received little recognition in written history. They lived far beyond the frontiers of white settlement decades before their descendants gained fame fighting wars or making treaties with white men. Yet such men as the Mandan Four Bears (pl. 8, fig. 1; pl. 10, fig. 1), Bull's Back Fat, Blood (pl. 20), The Light, Assiniboin (pl. 11, fig. 2), and Horse Chief, Pawnee (pl. 2, fig. 2) are remembered in the oral literature of their tribes as powerful leaders.

Probably the most appreciative viewers of Catlin's Indian portraits have been members of the tribes whose early chiefs he depicted. Less than 40 years after Catlin painted Indians on the Upper Missouri, Dr. Washington Mathews showed the small line illustrations in Catlin's 2-volume book to Mandan, Hidatsa, and Arikara Indians near Fort Buford. Some of these people were children and grandchildren of persons portrayed in Catlin's pictures. Dr. Mathews was impressed by their ability to recognize and identify the portraits of their forebears. All those who remembered the old chief, Black Moccasin (pl. 4), pronounced that portrait "a wonderful likeness." Rushing Eagle, son of Four Bears, the Mandan chief twice painted by Catlin in 1832, was still living. Old men of the tribe considered him "the image of his father." Mathews pointed out the close similarity in features between Catlin's profile of Four Bears and a profile photograph of Rushing Eagle (Mathews, 1888, entire; 1891, pp. 602–604). On plate 8 I have juxtaposed Catlin's previously unpublished three-quarter view of Four Bears and a photograph of Rushing Eagle taken in 1874. The similarity between the two in this more difficult pose is very striking.

Members of Indian delegations from western tribes to Washington have shown a lively interest in Catlin portraits of their tribal leaders of more than a century ago. These pictures serve to substantiate and complement their own oral traditions of great leaders in their grandfathers' or great-grandfathers' generations.

I have taken selected photographs of Catlin's portraits into the field to show elderly Indians as an aid to obtaining biographical information and data on the history of Indian costume and crafts. In 1947, I was surprised to find hanging on the wall of Maggie No Fat's log cabin on Pine Ridge Reservation a faded photographic print of one of Catlin's oil portraits in the U. S. National Museum.

This aged Oglala woman explained that a delegation of Sioux Indians had brought it to her from Washington some years before. It was a portrait of her father, Shell Man, as a young man. She had carefully made a porcupine-quilled buckskin frame for the photo and kept it where she could see it often because it reminded her very much of her father. My field photograph of Maggie No Fat holding her father's picture, a reproduction of Catlin's painting of Shell Man, appears on plate 9.

INDIAN COSTUMES AND ORNAMENTS

John James Audubon, the famous artist-naturalist, saw Assiniboin Indians clad in dirty garments at Fort Union in the summer of 1843, and was moved to write: "When and where Mr. Catlin saw these Indians as he represented them, dressed in magnificent attire, with all sorts of extravagant accoutrements is more than I can divine" (Audubon, 1897, vol. 2, p. 109). The answer is quite simple. Among the Assiniboin, as among other tribes of the west, Catlin painted prominent Indians attired in their finest clothes. Most of his subjects were chiefs and their wives and children. They were Indians of considerable wealth who owned the most elaborate suits, dresses, and ornaments to be found in their tribes.

Students of the history of costume should keep these facts in mind when viewing Catlin's portraits of Indians. Catlin doubtless had good reasons for painting the best families in their best clothes. It made the Indians feel honored to sit for him. It appealed to their pride and vanity. Had he painted these people in everyday dress they would have had much less interest for the average white viewer of Catlin's paintings. Indians in their drab, undecorated daily garments would have appeared about as unattractive as birds of paradise in molting season.

Catlin's interest in the details of Indian costume always was secondary to his keen desire to record his sitter's facial features. In some portraits Catlin ignored the details of his sitter's costumes (see pl. 7). In others he called particular attention to some items while slighting the delineation of other details. A good example is his full-length portrait of Four Bears (pl. 10, fig. 1). When we compare the shirt depicted in this painting with the actual garment preserved in the collections of the U. S. National Museum (pl. 10, fig. 2) we see that Catlin exaggerated both the length of the shirt and the diameter of the quilled rosette in the center of the chest. He did not attempt to indicate the exquisite pattern of finely woven quillwork appearing in the arm and shoulder bands. This was typical of Catlin's manner of painting when he was hurried, as he certainly was at the Mandan villages in 1832. I do not believe he intended to mislead or deceive anyone. In fact he ex-

hibited both the painting and the shirt in the same gallery for years. Anyone so minded could have made his own comparisons.

Catlin's renderings of ornaments are spotty. His reproductions of the geometric patterns painted on buffalo robes by Plains Indians are approximations, not exact copies of Indian paintings. This was true even of his drawings of actual specimens of painted robes in his own collection.

Nevertheless, the details of some of the ornaments of costumes worn by Catlin's sitters are rendered with remarkable accuracy. Dr. Waldo R. Wedel (1955, p. 152) noted that in Catlin's painting of the wife of the Arikara head chief he depicted the exact size, shape, and colors of distinctive "wire-wound" trade beads such as have been found in recent excavations in the cemetery near the village in which that woman lived. The beads may be very nearly contemporary with Catlin's painting. Catlin's portrait tells us how the beads were worn in a necklace in alternating colors, blue and white. (See pl. 11, fig. 1, shorter bead strand.)

Again, in his portrait of the Assiniboin delegate to Washington, painted in St. Louis in the fall of 1831, Catlin clearly depicted the colors and forms of small designs in porcupine quills on the shirt-sleeve band (pl. 11, fig. 2). An elderly Assiniboin craftworker, in discussing traditionally old quillwork patterns among that tribe, drew for me this "three-row quillwork" design. Later I showed her this picture of Catlin's which exactly illustrated the design.

It would be dangerous to generalize regarding Catlin's rendering of the details of Indian costume. As I have pointed out above, his treatment of costume details ranges all the way from omission, through generalization and exaggeration, to very accurate rendering of minute units in their true colors.

SCENES IN INDIAN LIFE

When we consider Catlin's scenes in Indian life it is well to remember that Catlin the portraitist preceded Catlin the illustrator. His interest in painting Indian activities developed as his first-hand experience among the Indians increased. He may have felt also that a considerable number of lively scenes in Indian life would be essential to relieve the monotony of a large series of portraits when he began to exhibit his Indian Gallery to the public.

Catlin's status among the Indians was that of an enthusiastic and sympathetic observer. His knowledge of Indian customs was limited to what he saw with his own eyes and what better-informed white traders or English-speaking Indian interpreters told him. He was no linguist. The names he recorded for the subjects of some of his portraits are incorrectly rendered or translated. For example, his

"Wi-jun-jon, the Pigeon's Egg Head," should be "Ah-jon-jon, The Light," as I have given it in the caption to plate 11, figure 2.

Most of the scenes in Indian life which Catlin actually witnessed were hurriedly painted. Yet the action in many of them is good. (See the dances and ceremonies pls. 14, 16, 17.) Catlin certainly did not understand everything he saw Indians do. But at times his secondary action is excellent. In his pencil drawing of a Blackfoot medicine-man, dressed in a grizzly-bear skin, doctoring his patient (pl. 15, fig. 1), Catlin shows a number of Indian onlookers trying to hide their astonishment by placing their hands over their mouths. This was typical Indian behavior under the circumstances. It shows the acuteness of Catlin's observation of the witnesses as well as the star performer in that dramatic action outside Fort Union in 1832. Catlin's oil painting of this action pictured only the medicine-man (pl. 15, fig. 2). The more interesting and meaningful elaboration was drawn (though possibly not for the first time) in 1852.

No series of his paintings was more severely criticized in Catlin's own time than those portraying the Mandan Okipa ceremony which he witnessed in 1832. D. D. Mitchell, Superintendent of Indian Affairs, declared two decades later that these scenes "existed almost entirely in the fertile imagination of that gentleman [Catlin]" (Schoolcraft, 1851–1857, vol. 3, p. 254). Sure of his ground, Catlin countered by publishing an entire illustrated volume, "O-Kee-Pa, a Religious Ceremony and Other Customs of the Mandans," in 1867. His written descriptions and pictures of this ceremony were upheld by the intelligent fur trader, James Kipp, in whose company the artist had witnessed the ceremony (Kipp, 1873). Catlin's painting of the most dramatic episode in that ceremony, the self-torture, appears as plate 16.

At times, however, in his haste to record on canvas what he saw, Catlin resorted to shortcuts which left him open to criticism. Audubon, on seeing the Mandan earth lodges near Fort Clark in 1843, commented: "The Mandan huts are very far from looking poetical, although Mr. Catlin has tried to render them so by placing them in regular rows, and all the same size and form, which is by no means the case. But different travellers have different eyes." (Audubon, 1897, vol. 2, p. 10.)

The outlines of Catlin's Mandan and Arikara earth lodges (pl. 12, fig. 1) are much more half-globular than those structures actually were. Likewise Catlin employed an artistic convention of simplified triangles, all about the same size, to denote the tipi villages of nomadic tribes. He failed to indicate the considerable range in the size of tipis in a camp, owing in large part to variations in family numbers and wealth.

WILDLIFE AND HUNTING SCENES

Catlin made the buffalo hunt a favorite subject for his brush. On his trip up the Missouri in 1832 he experienced the excitement of running buffalo on horseback. More than a score of paintings in his original Indian Gallery interpreted various aspects of hunting those big, shaggy beasts. Catlin continued to be fascinated by this subject after he went to Europe. Indeed, more than a quarter of the 100 paintings he created from field sketches or from memory while in Europe dealt with buffalo hunting on the Great Plains from Texas to Canada. The artist painted himself in several of them.

If Catlin had painted no other scenes than buffalo hunts he might have gained a measure of fame. He was the first artist to picture this American big-game hunting on horseback for the benefit of a host of readers and viewers. It was natural that many easterners and Europeans came to visualize buffalo hunting in Catlin's terms. Less adventurous illustrators found inspiration in Catlin's pictures. Even F. O. C. Darley, one of America's most competent draughtsmen, prepared an engraving entitled "Hunting Buffalo" for Graham's Magazine in 1844, which was a thinly disguised copy of one of Catlin's paintings (Baur, 1948, pp. 17–20).

Visitors to the Great Plains in later years were prepared to view the buffalo as Catlin had revealed that animal to them. Edward Harris, the nature enthusiast who accompanied Audubon to the Upper Missouri in 1843, observed that a buffalo bull wounded in a hunt in which he participated "was brought to a stand in exactly the position represented in Catlin's painting of the wounded bull" (Harris, 1951, p. 139).

Perhaps it was his enthusiasm for buffalo-hunting scenes that led Catlin to attempt pictures of Indians chasing buffalo on snowshoes in the dead of winter even though he had never seen the Great Plains when there was snow on the ground. The imaginative quality of such scenes reveals itself in his portrayal of winter hunters lightly garbed in *summer war dress.* Both Kurz (1937, p. 130) and Mathews (1891, p. 602) noted this strange error in Catlin's work.

Catlin's Indian Gallery also included other wildlife scenes—wild horses at play, Indians hunting horses, antelope, and grizzly bears on the plains, and deer in the woodlands. The paintings which he added to his collection while in Europe included a good many hunting and fishing scenes, some idyllic (possibly imaginary) views of elk and buffalo grazing, and several life-sized "portraits of Grizzly Bears."

LANDSCAPES

Catlin's landscapes are historically significant as interpretations of the appearance of the Great Plains and the Upper Mississippi Valley

before the advance of white settlement into those regions. Hundreds of thousands of easterners and western Europeans first saw the West in Catlin's paintings or book illustrations.

Modern art critics have taken a particular interest in Catlin's landscapes. They have approved their simplicity of form and color. Yet they convey a clear impression of the bigness of the West—the breadth of the plains, the distance to the horizon, the vastness of the sky (see pl. 19, fig. 1).

Earlier critics who knew the country Catlin portrayed have praised his landscapes in general. Joseph N. Nicollet, government explorer and mapmaker, who ascended the Missouri to Fort Pierre in 1839 and who knew the Upper Mississippi well, wrote: "The spirited pencil of Mr. Catlin has faithfully represented the pictorial features of this country in some of the sketches contained in the first volume of his travels" (Nicollet, 1843, p. 39). Dr. Washington Mathews, who traveled up and down the Missouri several times in the 1860's and early '70s, praised Catlin's ability to catch the distinctive characteristics of each locality, be it eroded sandstone bluffs in the South Dakota Badlands or the conical hills farther upriver with "marvelous quickness and insight" (Mathews, 1891, p. 599).

When they began to compare some of Catlin's landscapes with specific topographical features in that locality, critics found that he did take some liberties with what he saw. Audubon, who seemed to enjoy calling attention to Catlin's lapses, wrote at the mouth of Knife River, June 10, 1843: "We saw many very curious cliffs, but not one answering the drawings engraved for Catlin's work" (Audubon, 1897, vol. 2, p. 24). Again, while at Fort Union near the mouth of the Yellowstone River, he commented: "Sprague walked to the hills about two miles off, but could not see any portion of the Yellowstone River, which Mr. Catlin has given in his view, as if he had been in a balloon some thousands of feet over the earth" (idem, p. 96). This is the view reproduced in plate 19, figure 1.

Recently, Harvey B. Reynolds, Superintendent, Pipestone National Monument, informed me that Catlin's historic panorama of the pipestone quarry (pl. 19, fig. 2) exaggerates the height of the quartzite ledge and moves the boulders known as "Three Maidens" far to the left of their actual location to get these picturesque landmarks into his scene. It should be clear, then, that Catlin did exercise his artistic license when painting landscapes. While his landscapes show the general character of the country they are not all precise pictorial documents.

CATLIN AND HIS CONTEMPORARIES

George Catlin was not the first artist to paint western Indians from life. Delegations from some tribes beyond the Mississippi were

escorted to Washington to meet their Great White Father as early as the first decade of the nineteenth century. In 1806 the French artist St. Memin employed a mechanical device called a physionotrace to outline exactly the striking profiles of a Mandan chief and several Osage Indian visitors to the Nation's Capital. In 1821 Charles Bird King began to paint for the Government's own collection portraits of Indian leaders brought to Washington from tribes of the Great Lakes, the Southeast, and the central Great Plains. Yet these stay-at-home artists knew their red-skinned sitters only as picturesquely costumed, befuddled strangers in the complex civilization of the alien white man. They had little or no knowledge of the cultural backgrounds of these Indians or the country they called home.

Other artists had traveled and painted in the Great Plains before Catlin did. Samuel Seymour, official artist of Major Long's Expeditions to the Rocky Mountains in 1819–20 and to the Upper Mississippi in 1823, is said to have executed more than 150 landscapes in addition to a number of Indian portraits and some scenes in Indian life. Prince Paul of Würtemberg, a skilled draughtsman, traveled up the Missouri as a guest of the American Fur Co. in 1823. Peter Rindisbacher, a young Swiss settler on the Red River in Canada, painted winter and summer buffalo hunts and camp scenes among the Cree and Assiniboin tribes prior to 1826. But by and large these predecessors of Catlin had had little influence on the popular mind. They had written no popular illustrated books, organized no great traveling exhibitions to take their interpretations of the West to the people. Their message was muted or restricted to the few.

When George Catlin went west in 1830 the average easterner and the interested European had only a vague and confused impression of the country beyond the Mississippi and the people who lived there. Indians appeared in the popular art of the time as lovely dark-skinned maidens or tall handsome hunters beside some cool forest stream. They were the romantic creations of sentimental landscape painters, as unreal as James Fenimore Cooper's poetic redmen in Leatherstocking Tales. On the other hand, in the widely read horror stories of the period—the Indian captivities—Indians were presented as bloodthirsty savages who enjoyed torturing helpless prisoners. One extreme view of the Indian was as false as was the other.

George Catlin, master showman as well as artist, certainly was the first artist to win a great mass audience for his interpretation of the West. As a pioneer on-the-spot reporter Catlin broke the trail for a number of other artists who came to recognize that if they would truly picture the West and its people they must go there and see them with their own eyes. Among the best known of these artists in the pre-camera, pre-Civil War period were John James Audubon, Albert Bier-

stadt, Seth Eastman, Paul Kane, Baldwin Mollhausen, John Mix Stanley, and Charles Wimar. Catlin's pioneer work bore the brunt of the criticism of later artists. It set the standard they hoped to better. His, too, was the model for many eastern artists content to profit from the popular interest in the West without bothering to learn about it firsthand. All or very nearly all these later artists were familiar with Catlin's work, either in the original oils or in the little linecuts of his 1841 book. Audubon probably was not the only artist to carry a well-worn copy of Catlin's "Letters and Notes" into the field.

Catlin's paintings most frequently are compared with the works of Carl Bodmer, a 23-year-old Swiss artist who accompanied the noted German scientist, Maximilian, Prince zu Wied, to the upper Missouri in 1833–34. This comparison is an obvious one because Catlin and Bodmer saw much of the same country and met the same Indian tribes within a period of one year.

In this comparison Catlin's impressionistic field sketches commonly suffer at the hands of Bodmer's painstaking studies. Yet, as an admirer of the accomplishments of both artists, I should like to point out their very different backgrounds and the fact that even though they worked in the same region they did so under quite different conditions. George Catlin was self-taught. He developed a definite style, but it lacked the polish academic training might have given it. Catlin traveled on his own as a free-lance artist-writer. He had only 86 days on the Upper Missouri. Time was precious. He had to work very fast or miss a great deal.

Carl Bodmer, on the other hand, was academically trained in the best European tradition of fine draughtsmanship. His sole responsibility on the Upper Missouri was that of preparing field studies to illustrate the scientific writings of his employer, Prince Maximilian. They had to be exact to the finest detail. Indian costumes, ornaments, and accessories had to be so rendered as to suggest the qualities of materials from which they were made as well as their colors, sizes, and shapes. The Prince and Bodmer spent 11 months on the Missouri above Fort Pierre (May 30, 1833, to April 29, 1834). Bodmer worked slowly and methodically. His artistic production of 11 months (judging from the number of his known Upper Missouri field drawings in pencil and watercolor preserved in the collections of the estate of Prince Maximilian) little outnumbered Catlin's output of approximately 12 weeks. Maximilian's journal tells of the infinite care taken by himself and Bodmer in selecting subjects and the time devoted by Bodmer to some of his drawings. Bodmer worked several days on a watercolor of an elaborately costumed dancer. Several more days were given to sketching the interior of a Mandan earth lodge, and another series of days to recording a view of the Rocky Mountains from

the heights above Fort McKenzie. Restless Catlin probably could not have worked so deliberately even if he had had the time.

Perhaps, though, had Catlin known that an artist of Bodmer's technical skill and infinite patience was to follow him up the Missouri in the very next year he might have painted fewer pictures in greater and more precise detail. Bodmer, however, was well acquainted with Catlin's strengths and weaknesses as an artist as well as his coverage of Upper Missouri subject matter. Maximilian's account of his party's sojourn in St. Louis before traveling upriver tells of their visit to the country home of Maj. Benjamin O'Fallon, Indian Agent and friend of Catlin: "We found at his house an interesting collection of Indian articles, and a great number of Indian scenes by Catlin, a painter from New York, who had traveled in 1831 [sic] to Fort Union" (Maximilian, 1843, p. 111).

Possibly it was owing to Maximilian's and Bodmer's prior knowledge of Catlin's work that there were so few duplications in the subject matter of Catlin's and Bodmer's Upper Missouri pictures. Probably fewer than a dozen Indians posed for both artists. Comparison of the portraits of Buffalo Bull's Back Fat, head chief of the Blood Indians, by Catlin in 1832 (pl. 20, fig. 1) and Bodmer in 1833 (the lithograph here reproduced, pl. 20, fig. 2, is a very good copy of the original watercolor which I have seen) illustrates the different styles of the two artists. Nevertheless, the modern critic cannot say which is the better likeness of that great chief. They look very much like two views of the same face.

From the scientific viewpoint Catlin's and Bodmer's Upper Missouri pictures complement one another very nicely. Bodmer spent a month at Fort McKenzie, near the mouth of the Marias River (in present Montana), farther upriver than Catlin had traveled. He sketched scenes in the great summer encampments of the Blackfoot tribes and a large series of Piegan, Blood, and North Blackfoot portraits. Catlin met and painted a few Blackfoot Indians at Fort Union far from their home camps. On the other hand, he created many more Crow and Sioux portraits and scenes in Sioux life than did Bodmer. Although Catlin never saw the country west of Fort Union portrayed in a number of Bodmer's landscapes, the former painted many views on the Missouri downstream from Fort Union which Bodmer did not attempt. Bodmer wintered at Fort Clark and pictured winter life and ceremonies of the nearby Mandan and Hidatsa. Catlin depicted the important midsummer Okipa among the Mandan and self-torture in the Sioux sun dance, neither of which Bodmer witnessed. Together, the artistic endeavors of George Catlin and Carl Bodmer in 1832–34 on the Upper Missouri are of unique ethnological importance. They comprise the largest, most colorful,

and most comprehensive series of portraits and scenes executed from life in the country of any group of culturally related North American Indian tribes in the days before the perfection of photography. Undoubtedly these pictures have been very influential in implanting the stereotype of the Plains Indian as the American Indian par excellence in the minds of millions of Americans and Europeans.

CATLIN'S PAINTINGS AS ART, HISTORY, AND SCIENCE

George Catlin has been a controversial figure in American art for generations. His paintings have been enthusiastically praised and disparagingly condemned. Some art critics have tagged him a romantic, others a realist, and still others an American primitive. Catlin certainly was not a member of any traditional school of art. He was self-taught and there were both strong and weak points in that "teaching." Initially and primarily Catlin was a portraitist. At his best, in his "studio" portraits, Catlin deserves to rank among the better portrait painters of his time. There can be no question of his ability to create a realistic likeness of his sitter. Catlin's field-sketching style, however, was impressionistic. It was developed to meet the needs of his working conditions—a bold, rapid technique for pictorial reporting. What his field pictures lacked in technical skill they may have gained in freshness and directness. In his haste to make his field record as complete as his limited time permitted Catlin could not wait to fully exploit the artistic possibilities of each subject. To speed his work he adopted some shortcutting conventions—his own system of pictorial shorthand. Undoubtedly Catlin's reputation as an artist would have fared better had he not tried to paint so many pictures and to preserve them all—good, bad, and indifferent.

Nevertheless, the great number and variety of Catlin's western paintings give his work a comprehensiveness that is important to the historian and ethnologist. Catlin himself expressed the hope that visitors to his exhibitions would "find enough of historical interest excited by faithful resemblance to the physiognomy and customs of these people, to compensate for what may be deficient in them as works of art" (Catlin, 1871). Probably the great majority of men, women, and children who have enjoyed Catlin's pictures have preferred to look at them as historic documents or scientific illustrations rather than as works of art.

Catlin painted the largest collection of early pictures of the western wilds and their Indian inhabitants. How reliable are these pictures geographically and ethnologically? The only proper answer is that each painting must be appraised on its own merits. When we begin to do that we find that the scientific significance of Catlin's

paintings varies as does their artistic quality. One can neither praise nor condemn them all in the same words. Some paintings by Catlin do contain questionable or erroneous elements. In some other paintings he exaggerated the truth. But we know, too, that in still other pictures Catlin was remarkably accurate even to minor details. And finally there are paintings by Catlin that no one now living can appraise precisely because they are the only remaining records of their respective subjects. These pictures may be uniquely valuable as contributions to knowledge. Scholars, hobbyists, in fact anyone, adult or child, who enjoys learning about the old West should be grateful to George Catlin for his vision and accomplishment in preserving a pictorial record of a picturesque era in western history that is forever gone.

THE GEORGE CATLIN COLLECTION OF PAINTINGS IN THE U. S. NATIONAL MUSEUM

The collection of original paintings by George Catlin in the U. S. National Museum comprises 445 items, including the majority of the original oil paintings in Catlin's Indian Gallery exhibited by him in the United States and in Europe in the years 1833–1852. By actual count 422 of the 507 painting numbers listed in Catlin's exhibition catalog of 1840 are in this collection.[1] In addition the collection includes 33 of the 100 paintings which Catlin executed and added to his exhibition between 1840 and 1848.

When Thomas Donaldson prepared "The George Catlin Indian Gallery in the U. S. National Museum" published in the Annual Report of the Smithsonian Institution for 1885 he based his studies upon the entries in Catlin's exhibition catalogs rather than upon a precise check of paintings in the Catlin collection received by the U. S. National Museum. In consequence, the Donaldson catalog lists some 85 numbered items that refer to paintings in the original Catlin Gallery but that are not and never were in the collections of the National Museum. The Donaldson catalog has long been out of print. The checklist that follows has been compiled from the catalog records of the museum.

To facilitate use of this checklist by students it has been organized primarily by natural and cultural areas (i. e., Great Plains, Woodlands, Far Northwest) and secondarily by tribes, alphabetically, within each primary area. The reader interested in determining what paintings in the collection refer to the Mandan Indians, for example, will find all the Mandan portraits and scenes listed under that tribal heading in the Great Plains major division. Under each tribe is given a brief statement of its location at the time George Catlin visited it and of the present location of sizable concentrations of descendants of that tribe. Each painting is designated by a short title rather than by the lengthy one Catlin may have given it in his exhibition catalogs. The exhibition catalog number of each painting which was exhibited in Catlin's Indian Gallery is given and the U. S. National Museum catalog number of each painting is listed.

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[1] Catlin gave more than one number to portraits which included likenesses of two or more individuals. Hence painting numbers in his exhibition catalogs exceed the actual number of paintings.

Persons wishing to order photographs of paintings in this collection will find Catlin's 2-volume work (Catlin, 1841) a helpful reference for identifying many subjects. The majority of the subjects in this collection were reproduced as line illustrations in that publication. As a general rule, however, the large oil portraits (28″ x 23″), the landscapes, and many of the scenes in Indian life are more attractively rendered than are the same subjects in the little book illustrations. Those subjects not reproduced in Catlin's book are preceded by an asterisk in this list. Many of them never have been published.

INDIAN TRIBES OF THE GREAT PLAINS

Arikara

1832 location: On Missouri River north of mouth of Grand River, present South Dakota. Now on Fort Berthold Reservation, North Dakota.

	Catlin number	*U.S.N.M. number*
Bloody Hand, chief of the Arikara	123	386123
The Twin, wife of Bloody Hand	124	386124
Sweet-scented Grass, 12-year-old daughter of Bloody Hand	125	386125
Arikara village of earth-covered lodges, 1,600 miles above St. Louis	386	386371

Assiniboin

1832 location: North of Missouri River in present North Dakota and Montana and adjacent areas of Canada. Now on Fort Belknap and Fort Peck Reservations, Montana, and in Canada on Battleford, Edmonton, Assiniboin, Moose Mountain, and Stoney Reserves.

	Catlin number	*U.S.N.M. number*
Pigeon's Egg Head (The Light), distinguished young warrior	179	386179
Pigeon's Egg Head (The Light) going to and returning from Washington (1831–32)	474	386454
Fire Bug That Creeps, wife of above	180	386180
Assiniboin woman and child	181	386181
Pipe Dance, Assiniboin	453	386436
*Assiniboin Indians running buffalo on snowshoes	558	386480

Blackfoot

1832 location: Present north-central Montana and southern Alberta, Canada. Now on Blackfeet Reservation, Montana, and in Alberta, Canada, on Blackfeet, Blood, and Piegan Reserves.

	Catlin number	*U.S.N.M. number*
Buffalo Bull's Back Fat, head chief, Blood tribe	149	386149
Crystal Stone, wife of above	150	386150
Grandson of Buffalo Bull's Back Fat	159	386159

Blackfoot—Continued	*Catlin number*	*U.S.N.M. number*
Buffalo's Child	151	386151
Eagle's Ribs, a Piegan chief (full-length)	152	386152
*Eagle's Ribs, a Piegan chief (bust only)	160	386160
*Iron Horn, a warrior	153	386153
Woman Who Strikes Many	155	386155
*Bear's Child, a brave	157	386157
White Buffalo, an aged medicine man	158	386158
Medicine man, performing his mysteries over a dying man	161	386161

Caddo

1834 location: Northern Texas. Now in southwestern Oklahoma near Anadarko.

	Catlin number	*U.S.N.M. number*
*Caddo Indians chasing buffalo, Cross Timbers, Tex	589	386492

Cheyenne

1832 location: In Platte River valley, present eastern Wyoming and Colorado. Now on Cheyenne Reservation, Montana, and Cheyenne and Arapaho Reservation, Oklahoma.)

	Catlin number	*U.S.N.M. number*
Wolf on the Hill (High Wolf), tribal chief	143	386143
She Who Bathes Her Knees, wife of above	144	386144

Comanche

1834 location: In present northwestern Texas and western Oklahoma. Now in southwestern Oklahoma near Lawton.

	Catlin number	*U.S.N.M. number*
Bow and Quiver, first chief of the tribe	46	386046
Mountain of Rocks, second chief of the tribe	47	386047
Carries a Wolf, a distinguished brave	48	386048
*Hair of the Bull's Neck, a chief	49	386049
Wolf Tied with Hair, a chief	50	386050
Little Spaniard, a warrior	51	386051
*The Beaver, a warrior	52	386052
Two Comanche girls	53–54	386053–4
Comanche village. Women dressing robes and drying meat	346	386338
Comanche warriors, with white flag, receive Dragoons in 1834	353	386345
*Comanche war party, chief discovering enemy and urging his men at sunrise	459	386442
Comanche moving camp, dog fight en route	466	386447
*Comanche warrior lancing an Osage at full speed	471	386451
*Comanche giving the arrows to the Medicine Rock to bring success in war	472	386452
Comanche feats of horsemanship—sham battle	487	386463
Comanche meeting the Dragoons	488	386464
*Comanche skin lodge (tipi)	493	386467

Comanche—Continued	*Catlin number*	*U.S.N.M. number*
*Comanche mounted war party	496	386470
Breaking down the wild horse	501	386473
*Comanche chasing buffalo with bows and lances	564	386483
*Mounted war party scouring a thicket	586	386491
*War party on the march, fully equipped	596	386496
*Comanche (or Kiowa) Indians dressing skins, Red River	597	386497
*Comanche Indians chasing buffalo, Texas	600	386500

Crow

1832 location: Yellowstone River Valley, present Montana. Now on Crow Reservation southeastern Montana.

	Catlin number	*U.S.N.M. number*
Four Wolves, a chief, in mourning	162	386162
He Who Ties His Hair Before	163	386163
Two Crows, a band chief	164	386164
*Hó-ra-tó-a, a brave	165	386165
Woman Who Lives in a Bear's Den, her hair cut off in mourning	166	386166
Red Bear	167	386167
Two Crows (the younger)	168	386168
*Very Sweet Man	169	386169
Crow lodge of 25 buffalo skins	491	386491

Cree, Plains

1832 location: Northern North Dakota and adjacent area of southern Canada. Now several reserves in Saskatchewan and Alberta, Canada, and the Rocky Boy's Reservation, Montana.

	Catlin number	*U.S.N.M. number*
He Who Has Eyes Behind Him (also known as Broken Arm), a foremost brave	176	386176
Great Wonder, a Cree woman carrying her baby in her robe	177	386177
Tow-ée-ka-wet, a Cree woman	178	386178

Dakota, Eastern (Eastern Sioux)

1832 location: In present western Minnesota, eastern North and South Dakota. Now on reservations in the Dakotas and Minnesota.

	Catlin number	*U.S.N.M. number*
Big Eagle (or Blak Dog), chief of the O-hah-kas-ka-toh-y-an-te Band	70	386070
Blue Medicine, a medicine man of the Ting-ta-to-ah Band	73	386073
He Who Stands on Both Sides, a distinguished ball player	74	386074
Red Man, a distinguished ball player	75	386075
*Sioux village, Lake Calhoun, near Fort Snelling	335	386333
Pipestone Quarry on the Coteau des Prairies	337	386334

	Catlin number	*U.S.N.M. number*
Dakota, Eastern (Eastern Sioux)—Continued		
*Sioux Indians pursuing a stag in their canoes on St. Peter's (Minnesota) River	341	386336
Ball play of the women, Prairie du Chien	430	386414
Dog Dance at Fort Snelling	437	386421
*Brave's Dance at Fort Snelling	445	386428
*Sioux worshiping at the red boulders	470	386450
*Battle between Sioux and Sauk and Fox	545	386478

Dakota, Teton (Western Sioux)

1832 location: Present western Nebraska, South and North Dakota, eastern Montana and Wyoming. Now on reservations in South Dakota and North Dakota.

	Catlin number	*U.S.N.M. number*
One Horn, head chief of Miniconjou tribe	69	386069
Tobacco, an Oglala chief	71	386071
*Shell Man, an Oglala brave	76	386076
*Corn, a Miniconjou (?) warrior	78	386078
*No Heart, chief of "Wah-ne-watch-to-ne-nah" Band	79	386079
Black Rock, a Two Kettle (?) chief	80	386080
Red Thing That Touches in Marching, daughter of Black Rock	81	386081
Little Bear, a Hunkpapa brave	84	386084
The Dog, chief of "Bad Arrow Points" Band	85	386085
Steep Wind, a brave of the "Bad Arrow Points" Band	86	386086
Sand Bar, wife of the trader François Chardon	89	386089
Sioux encamped on the Upper Missouri, dressing buffalo meat and robes	377	386362
Dance of the chiefs, mouth of Teton River	436	386420
Scalp Dance, mouth of Teton River	438	386422–A
*Scalp dance, Sioux (variant of above)		386422–B
Beggar's Dance, mouth of Teton River	443	386426
Bear Dance, preparing for a bear hunt	447	386430
War Dance	457	386438–A
*War Dance (variant of above)		386438–B
Self-torture in Sioux ceremony	460	386443
*Butte de Mort (Hill of Death), Sioux burial ground	475	386455
*Smoking the shield (probably Sioux)	477	386457
Band of Sioux moving camp with dogs and horses	482	386460
*Medicine buffalo of the Sioux	485	386461
Sioux dog feast	494	386468
*Sioux Indian council	495	386469
*Sioux Indians on snowshoes lancing buffalo	565	386484

Dakota, Yankton

1832 location: East of Missouri River in present South Dakota. Now on reservations in South Dakota and North Dakota.

	Catlin number	*U.S.N.M. number*
*Torn Belly, a distinguished brave	77	386077
Stone with Horns, a chief	82	386082

Dakota, Yanktonai

1832 location: East of Missouri River in present North Dakota. Now on reservations in North Dakota, South Dakota, and Montana.

	Catlin number	U.S.N.M. number
*Wan-ee-ton, Yanktonai head chief (Mistermed "Sisseton" by Catlin)	72	386072

Eastern Dakota (see Dakota, Eastern)

Hidatsa (Catlin's "Minnatarree")

1832 location: On Knife River near the Missouri River in present North Dakota. Now on Fort Berthold Reservation, North Dakota.

	Catlin number	U.S.N.M. number
Black Moccasin, aged chief	171	386171
Red Thunder, son of Black Moccasin	172	386172
*Two Crows, a chief	173	386173
*Wife of Two Crows	174	386174
Mid-day Sun, a pretty girl	175	386175
Hidatsa village, earth-covered lodges, on Knife River, 1,810 miles above St. Louis	383	386368
Green Corn Dance of the Hidatsa	446	386429

Iowa

1832 location: In present Iowa east of Missouri River. Now on reservations in Kansas, Nebraska, and Oklahoma.

	Catlin number	U.S.N.M. number
No Heart, chief of the tribe	256	386256
Shooting Cedar, a brave	257	386257
*Walks in the Rain, a warrior	258	386258
*Walking Rain, war chief. (Same as above?)	518	386312
Man of Sense, a brave	259	386259
Busy Man, a brave	260	386260
*Mún-ne-o-ye, a woman	262	386262
*Little Wolf, a famous warrior	521	386313
*Strutting Pigeon, wife of White Cloud	525	386525
*Pigeon on the Wing, a woman	526	386526
*Female War Eagle, a woman	528	386528

Kansas

1831 location: On Kansas River about 70 miles west of the Missouri River in present Kansas. Now on the Kansas or Kaw Reservation, Oklahoma.

	Catlin number	U.S.N.M. number
The Wolf, a chief	22	386022
Cannot Be Thrown Down, a warrior	23	386023
No Fool, a great fop	24	386024
Little White Bear, a distinguished brave	25	386025
*Bear-catcher, a celebrated warrior	26	386026
*Man of Good Sense, a young warrior	27	386027
*Wife of Bear-catcher	28	386028

Kiowa

1834 location: In present southwestern Kansas, western Oklahoma, and northwestern Texas. Now on Kiowa Reservation in southwestern Oklahoma.

	Catlin number	U.S.N.M. number
Teh-toot-sah (better known as Dohásän, Little Bluff), first chief	62	386062
Smoked Shield, a distinguished warrior	63	386063
New Fire, a Band chief	64	386064
Stone Shell, a brave	65	386065
Thunderer (a boy) and White Weasel (a girl)	66–67	386066–7

Mandan

1832 location: On Missouri River, North Dakota. Now on Fort Berthold Reservation, North Dakota.

	Catlin number	U.S.N.M. number
Wolf Chief, a head chief of tribe	127	386127
Four Bears, second chief (full-length)	128	386128
*Four Bears, second chief (half-length)	131	386131
Old Bear, a medicine man	129	386129
Rushes through the Middle, a brave	130	386130
Mouse-colored Feather, a noted brave	132	386132
Mink, a beautiful girl	133	386133
Mint, a pretty girl of 12 years	134	386134
Distant view of Mandan village	379	386364
Back view of Mandan village, showing cemetery	392	386377
Mandan game of "Tchung-kee" (hoop-and-pole game)	431	386415
Mandan horseracing on racecourse back of village	432	386416
*Mandan footrace on the same ground	433	386417
Mandan archery contest	435	386419
Mandan buffalo dance	440	386424
Mandan boys in sham fight	455	386437
Foot war party in council, Mandan	458	386441
*Mandan attacking a party of Arikara near Mandan village	464	386445
Rainmaking among the Mandan	476	386456
Mandan scalping an enemy	498	386471
Bird's-eye view of Mandan village	502	386474
Interior view of Mandan medicine lodge	504	386475
Bull dance, part of Mandan Okipa ceremony	505	386476
The Last Race, part of Okipa ceremony	507	386477

Missouri

1831 location: With the Oto on Platte River in present Nebraska. Now in Oklahoma.

	Catlin number	U.S.N.M. number
He Who Kills the Osages, chief of the tribe	122	386122

Ojibwa, Plains (Catlin's "Chippeways")

1832 location: Northern present North Dakota and adjacent Canada. Now on Rocky Boy's Reservation, Montana, and Turtle Mountain Reservation, North Dakota.

	Catlin number	*U.S.N.M. number*
The Six, chief of the Plains Ojibwa	182	386182
Wife of The Six	195	386195
*Kay-a-gis-gis, a young woman	183	386183
Travels Everywhere, a warrior	189	386189

Omaha

1832 location: On Missouri River in present Nebraska. Now on Omaha Reservation, Oklahoma.

	Catlin number	*U.S.N.M. number*
Brave Chief, chief of the Omaha	113	386113
Big Elk, a famous warrior	114	386114
*There He Goes, a brave	115	386115
*Double Walker, a brave	116	386116
*Grave of Blackbird, Omaha chief, on Missouri River, 1,100 miles above St. Louis	365	386350

Osage

1834 location: On Arkansas and Neosho Rivers in present Oklahoma. Now on Osage Reservation, Oklahoma.

	Catlin number	*U.S.N.M. number*
Clermont, first chief of the tribe	29	386029
Wáh-chee-te, wife of Clermont, and child	30	386030
Black Dog, second chief	31	386031
Tal-lee, a warrior of distinction	32	386032
*Wa-ho-béck-ee, a handsome brave	33	386033
He Who is Not Afraid, Big Crow, and Man of the Bed, three young warriors	34–36	386034–36
*He Who Takes Away, War, and Mink-chésk, three distinguished young men	38–40	386038–40
*Mad Buffalo, murderer of two white men	41	386041
*Madman, a distinguished warrior	42	386042
*White Hair, the Younger, a Band chief	43	386043
*Handsome Bird	44	386044
*Little Chief	45	386045
*An Osage Indian lancing a buffalo	567	386485

Oto

1831 location: Lower Platte River, present Nebraska. Now on Oto Reservation, Oklahoma.

	Catlin number	*U.S.N.M. number*
*The Surrounder, Oto chief	117	386117
Strikes Two at Once, a brave	119	386119
Loose Pipe-stem, a brave	120	386120
*He Who Exchanges	121	386121

Pawnee

1831 location: On tributaries of the Platte and Kansas Rivers in present Nebraska and Kansas. Now on Pawnee Reservation, Oklahoma.

	Catlin number	*U.S.N.M. number*
Horse Chief, Grand Pawnee head chief	99	386099
Buffalo Bull, a Grand Pawnee	100	386100
*Medicine Horse, a Grand Pawnee brave	101	386101
*Little Chief, Tapage Pawnee warrior	102	386102
*Bird That Goes to War, a Tapage Pawnee	103	386103
*Mole in the Forehead, Republican Pawnee chief	104	386104
*Man Chief, a Republican Pawnee	105	386105
*War Chief, a Republican Pawnee	106	386106
*The Cheyenne, a Republican Pawnee	107	386107
Big Elk, Skidi (Wolf) Pawnee	108	386108
*Brave Chief, Skidi (Wolf) Pawnee	110	386110
*Ill-natured Man, Skidi (Wolf) Pawnee	111	386111

Plains Cree (See Cree, Plains)

Plains Ojibwa (See Ojibwa, Plains)

Ponca

1832 location: On the Missouri River in vicinity of mouth of Niobrara River in present Nebraska. Now on reservations in Nebraska and Oklahoma.

	Catlin number	*U.S.N.M. number*
The Smoke, chief of the tribe	95	386095
Pure Fountain, wife of The Smoke	96	386096
Great Chief, son of The Smoke	97	386097
Bending Willow, wife of Great Chief	98	386098

Teton Dakota (see Dakota, Teton)

Waco

Until after 1830 their village stood on site of present Waco, Tex. Now on reservation with Wichita in Oklahoma.

	Catlin number	*U.S.N.M. number*
He Who Fights With a Feather, chief of tribe	68	386068

Wichita (Catlin's "Pawnee-Picts")

1834 location: Near Wichita Mountains, southwestern Oklahoma. Now on Wichita Reservation, Oklahoma.

	Catlin number	*U.S.N.M. number*
Wee-ta-ra-sha-ro, head chief of the tribe	55	386055
Sky-se-ró-ka, second chief of tribe	56	386056
*Kid-á-day, a distinguished brave	57	386057
Thighs, a Wichita woman	58	386058
Wild Sage, a Wichita woman	59	386059
*Rotten Foot, a noted warrior	60	386060
*Grass-covered lodge of the Wichita	492	386466

Yankton Dakota (see Dakota, Yankton)

Yanktonai Dakota (see Dakota, Yanktonai)

WILDLIFE AND HUNTING SCENES ON THE PLAINS

	Catlin number	*U.S.N.M. number*
Antelope		
Antelope-shooting—decoyed up	419	386404
Bear		
*Indians on horseback with lances attacking the grizzly bear	418	386403
*Weapons and appearance of the grizzly bear	563	386481
*Weapons and appearance of the grizzly bear	----	386482
*Catlin and party in canoe confronted by bears on shore, Upper Missouri	585	386490
*Grizzly bear and mouse (life size)	603	386501
*Five heads of bears (oil study)	----	386502
Buffalo		
Buffalo bull grazing	404	386389
Buffalo cow grazing	405	386390
Wounded buffalo	406	386391
Dying buffalo	407	386392
Buffalo chase—single death	408	386393
Buffalo chase—a surround by the Hidatsa	409	386394
Buffalo chase with bows and lances	410	386395
*Buffalo chase with bows and lances	411	386396
Buffalo chase—bull protecting cow and calf	412	386397
Buffalo chase—bulls making battle with men and horses	413	386398
Buffalo hunt under the wolf-skin mask	414	386399
*Buffalo chase, mouth of Yellowstone	415	386400
*Buffalo chase in winter, Indians on snowshoes	416	386401
Buffalo chase in winter, Indians on snowshoes	417	386402
Batiste and I running buffalo, mouth of the Yellowstone	421	386405
*Dying buffalo in a snowdrift	423	386406
Buffalo bulls fighting in running season, Upper Missouri	424	386407
Buffalo bulls in a wallow	425	386408
Batiste, Bogard, and I approaching buffalo on the Missouri	473	386453
*Bogard, Batiste, and I chasing buffalo in high grass on a Missouri bottom	486	386462
*Catlin and party stalking buffalo on the Upper Missouri	579	386487
*Catlin and guide approaching buffalo under white wolf skins	590	386493
*Catlin and party stalking buffalo in Texas	594	386494
*Stalking buffalo, Arkansas	599	386499
Buffalo and Elk		
*Elk and buffalo grazing, Texas	580	386488
*Elk and buffalo making acquaintance, Texas	581	386489

	Catlin number	U.S.N.M. number
Buffalo and Wolves		
White wolves attacking a buffalo bull	467	386448
White wolves attacking a buffalo bull	468	386449
Elk		
*Elk grazing on an autumn prairie	598	386498
Grouse		
*Grouse-shooting—on the Missouri prairies	426	386409
Wild Horses		
Wild horses at play, Texas	499	386472

MISSOURI RIVER VALLEY LANDSCAPES

	Catlin number	U.S.N.M. number
View on the Missouri, alluvial banks falling in, 600 miles above St. Louis	363	386348
"Brick Kilns," clay bluffs, 1,900 miles above St. Louis	366	386351
*Foot war party on the march, Upper Missouri	367	386352
*Prairie bluffs at sunrising, near mouth of Yellowstone River	368	386353
Mouth of the Platte River, 900 miles above St. Louis	369	386354
*Magnificent clay bluffs, 1,800 miles above St. Louis	370	386355
*Cabane's trading house, 930 miles above St. Louis	371	386356
*View in the Grand Detour, 1,900 miles above St. Louis	372	386357
Beautiful grassy bluffs, 110 miles above St. Louis	373	386358
Prairie meadows burning	374	386359
Prairie bluffs burning	375	386360
"Floyd's Grave," where Lewis and Clark buried Sergt. Floyd (August 1804)	376	386361
*"The Tower," 1,100 miles above St. Louis	378	386363
Picturesque clay bluff, 1,700 miles above St. Louis	380	386365
"Belle Vue," Indian Agency of Major Dougherty, 870 miles above St. Louis	381	386366
*Beautiful clay bluffs, 1,900 miles above St. Louis	382	386367
Fort Pierre, mouth of Teton River, 1,200 miles above St. Louis	384	386369
*Nishnabottana Bluffs, 1,070 miles above St. Louis	385	386370
*South side of Buffalo Island, showing buffalo berries in foreground	387	386372
Fort Union, mouth of Yellowstone, 2,000 miles above St. Louis	388	386373
*"Iron Bluff," 1,200 miles above St. Louis	389	386374
Big Bend on the Upper Missouri, 1,900 miles above St. Louis	390	386375
*View in the Big Bend of the Upper Missouri	391	386376
"The Three Domes," group of clay bluffs, 15 miles above the Mandans	394	386379
"Square Hills," 1,200 miles above St. Louis	395	386380

	Catlin number	U.S.N.M. number
*Upper Missouri river bluffs and white wolves in foreground	396	386381
Beautiful prairie bluffs above the Poncas, 1,050 miles above St. Louis	397	386382
*View from Floyd's Grave, 1,300 miles above St. Louis	398	386383
River bluffs, 1,320 miles above St. Louis	399	386384
Buffalo herds crossing the Upper Missouri	400	386385
*Clay bluffs, 20 miles above the Mandans	401	386386
*Nishnabottana Bluffs, 1,070 miles above St. Louis	402	386387
*Indians encamping at sunset, Upper Missouri	403	386388
*Traveling through tall grass in a Missouri bottom	481	386459

SOUTHERN GREAT PLAINS LANDSCAPES

	Catlin number	U.S.N.M. number
*View on the junction of Red River with the False Washita in Texas	345	386337
*Dragoons crossing the Canadian River, 1834	351	386343
*Ta-wa-que-nah, or Rocky Mountain, near the Comanche village, Texas	352	386344
*View in the "Cross Timbers," Texas	362	386347
*An Indian family alarmed at approach of a prairie fire	595	386495

INDIAN TRIBES OF THE GREAT LAKES AND WOODLANDS

Cherokee

1834 location: In process of gradual removal to lands west of Mississippi River from North Carolina and Georgia. Now in Oklahoma and on Qualla Reservation, North Carolina.

	Catlin number	U.S.N.M. number
Col-le, a Band chief	285	386285
*Black Coat, a chief	286	386286

Choctaw

1834 location: In process of removal from Mississippi and Alabama to present Oklahoma. Now in Oklahoma and on Choctaw Reservation, Mississippi.

	Catlin number	U.S.N.M. number
Puts Out and Kills, first chief	294	386294
*How Did He Kill?, a brave	295	386295
Snapping Turtle, well-educated half-breed	296	386296
*A Choctaw woman	297	386297
*Drinks the Juice of the Stone	298	386298
Drinks the Juice of the Stone, in ball-player's dress	299	386299
Ball-play dance	427	386410
Ball play of the Choctaw—ball up	428	386411
*Variant of above, but with tipis in background	---	386412
Ball play of the Choctaw—ball down	429	386413
Eagle Dance of the Choctaw	449	386449

Creek

1834 location: In process of removal from Georgia and Alabama to present Oklahoma. Now primarily in the area of the old Creek Nation in Oklahoma.

	Catlin number	*U.S.N.M. number*
Great King, called Ben Perryman, a chief	288	386288
Sam Perryman, brother of above	289	386289
*Wat-ál-le-go, a brave	290	386290
*Hose-put-o-káw-gee, a brave	291	386291
*Tchow-ee-pút-o-kaw, a woman	292	386292
*Tel-maz-há-za, a warrior	293	386293

Delaware

1831 location: Remnant living on western borders of Missouri. Great majority of remaining Delaware are now living in Oklahoma.

	Catlin number	*U.S.N.M. number*
*Bód-a-sin, the chief	274	386274
The Answer, second chief	275	386275
Non-on-dá-gon, a chief	276	386276

Iroquois

1830 location: Primarily on reservations in New York and Ontario, Canada. Now located in same areas.

	Catlin number	*U.S.N.M. number*
Nót-to-way, a chief	196	386196
*Chée-ah-ká-tchée, wife of above	197	386197

Kaskaskia

1831 location: Tribal remnant near Fort Leavenworth in present Kansas. This was once the leading tribe of the Illinois Confederacy. Survivors primarily in Oklahoma.

	Catlin number	*U.S.N.M. number*
Little Chief, a chief	246	386246
Wah-pe-séh-see, mother of above	247	386247

Kickapoo

1831 location: Part of tribe removed from Illinois to west bank of Missouri River near Fort Leavenworth in present Kansas. Now on Kickapoo Reservations in Oklahoma and Kansas.

	Catlin number	*U.S.N.M. number*
The Foremost Man, chief of tribe	240	386240
Cock Turkey, repeating his prayer	241	386241
*Elk's Horn, a subchief	242	386242
*Big Bear	243	386243
*A'h-tee-wát-o-mee, a woman	244	386244
*Shee-náh-wee	245	386245

Menominee

1835 location: On the Fox River and western shore of Green Bay, Wisconsin. Now on Menominee Reservation, Wisconsin.

	Catlin number	*U.S.N.M. number*
Grizzly Bear, chief	218	386218
Wounded Bear's Shoulder, wife of above	219	386219
Great Cloud, son of Grizzly Bear	220	386220
*Little Whale, a brave	221	386221
*The South, a noted warrior	222	386222
*Mash-kee-wet, a great dandy	223	386223
*Pash-shee-nau-shaw, a warrior	224	386224
Great Chief	225	386225
*One Sitting in the Clouds, a boy	226	386226
*Earth Standing, an old warrior	227	386227
*Big Wave, old and distinguished chief	228	386228
*Small Whoop, a warrior	229	386229
*Ah-yaw-ne-tah-car-ron, a warrior	230	386230
The Owl, an old chief	232	386232
*Wah-chees, a brave	233	386233
*Portrait of two unnamed men	235–6	386235–6

Mohegan (Stockbridge)

1830 location: At New Stockbridge and Brotherton in western New York, already removed from farther east. Now on reservation on east side of Lake Winnebago, Wisconsin.

	Catlin number	*U.S.N.M. number*
Both Sides of the River, tribal chief	272	386272
John W. Quinney (The Dish), missionary preacher	273	386273

Ojibwa (Chippewa)

1835 location: East of Mississippi River in woodlands of present Minnesota, Wisconsin, and adjacent areas of Canada. Now primarily on reservations in Minnesota, Wisconsin, and southern Canada.

	Catlin number	*U.S.N.M. number*
*Meeting Birds, a brave	184	386184
*Tries the Ground with His Foot	185	386185
Jú-ah-kís-gaw, woman with child in cradle	186	386186
Sits Everywhere, a brave	187	386187
The Ottaway, a warrior	188	386188
*He Who Halloes	192	386192
The Crow, a dandy	193	386193
*Male Caribou, a brave	194	386194
*Strong Wind (painted in Europe)	513	386311
*The Hail Storm (painted in Europe)	532	386317
*Tempest Bird (painted in Europe)	535	386318
*Bird of Thunder (painted in Europe)	536	386319
*Pelican, a boy of 10 years (painted in Europe)	538	386320

Ojibwa (Chippewa)—Continued	Catlin number	U.S.N.M. number
Canoe race near Sault Ste. Marie	434	386418
Snowshoe dance at first snowfall	451	386434
*Brave's Dance	452	386435
*Four dancers (probably Ojibwa, painted in Europe)		386439
Making portage around Falls of St. Anthony with bark canoes	465	386446
*Spearing salmon by torchlight	575	386486

Oneida

1830 location: In New York and Ontario, Canada. Now primarily on Oneida Reservation, Wisconsin, and Oneida Reservation, New York.

	Catlin number	U.S.N.M. number
Bread, the chief	270	386270

Ottawa

1830 location: Upper Canada and Michigan. Now in Michigan, Wisconsin, Oklahoma, and vicinity of Lake Huron, Canada.

	Catlin number	U.S.N.M. number
*Big Sail, a chief	198	386198

Peoria

1831 location: Remnant of tribe of the Illinois Confederacy removed to vicinity of Fort Leavenworth in present Kansas. Now on reservation in northeastern Oklahoma.

	Catlin number	U.S.N.M. number
Man Who Tracks, a chief	251	386251
No English, a dandy	253	386253

Piankashaw

1831 location: Remnant of tribe from Indiana and Illinois removed to vicinity of Fort Leavenworth in present Kansas. Now consolidated with Peoria in Oklahoma.

	Catlin number	U.S.N.M. number
Fix with the Foot, a brave	254	386254
Left Hand, a warrior	255	386255

Potawatomi

1831 location: Tribe in process of removal from Michigan, portion resettled near Fort Leavenworth in present Kansas. Now on reservations in Wisconsin, Michigan, Oklahoma, and Kansas.

	Catlin number	U.S.N.M. number
The Sauk, in act of praying	237	386237
Bear Traveling at Night, a chief	238	386238

Sauk and Fox (Sac and Fox)

1834 location: On Upper Mississippi and Des Moines Rivers in present Iowa. Now on Sac and Fox Reservations in Oklahoma, Kansas, and Iowa.

	Catlin number	*U.S.N.M. number*
Keokuk (The Watchful Fox), chief of Sauk tribe	1	386001
*Keokuk on horseback	------	386000

	Catlin number	*U.S.N.M. number*
Black Hawk, prominent Sauk chief	2	386002
Whirling Thunder, eldest son of Black Hawk	3	386003
*Roaring Thunder, youngest son of Black Hawk	4	386004
Wife of Keokuk	5	386005
Deer's Hair, favorite son of Keokuk	6	386006
White Cloud (called The Prophet), adviser to Black Hawk	7	386007
*Soup, adviser to Black Hawk	8	386008
The Whale, one of Keokuk's principal braves	9	386009
The Buck's Wife, wife of The Whale	10	386010
Little Stabbing Chief, venerable old Sauk chief	11	386011
*The Ioway, one of Black Hawk's principal warriors	12	386012
*The Swimmer, one of Black Hawk's warriors	13	386013
*Little Stabbing Chief the Younger, one of Black Hawk's braves	15	386015
*Bear's Track, Sauk	16	386016
*The Fire, a Fox medicine man	17	386017
Sturgeon's Head, a Fox warrior	18	386018
*Three Fox Indians (names not given)	19–21	386019–21
Begging Dance, Sauk and Fox	439	386423
Dance to the berdash	442	386425
Dance to the medicine bag of the brave	444	386427
Discovery Dance	448	386431
Slave Dance	450	386433
"Smoking Horses." Fox going to war beg horses from the Sauk	463	386444
Sailing in canoes	479	386458

Shawnee

1831 location: Removed from land east of the Mississippi River to present Kansas. Now on Shawnee and Eastern Shawnee Reservations, Oklahoma.

	Catlin number	*U.S.N.M. number*
Goes Up the River, an aged chief	277	386277
The Open Door, known as The Prophet, brother of the great chief Tecumseh	279	386779
Straight Man, semicivilized	280	386280
*Grass, Bush, and Blossom, semicivilized	281	386281

Seminole

1837 location: Part of tribe removed from Florida to present Oklahoma. Now on reservations in Florida and Oklahoma.

	Catlin number	U.S.N.M. number
Mick-e-no-páh, first chief of the tribe	300	386300
*Osceola, the Black Drink, distinguished warrior	301	386301
King Phillip, second chief	302	386302
The Cloud, a chief	303	386303
Co-ee-há-jo, a chief	304	386304
The Licker, called "Creek Billy"	305	386305
A Seminole woman	307	386307
Osceola Nick-a-no-chee, a boy		386307½
Seminole drying fish, White Sand Bluffs on Santa Rosa Island, near Pensacola	354	386346

Seneca

1830 location: Primarily on reservation in western New York. Now primarily on reservations in New York and Oklahoma.

	Catlin number	U.S.N.M. number
*Deep Lake, an old chief	264	386264
*Round Island, a warrior	265	386265
Hard Hickory, an amiable man	266	386266
Good Hunter, a warrior	267	386267
*String, a renowned warrior	268	368268
*Seneca Steele, a great libertine	269	386269

Tuscarora

1830 location: Primarily on reservation in western New York. Now primarily on Tuscarora Reservation in western New York.

	Catlin number	U.S.N.M number
Cú-sick, son of the chief	271	386271

Wea

1831 location: Removed from Indiana to the Missouri Valley south of Fort Leavenworth in present Kansas. Later consolidated with Peoria and other remnant tribes in Oklahoma.

	Catlin number	U.S.N.M. number
Stands by Himself, a distinguished brave	248	386248
The Swan, a warrior	249	386249

Winnebago

1836 location: North of Wisconsin and Fox Rivers in Wisconsin. Now on the Winnebago Reservation, Nebraska, and in public domain allotments of Wisconsin.

	Catlin number	U.S.N.M. number
*Du-cor-re-a, chief of tribe, and his family	199–206	386199–206
Man Who Puts All out of Doors	207	386207
*The Wonder	208	386208

Winnebago—Continued	*Catlin number*	*U.S.N.M. number*
Wood	209	386209
*Káw-kaw-ne-chóo-a, a brave	210	386210
*Comes on the Thunder	211	386211
*The Soldier	212	386212
The Snake	213	386213
*The Spaniard	214	386214
*The Little Elk	215	386215
*Breaks the Bushes	216	386216
*Moistens the Wood	217	386217
*Winnebago shooting ducks on Wisconsin River	347	386339

Yuchi

1837 location: Part of tribe with Seminole and part with Creek Indians. Now primarily in Oklahoma.

	Catlin number	*U.S.N.M. number*
*Deer without a Heart, a chief	309	386309
*Chee-a-ex-e-co, daughter of above	310	386310

MISSISSIPPI VALLEY LANDSCAPES

	Catlin number	*U.S.N.M. number*
*St. Louis from the river below	311	386325
*Beautiful prairie bluffs on Upper Mississippi	312	386326
Picturesque bluffs above Prairie du Chien	317	386327
*Madame Ferrebault's Prairie above Prairie du Chien	322	386328
*Rock Island, U. S. Garrison	328	386329
*Beautiful Prairie bluffs, Upper Mississippi	329	386330
Dubuque's grave, Upper Mississippi	330	386331
Prairie du Chien, United States Garrison	333	386332
Swan Lake near the Coteau des Prairies	348	386340
*View on Lake St. Croix, Upper Mississippi	350	386342

GREAT LAKES LANDSCAPES

	Catlin number	*U.S.N.M. number*
Sault Ste. Marie from the Canadian shore, Lake Superior, showing U. S. Garrison in distance	339	386335
*Niagara Falls (on roll canvas 86½″ long)		386504

FLORIDA LANDSCAPE

	Catlin number	*U.S.N.M. number*
Beautiful Savannah in the pine woods of Florida	349	386341

WILDLIFE AND HUNTING IN THE WOODLANDS

	Catlin number	*U.S.N.M. number*
*Deer hunting by torchlight in bark canoes	554	386479

INDIAN TRIBES OF THE FAR NORTHWEST

Chinook

Home territory Lower Columbia River, a region not visited by George Catlin at time these paintings were executed.

	Catlin number	*U.S.N.M. number*
Woman and child, showing how heads of children are flattened	147	386147
Hee-doh′ge-ats, a young man	148	386148

Nez Perce

These two men visited St. Louis in 1832. Catlin painted them on their return journey up the Missouri dressed in Sioux costumes.

	Catlin number	*U.S.N.M. number*
Rabbit's Skin Leggings	145	386145
No Horns on His Head	146	386146

UNIDENTIFIED PAINTINGS IN COLLECTION

Portraits

	U.S.N.M nnmber
*Unidentified man (probably Ojibwa, painted in Europe)	386321
*Unidentified man (probably member of a Southeastern tribe)	386322

Scenes

	U.S.N.M number
*Group of dancers (probably eastern marginal Great Plains)	386440
*Group of dancers in india ink (probably Ojibwa, in Europe)	386503

OTHER MAJOR COLLECTIONS OF GEORGE CATLIN PICTURES

1. *O'Fallon Collection.* Chicago Museum of Natural History. Chicago.
   35 oil paintings (majority Indian portraits 28″ x 23″) based on Catlin's travels ante 1833. Collection purchased in 1894 from Miss Emily O'Fallon, daughter of Catlin's friend, Maj. Benjamin O'Fallon, Indian Agent. These may have been in collection of Catlin paintings seen by Prince Maximilian and Carl Bodmer at O'Fallon's country home near St. Louis in 1833. Some 25 of these paintings are less finished renderings of same subjects in U. S. National Museum collection. All 35 paintings are described and illustrated in Quimby, 1954.
2. *Catlin's Cartoon Collection.* American Museum of Natural History. New York City.
   418 oils on cardboard of the 603 items in Catlin's Cartoon Collection exhibited by him in New York in 1871. Includes many replicas executed in Europe of original Indian Gallery subjects. Portraits commonly full-length and three or more to a painting. In addition there are many pictures based on Catlin's travels in South America and North America west of the Rockies in the 1850's, and a series of historical paintings interpreting La Salle's explorations in America intended for King Louis Philippe of France. (Catlin, 1871).

3. *Souvenir of the North American Indians.* The New York Public Library. New York City.

Bound volumes containing 167 plates of pencil drawings with page of explanation opposite each plate. Drawings executed in Europe ante 1852. Includes many replicas of original Indian Gallery subjects. Portraits commonly full-length and three or more to a plate. In addition there are portraits of Indians of North America west of Rockies seen by Catlin in 1850's and facsimiles of painted buffalo robes presumably owned by the artist.

4. *The North American Indians in the Middle Nineteenth Century.* The Henry E. Huntington Library and Art Gallery. San Marino, Calif.

155 pencil drawings, many identical to those in New York Public Library (see No. 3 above), and 50 oil-on-paper cartoons, many identical to those in American Museum of Natural History (see No. 2 above).

5. The New York Historical Society. New York City.

221 pencil and pen-and-ink drawings, many of them very similar if not identical to No. 3 above. (See Holloway, 1942.)

6. *Souvenir of the North American Indians.* The Newberry Library. Ayer Collection. Chicago.

Bound volumes comprising 217 pencil portraits, one to a page. Title page signed "Geo. Catlin, 1852." Includes portraits of Indians west of Rockies not seen by Catlin until 1850's.

7. Yale University Library. New Haven, Conn.

Two bound volumes comprising 216 pencil portraits, one to a page. Similar to No. 6 above. Also 3 oil portraits on cardboard.

8. The Thomas Gilcrease Institute of American History and Art. Tulsa, Okla.

Set of watercolor replicas of Indian Gallery subjects. (Haberly, 1948, p. 233.) Mrs. Owen A. Teague, Registrar, has informed me that this collection comprises approximately 150 Catlin watercolors and 75 oil paintings.

9. New York State Library. Albany, N. Y.

Bound volume containing 100 watercolor replicas of Indian Gallery oil paintings. (Haberly, 1948, p. 233.)

10. The University Museum. University of Pennsylvania. Philadelphia, Pa.

8 oil paintings, including the unfinished study of Keokuk on horseback reproduced in Haberly (1948, p. 129), and the series of 4 Mandan Okipa Ceremony scenes.

11. The Royal Ontario Museum of Archaeology. Toronto, Canada.

33 oil paintings the majority of which are wildlife and hunting scenes.

There are in addition to these 11 collections several small collections of Catlin's works in other libraries and museums in the United States. Catlin was unusually industrious as a copier of his own works in oils, watercolors, pencil, and pen-and-ink. Other artists of the precamera period commonly redrew or repainted their most popular works. But Catlin made replicas of literally hundreds of his pictures. Some of his more popular ones he must have copied more than a half-dozen times. As I have shown in plates 13 and 15 of this article, Catlin sometimes sharpened the details or elaborated upon the Indian Gallery oil painting when he redrew the subject in pencil. Consequently some of his later scenes in Indian life are more revealing as pictorial documents than are the presumed originals from which they were adapted. There are also a fair number of scenes among the later pencil draw-

ings and cartoons that have no predecessors in the Indian Gallery series. Some significant revelations of little-known Catlins undoubtedly would result from a careful comparative study of all known collections of this artist's work.

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George Catlin. Portrait by William H. Fisk in 1849. (National Collection of Fine Arts.)

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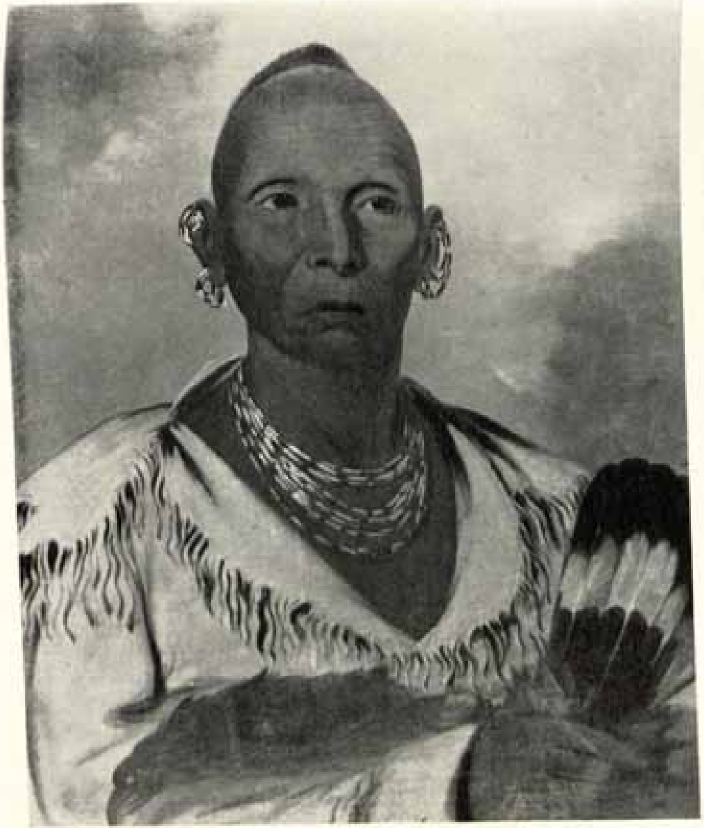
2. Horse Chief, Grand Pawnee head chief. (99.)



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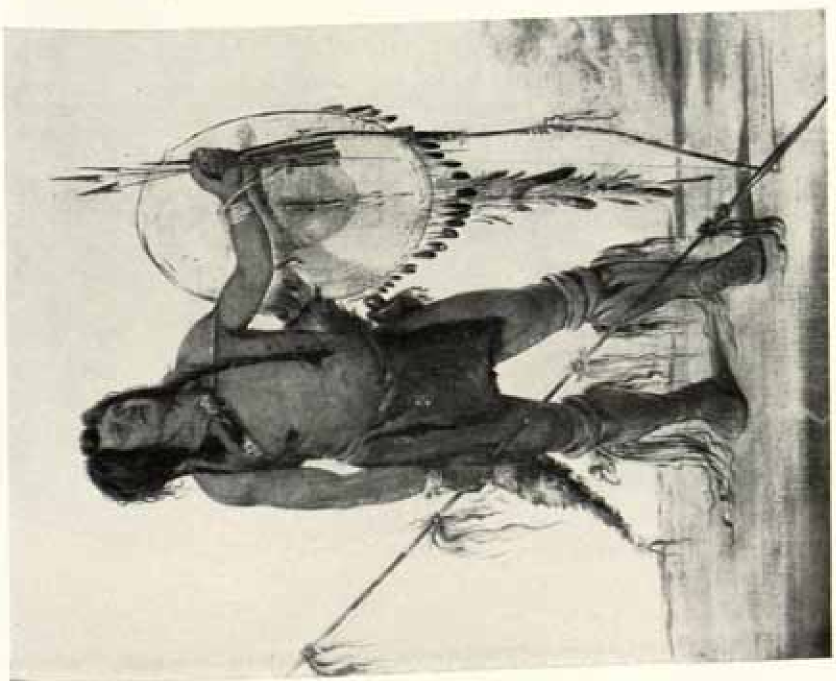
Black Moccasin, aged head chief of the Hidatsa. Lewis and Clark knew him in 1804. (171.)



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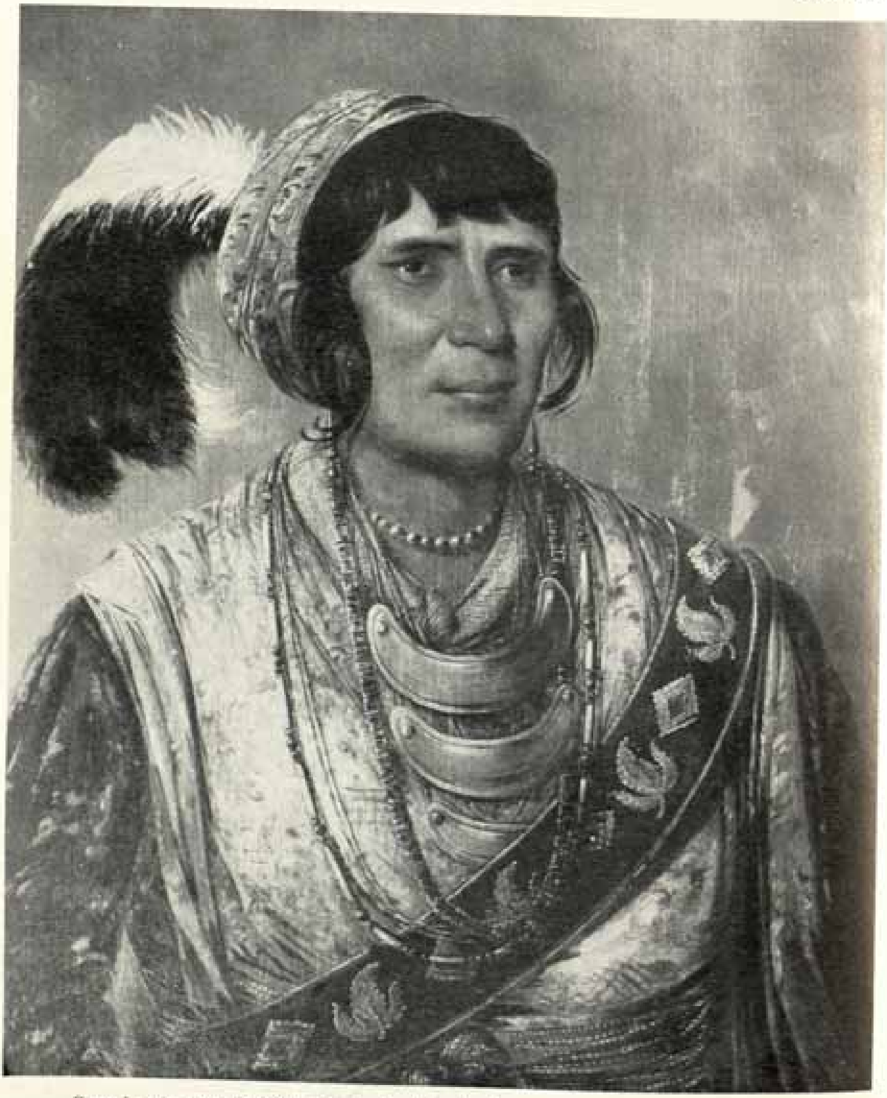

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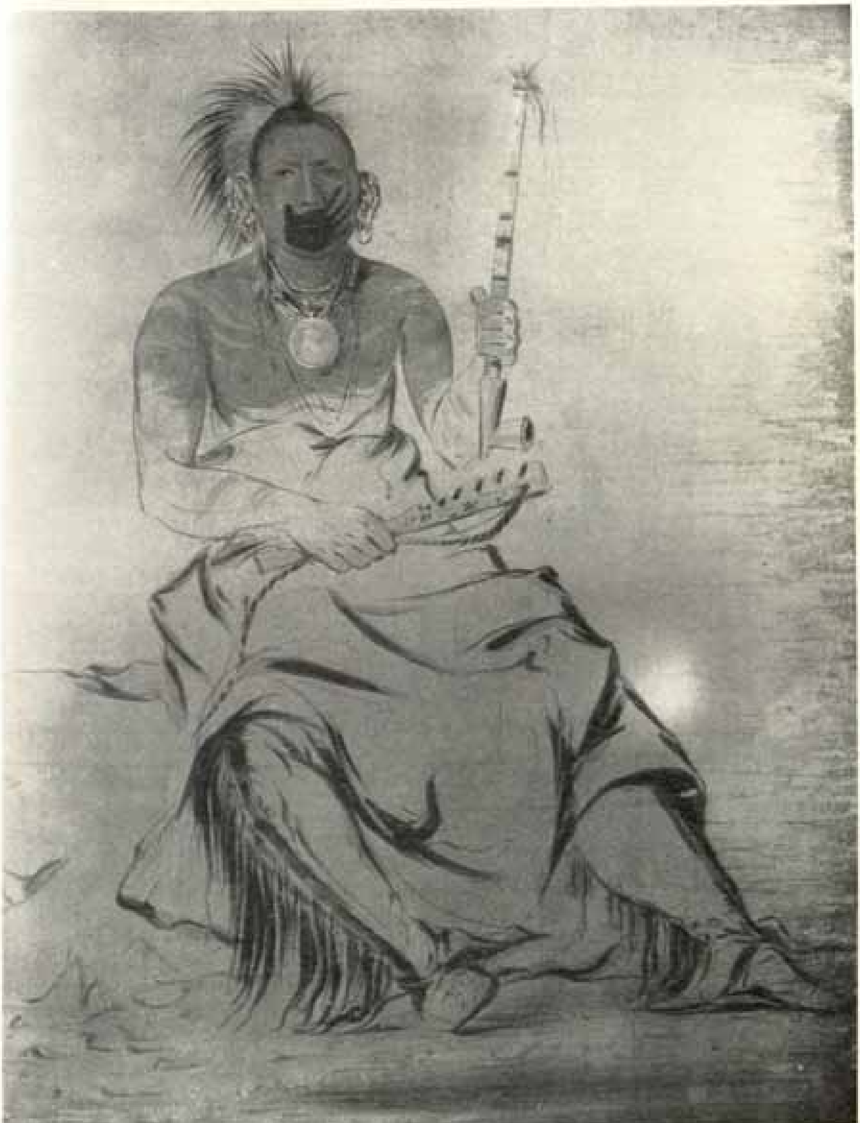

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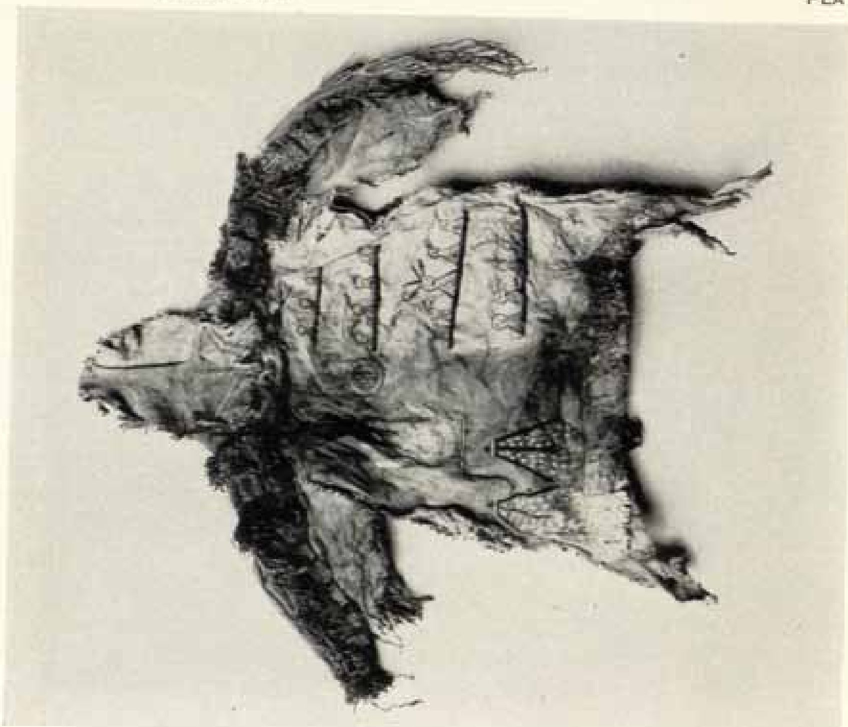

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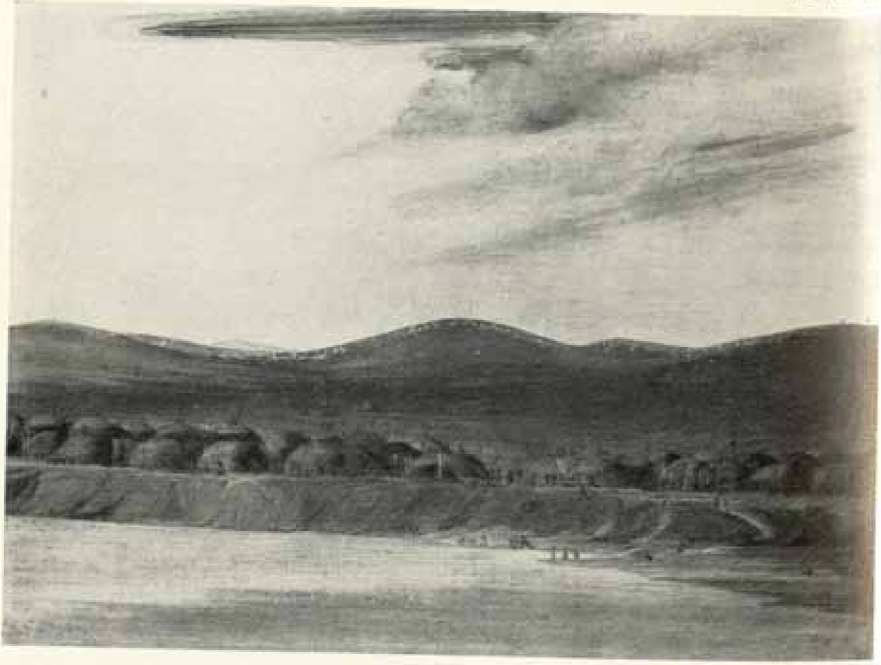

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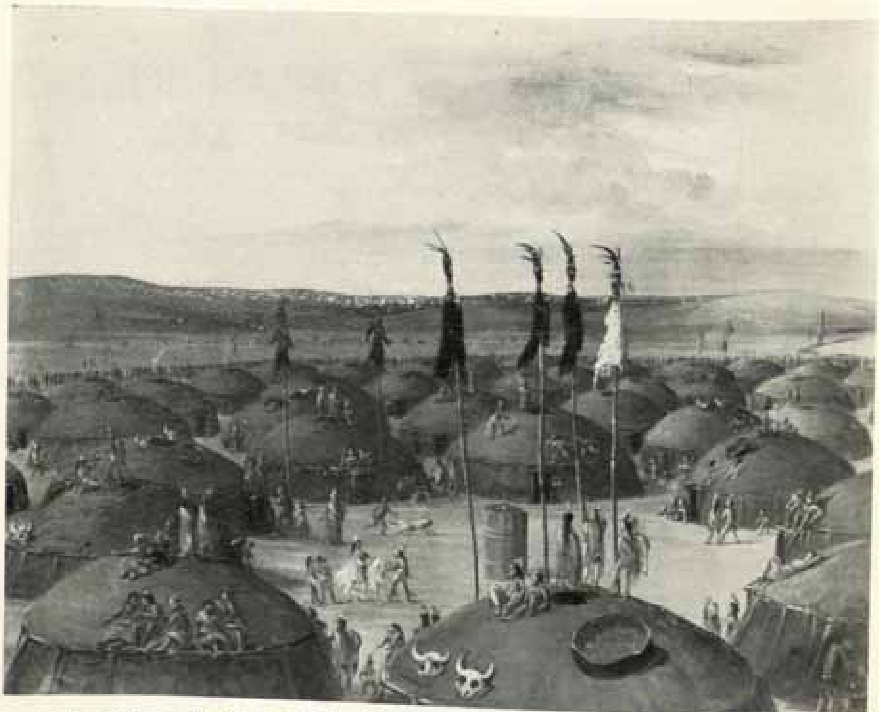

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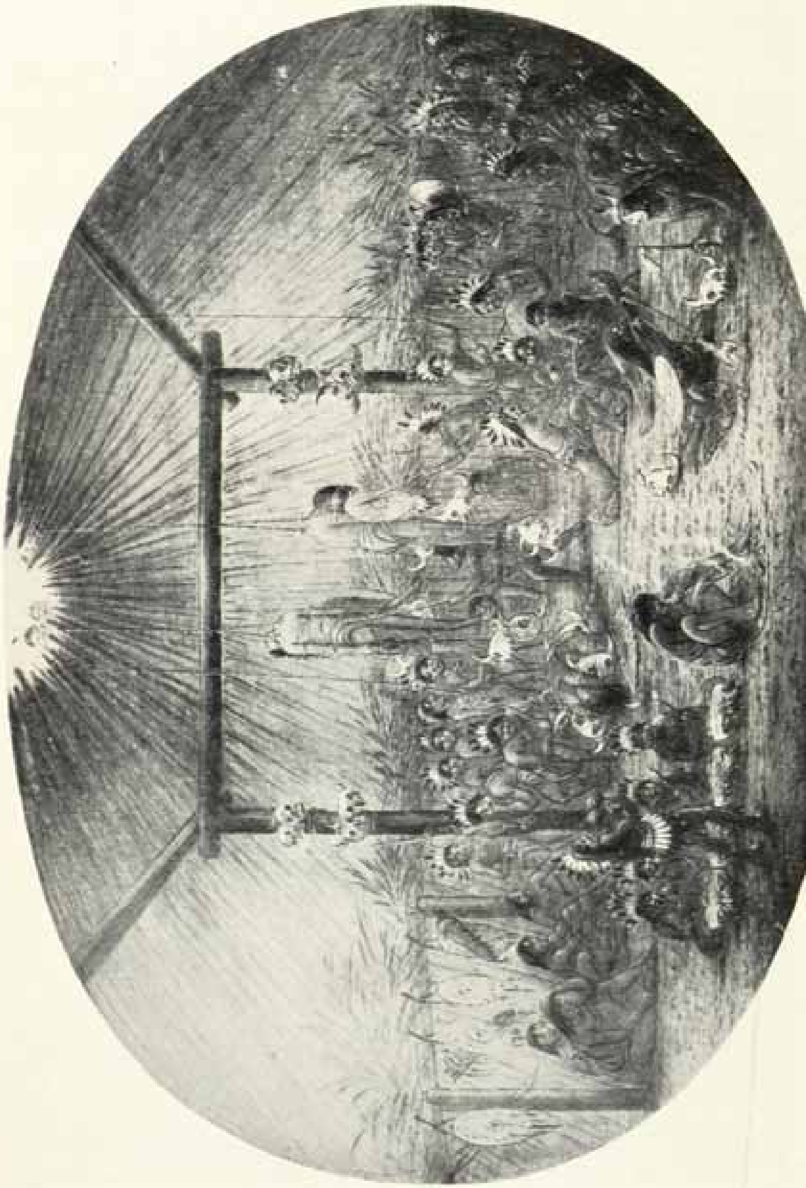

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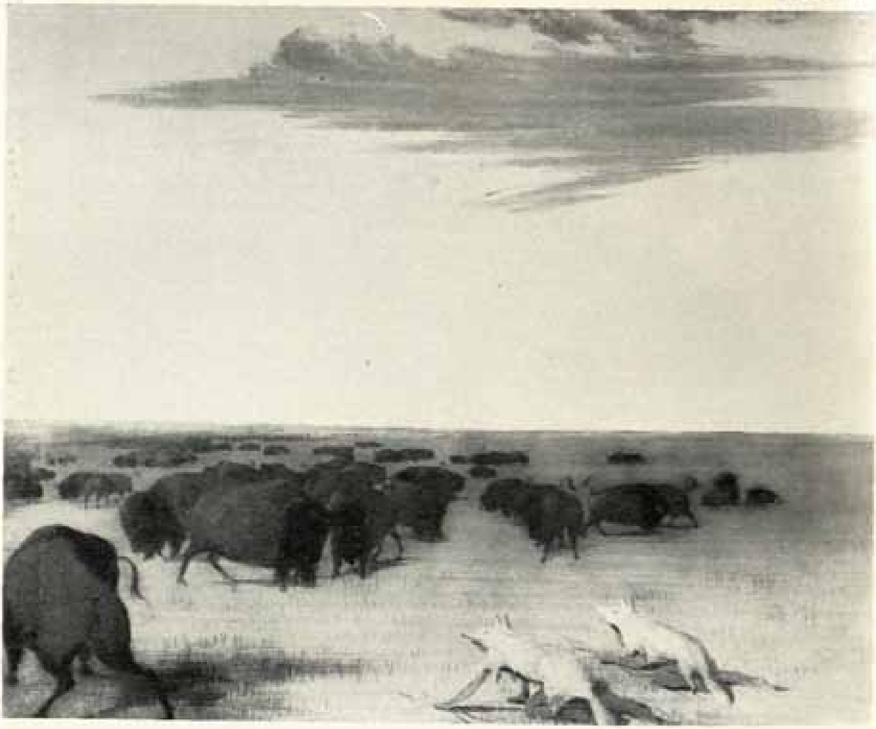

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