FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN

PER ORBEM

SMITHSONIAN INSTITUTION

WASHINGTON 1846

Annual Report of the Board of Regents

of the

SMITHSONIAN INSTITUTION

PUBLICATION 4530

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

1963

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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, January 24, 1964.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, on behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1963.

Respectfully,

LEONARD CARMICHAEL, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1963

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LUTHER H. HODGES, Secretary of Commerce.
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Division of Mammals: D. H. Johnson, curator; H. W. Setzer, C. O. Handley, Jr., associate curators.
Division of Birds: P. S. Humphrey, curator, G. E. Watson, assistant curator.
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Division of Naval History: P. K. Lundeberg, curator; M. H. Jackson, associate curator.

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Museum of History and Technology Laboratory: B. W. Lawless, chief; B. S. Bory, production supervisor.

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John E. Graf
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United States National Museum

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W. J. Tobin, Physical Anthropology.

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W. L. Jellison, Insects.
Allen McIntosh, Mollusks.
J. P. Moore, Marine Invertebrates.
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W. L. Schmitt, Marine Invertebrates.
Benjamin Schwartz, Helminthology.
T. E. Snyder, Isoptera.
H. K. Townes, Insects.
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E. C. Leonard, Phanerogams.
F. A. McClure, Grasses.
Mrs. Kittie F. Parker, Phanerogams.
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J. T. Dutro, Invertebrate Paleontology.
A. A. Olsson, Invertebrate Paleontology.
W. T. Schaller, Mineralogy.
W. P. Woodring, Invertebrate Paleontology.

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E. C. Herber, History.
I. N. Hume, Cultural History.
F. W. McKay, Numismatics.
Emery May Norweb, Numismatics
R. Henry Norweb, Numismatics

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F. C. Lane.
Byron McCandless.

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Bureau of American Ethnology

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M. W. Stirling.
A. J. Waring, Jr.

Astrophysical Observatory

C. G. Abbot

Freer Gallery of Art

Oleg Grabar.
Grace Dunham Guest.
Max Loehr.
Katherine N. Rhoades.

National Air Museum

Frederick C. Crawford.
John J. Ide.
Alfred V. Verville.

National Zoological Park

E. P. Walker

Canal Zone Biological Area

C. C. Soper

Report of the Secretary of the Smithsonian Institution

LEONARD CARMICHAEL

For the Year Ended June 30, 1963

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, 1963.

GENERAL STATEMENT

James Smithson directed that the Institution founded by him should be an establishment for the *increase and diffusion of knowledge among men.* The 117th year of the Smithsonian Institution, covered in the present report, shows notable achievements in research; that is, in the *increase of knowledge.* The publications, museum displays, and the answering of letters requesting information have all served during the year to further *the diffusion of knowledge.*

In the pages that follow, reports of the activities of each of the bureaus of the Smithsonian present in some detail the story of the year. Additions to the collections, publications, new exhibits, new research findings, and explorations are all described.

The year's most notable development has been the progress made in the completion of the great new Museum of History and Technology Building. This marble structure will be one of the largest and one of the most modern and effective museums in the world. Its 50 public exhibition halls will almost certainly be viewed each year by at least 5 million visitors. The building has been planned so that access to exhibits and the movement of visitors through the halls will be as convenient as possible and produce a minimum of what is often all too accurately called "museum fatigue." In planning each new exhibit an effort has been made to make every display a complete instructional unit. Space has also been set aside for the great study collections of the Institution in the fields of history and technology, containing objects that are not on public exhibition but that are of importance to the thousands of research scholars, specialists, and collectors who come to the Smithsonian every year to learn more in detail about some particular field of inquiry.

The new east-wing addition to the National History Building, virtually completed by the end of the year, has been occupied by staff scientists. Many of the great biological and geological study and research collections of the Institution have been moved into space provided in this wing. The completion of these additional facilities, when supplemented by the later completion of the west wing, will again allow the opening of some large public halls of the Natural History Building that have had to be closed for many years in order to provide space for research activities. During the more than 50 years between the completion of this great Natural History Building and the construction of these new wings, much exhibition space had necessarily been encroached upon. Now these fine halls, originally planned for natural-history exhibitions, can be returned to their proper use.

As noted in the reports that follow, physical improvements have also been carried on at the National Zoological Park. Planning has also been completed for the renovation of the old Patent Office Building. This building, by an act of Congress, has been assigned to the Smithsonian Institution as the new home of the National Collection of Fine Arts and of the new National Portrait Gallery.

The Decade 1953–63

Each annual report of the Smithsonian Institution describes the advances that have been made in a single period of 12 months. It may not be inappropriate occasionally in an annual report to summarize accomplishments and changes that have taken place in the Institution over a longer period of time. The decade 1953–63 has been one marked by much progress at the Institution. As the present report is the last one that will be submitted to the Board of Regents by the present Secretary, it has seemed fitting to review here briefly some of the highpoints of this 10-year period. These years cover the major period of tenure of the present Secretary.

It must be emphasized that all the advances made at the Smithsonian Institution during the period under review are a result of the actions and support of the Board of Regents of the Smithsonian Institution and of the Congress of the United States.

In the paragraphs that follow, brief summaries are presented of some of the major activities in this notable decade of each of the bureaus of the Smithsonian.

United States National Museum, 1953–63

Ten years ago, as at the present time, the United States National Museum consisted of two major sections. The Natural History Museum, in terms of national and indeed international recognition, probably the best known part of the Museum, has developed in the decade under consideration in an outstanding way. The other section, now called the Museum of History and Technology, has seen an equally important development.

In 1953 there were more than 34 million cataloged objects in the National Museum of the Smithsonian Institution. By 1963 this number had grown to over 57 million such objects. Sometimes those who do not know intimately the work of the Smithsonian ask why the collections have been allowed to develop so rapidly. The answer, of course, is that the scientific work of the Smithsonian depends very largely upon the use of these study collections by literally thousands of competent investigators. Much of the world-famous scientific study of insects, of plants, of minerals, and of other areas of the natural resources of our Nation that is carried out at the Smithsonian Institution, could not be performed if it were not for the presence of these great, and in many cases unique, assemblages of carefully documented and labeled scientific specimens. During the decade under consideration the staff of the Natural History Museum has been markedly strengthened so that it can more adequately perform necessary investigations related to these collections. Much of this research has specific applications to medicine, especially military medicine, the effect of radiation on living cells, insect control, general problems of conservation, the development of food resources, and the scientific knowledge of the natural history of the earth.

Field investigations conducted by the Museum have more than doubled in number during this decade, and nearly all of them have been conducted, not with funds appropriated to the Smithsonian, but with gifts or grants made by individuals, foundations, or government agencies. Recently the Smithsonian Oceanographic Sorting Center was established to receive, screen, sort, and distribute for scientific study the animals, plants, and minerals collected in the expanding oceanographic program of the United States. Public and private funds have also made it possible for the Smithsonian to participate in the development of techniques for underwater scientific study.

Only 10 years ago most of the corridors of the great Natural History Museum Building were lined from floor to ceiling with cases containing the working scientific reference collections of the Institution. Scientists were required to work on stepladders and in walled-off stairwells or behind screens in exhibition halls. In 1958 Congress appropriated funds for the design of desperately needed additions to the Natural History Building that had been authorized many years before. The east wing, now complete, has added 214,000 square feet of space to allow the proper and effective housing of scientific collections of the Smithsonian. Funds have also been appropriated to allow the erection of the symmetrically matching west wing. Work on the building of this wing is expected to start in calendar year 1963.

In 1953 the 72-year-old Arts and Industries Building was rather generally known in the American press as the "nation's attic." This old building for years had led most of the rest of the museums of the world in the popularity of its exhibits as measured by annual attendance, but it was almost pathetically inadequate to accommodate its great collections or to provide adequately for the tremendous crowds that pushed into it day after day. In 1955 Congress authorized the construction of a new building to be known as the Museum of History and Technology of the Smithsonian Institution. This additional magnificent building is now nearing completion and will soon be equipped with exhibits and be open to the public. The old Arts and Industries Building will not be abandoned but will be used for special exhibits and for the display of important objects that are appropriate for its large halls.

During the decade under review, historians of science and technology, some of them recent additions to the staff of the Institution, have systematized the collections of the Smithsonian in both history and technology. They have developed modern exhibits and have prepared scholarly publications to present to the world the results of their investigations of the collection of treasures housed at the Smithsonian. Until the beginning of this decade most of the publications of the Smithsonian Institution were in fields of study related to the sciences of astronomy, anthropology, botany, zoology, and geology. Today more than 250 monographs and books have been published to provide a scholarly basis for the understanding of some of the great collections of objects in the Museum of History and Technology.

These new Smithsonian publications and the new exhibits in the fields of history and technology have brought to the attention of collectors all over America, and indeed all over the world, the significance of the Smithsonian's work. New interest in the Institution's collections in the field of the decorative arts, and in the collections of furniture, silver, ceramics, textiles, and prints, has been especially notable. Increasingly during these years Smithsonian experts have taken important parts in the programs of seminars and museum conferences dealing with the preservation and understanding of objects in these fields. New methods of examination, interpretation, exhibition, and, above all preservation have been developed during this time in the workrooms and laboratories of the Smithsonian.

During this period the Institution has participated in excavations at a number of colonial American sites. Nearly all this work has been fully or partly supported by funds provided from private sources. As a result of these studies new knowledge has come concerning the mode of life of Americans during the early years of the country, and the pottery, weapons, insignia, tools, and trade objects of our young nation are now much better understood than they were 10 years ago.

One of the prime reasons for the vast increase in the number of visitors at the Smithsonian museums has been the development that has taken place in this decade in the presentation of exhibits. It is not by chance that the number of visitors in the old Smithsonian buildings on the Mall in 1952–53 totaled 3,429,000, whereas the number in 1963 reached the amazing figure of 10,309,000. Since 1953, 28 large exhibition units have been transformed from halls full of poorly lighted cases crammed with objects to well-labeled, modern, teaching exhibits. It is not an exaggeration to say that the truly creative work of the exhibit staff of the Smithsonian has become famous, not only in every other great museum of America but also in all the large museums in the rest of the world.

A few additional notes may be made concerning developments in particular areas of interest:

The Institution has long had one of the great collections of musical instruments of the country. Unfortunately, most of these were not in condition to be played and were not easily viewed. Many of the most important have been restored and can now be played. Some of them have been used in concerts provided free for the public by volunteer musicians. A scientific analytical laboratory has been established at the Smithsonian, and here physical and chemical techniques are now employed in the important task of providing better methods for protecting and conserving the treasures of the Smithsonian. During this decade the White House has been generally renovated. Under the direction of the President of the United States and the staff of the White House, the Smithsonian has played a role in the development of exhibits of the history of the White House as now displayed in the visitor's entrance to this historic center of our Nation. An act of Congress, passed in 1961, provided that objects not needed for use or display at any time at the White House are to be transferred to the Smithsonian Institution.

Annual reports of the Smithsonian list the splendid donations that come to the Institution in each 12-month period. Among the especially notable gifts of the decade may be mentioned the following:

President John F. Kennedy presented a magnificent volume, the "Atlas Nouveau" by Nicolas Sanson, 1692, beautifully bound for the instruction of the Dauphin of France.

Mrs. Arthur M. Greenwood gave many objects illustrating American colonial living, including an entire two-story, four-bedroom house built in Massachusetts in 1678.

The Honorable and Mrs. Wiley T. Buchanan, Jr., purchased for the Museum 600 fine examples of early Rhenish and Dutch pottery; Harry Winston gave the great blue Hope Diamond; and the estate of Mrs. Maude Monell Vetlesen, through her son Edmund C. Monell, donated 130 pieces of beautifully carved jade ranging in age from the Ming through the Ching dynasties.

Dr. Hans Syz began presenting in annual installments one of the outstanding privately owned collections of fine European porcelain of the earliest period. Mrs. Herbert Arthur May made gifts of laces, glass, Americana, Indian materials, and the magnificent necklace of diamonds which Napoleon I gave to the Empress Marie-Louise on the occasion of the birth of their son in 1811.

Lessing J. Rosenwald presented an outstanding English astrolabe of 1325 and a 16th-century folding sundial compass engraved with maps and travel routes of central Europe. The International Business Machines Corp. presented 21 beautifully engraved astrolabes from Persia, India, North Africa, and Europe of the 13th and later centuries, and 24 rare pre-Spanish textiles.

Willis H. du Pont made two outstanding gifts: a collection of coins and medals struck in the name of Peter the Great, with a copy of the rare 11-volume monograph on Russian coins by the Grand Duke Georgiĭ Mikhailovitch; and 860 coins and medals issued in the reigns of Czar Ivan III and Czarina Elizabeth, also from the Grand Duke's collection.

The family of the late Henry T. Peters presented nearly 2,000 lithographs by American printmakers other than Currier and Ives, from the "America on Stone" collection.

Mrs. W. Murray Crane presented a fine collection of French and English furniture of the 18th century, and the Misses Helen R. and Elizabeth W. Newcombe gave the complete furnishings of a 19th-century American parlor.

Senator Clinton P. Anderson, Regent of the Smithsonian, presented a fine copy of the Kelmscott Chaucer printed by William Morris in 1896; and the late Mrs. Richard Saltonstall, mother of Senator Leverett Saltonstall, Regent of the Smithsonian, gave a handsome family carriage made by Thomas Goddard of Boston in 1851; included with the gift was a grant for its restoration.

Mrs. Clara W. Berwick made several gifts, one of 176 pieces of early American glass; Mrs. George Hewitt Myers gave 48 pieces of rare Castleford porcelain of 1790–1820. Arthur E. Wullschleger discovered a French hand-and-foot treadle loom of the 18th century equipped with a Jacquard mechanism of the early 19th century, which he restored and presented to the Smithsonian.

Joseph J. Fényközi donated an African elephant of record size.

Mrs. John Logan (the former Mrs. Rebecca Pollard Guggenheim) presented a 423-carat sapphire. Ralph E. Becker gave many outstanding objects from his collection of political campaign materials, including a painted banner celebrating the victory of Thomas Jefferson in 1801.

Through the foresight of Dr. Robert V. Fleming, Regent of the Smithsonian, the Southern Railway Co. preserved and presented a fine example of a late steam locomotive which has been installed in the new Museum of History and Technology.

The Revolutionary War gunboat *Philadelphia*, complete with its cannons and 700 pieces of military equipment found in it, was acquired from the estate of the late Col. Lorenzo F. Hagglund, who expressed in his will the hope that it be preserved in the National Museum. Also acquired was the unmatched W. Stokes Kirk collection of 3,000 items of military insignia and accouterments.

Dr. W. L. Libby presented the experimental equipment he used in developing the carbon-14 method of dating archeological objects. The Bell Telephone Laboratories gave 66 pieces of early telephone equipment for the telephone exhibit gallery presented by the Bell System and the independent telephone industry. Gifts of the American Telephone & Telegraph Co. include the duplicate Telstar communications satellite. The original equipment of the Nobel prize winners Drs. T. D. Lee and C. N. Yang employed in their nonparity nuclear experiments was collected for preservation, as was the electronic digital computer "Maniac," the gift of Princeton University.

During the period a number of administrative developments strengthened the work of the United States National Museum. By act of Congress a National Armed Forces Museum Advisory Board has been established. The volunteer unpaid Junior League Docent Service and the Smithsonian Museum Service have both been established to provide better educational work for schoolchildren at the Smithsonian. The installation of an Audio-Guide system in many exhibition halls has given information about the collections that appeals to the ear to supplement the labels intended for the eye.

International Exchange Service, 1953–63

The International Exchange Service is one of the oldest units of the Smithsonian. Its work, originated and organized by the first and great Secretary of the Smithsonian, Joseph Henry, more than a century ago, is specifically authorized in 49 international treaties and conventions.

During the decade under considerations, the International Exchange Service received for transmission more publications than in any like period of its long history. There were 12,704,583 publications weighing 9,228,617 pounds received for forwarding through the Service.

The increased workload was handled at little or no additional increase in cost and with no additional employees. The use of cardboard cartons in place of wooden boxes for packing publications for oversea shipments has resulted in a large saving.

Direct booking of ocean freight shipments with the steamship lines, instead of through forwarding agents, has resulted not only in a large saving of the fees that would have been charged by the forwarding agents for their services but also in a more efficient operation. Three weeks or more were necessary under the old system of booking between packing and the shipping of the publications to the steamship piers. Publications are now packed, booked, and shipped in a period of 1 day to 1 week. This method of transmission has reduced the amount of space necessary for storage of cartons of publications awaiting shipment to the steamship lines and has speeded up the turnover of publications on hand for shipment.

A new method of processing publications for mailing has resulted in a faster transmission to the intended addressees. The old method of processing required a period of from 1 to 2 weeks before mailing. The new method provides for mailing on the day of receipt or the following day.

Bureau of American Ethnology, 1953–63

During the decade 1953–63 the activities of the Bureau of American Ethnology were concerned principally with expeditions and researches in the field and publication of anthropological monographs. This unit of the Smithsonian, founded by the great Major John Wesley Powell, is possibly the first center in the country, or even in the world, for research in cultural anthropology. Its publications are famous wherever anthropology is studied.

Of particular significance in the decade under review is the program in archeology carried on in the extreme northern part of the continent. In the earlier years of the period, archeological excavations were conducted at Cornwallis Island in the Canadian Arctic, the work being sponsored jointly by the Smithsonian Institution and the National Museum of Canada. In the Hudson Bay area, investigations on Southampton and Coats Islands occupied several seasons, a cooperative project of the Smithsonian Institution, the National Museum of Canada, and the National Geographic Society. Subsequently the American Philosophical Society joined in the financial sponsorship of those activities and attention was turned to Walrus Island. The extensive materials collected from the various islands greatly increased knowledge about the various peoples who have lived there over a long period of time. Articles about the results and significance of the studies were published by the Smithsonian and in professional journals.

An extensive program of archeological research was carried on at the important Olmec site of La Venta, Tabasco, Mexico. This was a cooperative project in which the Smithsonian Institution, the National Geographic Society, and the University of California participated. The results obtained at La Venta, published as a bulletin of the Bureau, contribute significantly to a proper understanding of the place the Olmecs occupied in the cultural development of early America.

During this decade excavations at Russell Cave in Alabama were sponsored by the Smithsonian Institution and financed by the National Geographic Society. Russell Cave is important because of the long sequence of cultural deposits it contains, and the materials from it make possible the reconstruction of aboriginal developments over a period extending back about 9,000 years. Evidences for many cultural traits not previously recognized in the American South came to light during the course of the digging. The National Geographic Society subsequently purchased the cave and presented it to the National Park Service to be established as a national historic site.

During the 10-year period the work of the River Basin Surveys progressed in a rewarding manner. During that time 23 reservoir areas were surveyed and archeological excavations were conducted in 324 sites. The funds for the program, transferred to the Smithsonian from other government agencies and private donors, were greatly increased during the last 3 years of the decade, making it possible to expand and speed up the salvage operations. Thirty-two papers reporting on the investigations and their significance were published during the period. Others are currently in press. The information thus far obtained has added tremendously to our knowledge of the aboriginal Americans.

The archives of the Bureau, constituting a great national scientific research tool, have increased notably in size and diversity of material in this decade. Large collections of Indian photographs have been made available, and either the original negatives or copies have been added to the files. Included are 312 glass negatives of individual and group portraits of Indian delegates to Washington during the period 1874–90. The papers of Alice Cunningham Fletcher and her adopted son, Francis La Flesche, both of whom had been members of the Bureau staff in earlier years, were donated to the archives by Mrs. G. David Pearlman of Washington, D.C., in memory of her husband. The collection, filling 36 manuscript boxes, includes correspondence and other personal papers of both Miss Fletcher and La Flesche and also extensive ethnographic items relating to the Omaha, Osage, Pawnee, Dakota, and Nez Perce Tribes, with smaller amounts on the Winnebago, the Indians of Alaska, and a few other North American tribes. Much of this material has not been published and is a fruitful source of data for students investigating those groups. Another significant addition to the archives consists of papers of Dr. Frans M. Olbrechts relating to his studies of the Cherokee Indians of North Carolina in 1926–31, when he was a collaborator of the Bureau. Dr. Olbrechts was associated with the Kominklijh Museum, Tervuren, Belgium, and following his death, Mrs. Olbrechts sent all his field notes and other pertinent data to the Bureau.

A noteworthy event in the latter part of the 10-year period was the appointment of a librarian and the reopening of the Bureau library, with its extensive collection of reference works and documentary records concerning all aspects of the life of the American Indian.

The Bureau issued several important bulletins during the period. One of the most noteworthy is "Isleta Paintings," a book outstanding both as a contribution to ethnology and as an excellent example of the effective use of good color reproductions for scholarly reasons.

National Zoological Park, 1953–63

The National Zoological Park was founded as the result of the efforts of the third Secretary of the Smithsonian, Dr. Samuel Pierpont Langley, about 75 years ago. It was established by an act of Congress and assigned to the Smithsonian Institution. Previously a number of great American animals, such as bison, were kept in pens near the original Smithsonian Building. During the years since its establishment, the Park has grown to become one of the world's great animal collections, as well as one of the most visited zoological parks in the world. In 1961 the Congress of the United States authorized the Federal Government to make appropriations to the Smithsonian Institution for capital improvements at the National Zoological Park. As a result, funds have been provided for a master plan for the modernization of the Zoo. This project, planned to be completed in 1972, will be carried out gradually so that there will be very little inconvenience to visitors or disruption of normal activities. One example of the additions made possible by this new program is the constructing of an aviary, 70 feet high and 120 feet in diameter, now nearing completion.

Gifts of animals have been numerous during this decade. Among them were a pair of Barbary apes from Sir Gordon MacMillan of MacMillan, Governor and Commander-in-Chief of Gibraltar; three East Indian monitor lizards from Hon. Carlton Skinner, Governor of

Guam; a tuatara from the Government of New Zealand; two Philippine macaques, early pioneers in space from the U.S. Air Force; two Korean bears from President Syngman Rhee of Korea; pronghorn antelopes from both the Wyoming and the Montana State Fish and Game Commissions; a pair of gorillas from Russell Arundel of Warrenton, Va.; emperor and Adelie penguins from Hon. Charles Thomas, Secretary of the Navy; a young Bengal tiger from the Ambassador of Pakistan, Syed Amjad Ali; a pair of okapis from the Government of the Belgian Congo; an African forest elephant from the Community of French Republics; two dorcas gazelles from President Habib Bourguiba of Tunisia; a spotted leopard and a male pygmy hippopotamus from President William V. S. Tubman of Liberia; an Indian rhinoceros from the Forestry Service of Assam; two Bengal tigers from Ralph Scott of Washington and Miami Beach; the beautiful white tigress "Mohini," from the Metropolitan Broadcasting Corp., the first to be seen outside of Rewa, India; "Ambika," an Indian elephant, from the "Share Your Birthday Foundation" and the Maharajah of Mysore; six North African cranes from President Ibrahim Abboud of Tunisia; three tree kangaroos from Sir Edward Hallstrom of Sydney, Australia; and a sea-lion from Attorney General Robert Kennedy.

The Zoo continued to be fortunate in its breeding program. Among the interesting births, the first in importance was that of "Tomoka," a male lowland gorilla, on September 9, 1961. Other noteworthy births were those of giraffes, pygmy hippos, gaur, Nile hippopotamus, eland, snow leopard, wisent, Cape hunting dogs, striped hyena, margay and serval cats, ring-tailed lemur, and lesser pandas. The kookaburras have laid eggs and successfully reared the young for the past 2 years, and the Surinam toads laid eggs and hatched them in their peculiar manner twice during the 10-year period.

Purchases of unusual interest were a pair of cheetahs; two flat-tailed Brazilian otters (the first to be exhibited in the United States); a pair of black rhinoceroses and a pair of the much rarer white rhinos (these also were the first to come to the States); two giant armadillos; two Père David deer, the rare fossa from Madagascar; a pair of wisent, or European bison; a trio of Saiga antelope; two Sumatran orangutans; a pair of snow leopards; a trio of Masai giraffes; three Cape buffalo; three brindled gnus; Dall sheep; Pallas's cats; maned wolves; two yaks; a Colombian red-eyed cowbird that had not been seen for so many years it was supposed to be extinct; pygmy teal; crocodile birds; and two king cobras. Scientific work, necessary to the maintenance of the great animal collection at the National Zoological Park and also important in adding knowledge concerning the conservation of animals, has also been carried on with increasing success during this 10-year period at the Zoo.

Astrophysical Observatory, 1953–63

During the decade ending in 1963 the Smithsonian Astrophysical Observatory experienced greater change and generated more scientific data than in any other comparable period since its establishment in 1890. In the decade the staff has increased to over 300 members. Its publications include 130 special scientific reports, plus 7 volumes of a new scientific series, Smithsonian Contributions to Astrophysics.

At the beginning of the decade the Observatory maintained two high-altitude stations for solar observations: the resultant data were used to determine the solar constant and to relate it to atmospheric phenomena. This important groundbreaking study was discontinued in 1962 because the method had reached the limit of usefulness.

When Loyal B. Aldrich retired as Director in 1955, Dr. Fred L. Whipple was appointed his successor, and in fulfillment of an arrangement with Harvard University the Observatory was moved to Cambridge, Mass., where it has gained much from close association with the large number of scientific research workers in that area.

The following year the Observatory received, through the Smithsonian Institution in Washington, the first of a series of grants from the National Academy of Sciences and the National Science Foundation for the optical tracking of artificial earth satellites to be launched during the International Geophysical Year. At the end of the IGY in 1959, the resultant tracking program of the Observatory continued under a grant from the National Aeronautics and Space Administration. The tracking camera was designed to achieve a position accuracy of 1 second of arc, and a time accuracy of 1 millisecond in photographing satellites. In addition, there were organized a Moonwatch program of amateur astronomers to make preliminary observations of satellites, a computations division to prepare orbital predictions and ephemerides, and a communications network to tie together the tracking headquarters in Cambridge with the camera stations, the volunteer Moonwatch teams, and other Government agencies.

When Sputnik I was launched on October 4, 1957, the first camera had been completed, the Moonwatch teams were ready to begin visual observing immediately, and orbital calculations and predictions commenced. In the next 9 months 12 Baker-Nunn cameras were completed and shipped to stations established by the Smithsonian Observatory in Japan, Australia, South Africa, India, Iran, Spain, Peru, Argentina, and the Netherlands West Indies, as well as in Florida, New Mexico, and Hawaii.

By the end of the decade the Moonwatch teams had made more than 53,000 observations of 191 different satellites and the cameras 81,750 observations of 73 satellites. The photoreduction division had determined more than 54,000 precise satellite positions reduced to atomic time. Meanwhile, the Observatory had evolved a number of computer programs to process observational data, prepare predictions of satellite passages, and provide the means of analyzing atmospheric densities and temperatures, solar radiation, the shape of the earth and similar phenomena.

The research and analysis division of the Smithsonian unit has produced some of the major scientific results of the U.S. space program, including determinations of the coefficients of spherical harmonics for the earth's gravitational potential, improved geodetic data, a theory of the critical inclination of satellite motion, and, from extremely accurate studies of atmospheric drag, determination of density and temperature in the high atmosphere as a function of time of day, and geographical position and solar activity.

The space science of the Observatory has extended beyond satellite tracking. Project Celescope, as a part of NASA's orbiting astronomical observatory, is now being developed to make an ultraviolet survey of the entire celestial sphere. An experiment on board one of NASA's orbiting solar observatories to study solar phenomena is being readied.

A network of automatic camera stations will make simultaneous observations of meteors over an area of a million square kilometers. This advanced program will provide the basis for a scientific project of collecting meteorites and give vital new data for detailed study of hypervelocity entry, meteoritic physics, and the upper atmosphere.

At the Observatory the first measurements were made of the radioactive isotopes, argon of atomic mass 37 and 39, produced by cosmic rays on meteorities in space. These measurements contributed to the determination of erosion rates of meteoritic materials of various kinds in space. Radiochemical analyses of recovered satellite materials first proved that solar flares introduce tritium into such material in space as well as producing transmutations of elements. The Observatory participated in a program showing that optical flare stars are also variable in the radio region of the spectrum.

Other research at the Smithsonian Observatory in the decade included analyses of sophisticated problems in celestial mechanics; precision linking of the several geodetic networks of the earth; experiments involving the origins of life and the possibilities of the extraterrestrial organisms; studies of comets, meteors, and interplanetary dust; new methods, theories, and conclusions relating to stellar atmospheres and stellar pulsation; and other astrophysical problems.

The Division of Radiation and Organisms is a special unit of the Smithsonian Astrophysical Observatory. Research in this unit during the past 10 years has been directed principally toward solving problems in radiation biology, with specific emphasis on elaborating the intracellular mechanisms involved in regulatory responses of biological systems controlled by ionizing or nonionizing radiation.

Emphasis has been centered on the precise determination of the initial processes involved in a number of diverse light-regulated responses. In this division were determined the most precise and detailed action spectra that have been reported for photomorphogenic responses, such as bean hypocotyl hook opening, photoreversal of this response, seed germination, interaction of visible light with X-ray-induced chromosome aberrations, and the phototropic response of oat seedlings in the blue and near-ultraviolet spectral regions. From such action spectra, a great deal of significant information has been obtained about the primary photoreceptors responsible for the absorption and transfer of radiant energy in biological systems.

Kinetic studies have been carried out determining the time course of sensitivity, temperature-dependence of secondary dark reactions, the interaction of photomimetric substances, auxins and antiauxins, with the light-sensitive mechanisms. Descriptions have been educed for some of the physical factors in plant reactions, including optical and mechanical properties of cells. The morphological development of chloroplasts after irradiation has been examined and measured, using cytochemical techniques.

Investigations have been focused on the intracellular biochemical mechanisms regulated or altered by radiation. These efforts have resulted in a number of published articles on chlorophyll synthesis, the effects of ionizing radiation on chlorophyll synthesis, and the activity and concentrations of various subcellular components isolated after irradiation, such as high energy phosphate compounds, mitochondrial activity, protein synthesis in the photosynthetic apparatus, pigment synthesis, carbohydrate metabolism, and various other enzymatic activities.

During the past several years, the division staff and facilities have expanded in order to approach radiobiological problems with a wider range of disciplines employing the most advanced techniques of biochemistry, biophysics, cytology, and plant physiology. A temperature-regulated greenhouse with controlled environment rooms has been constructed with funds provided by a nonpublic foundation, the Research Corporation. The growth of plants under natural and artificial light conditions has been measured with great accuracy. Concurrently, the construction and acquisition of specialized automatic equipment for measuring the spectral distribution of total sky light at frequent intervals have been completed, and long-term correlations of daily and seasonal fluctuations with observed plant responses are being made.

A carbon-dating laboratory has been operating in this unit of the Smithsonian for about a year, dating samples of archeological interest and initiating a research program aimed at developing new dating technics for geological samples.

Two years ago a section was incorporated for research in marine biology. This work in pure science has been financed by special gifts from a non-Federal source, the Bredin Foundation. Marine organisms are well suited to fundamental investigation of radiation responses. Studies have been initiated to identify high molecular weight phosphate compounds and determine the metabolic role of these compounds in the conversion of radiant energy to chemical energy.

Electronic and instrument shop facilities are maintained for the design, construction, and service of the complex and highly specialized instrumentation necessary to research program of the sort mentioned above.

The division has published widely and it is safe to say has achieved a favorable international reputation in radiation biology in the areas of techniques for the generation, control, and measurements of radiation; kinetics and biochemistry of photoresponses; action spectra; and solar radiation measurements. Several foreign scientists have come to the division to study its methods for 1- or 2-year periods, and work has been done in collaboration with other laboratories utilizing our specialized facilities.

National Collection of Fine Arts, 1953–63

The original act establishing the Smithsonian Institution directed that it maintain a gallery of art. The National Collection of Fine Arts, as a bureau of the Smithsonian, is the oldest gallery of art directly related to the U.S. Government.

In the decade under consideration many notable paintings, largely by distinquished American artists, have been added to the national collections under the care of the National Collection of Fine Arts, and restoration of anmy works of art in the collection of this bureau has been carried on.

In the first year of the present decade the exhibits of the National Collection of Fine Arts were reorganized and a main hall was opened in the Natural History Building. During the years that have followed, many temporary exhibits of importance have been shown in the foyer gallery in the Natural History Building, and under the direction of the Traveling Exhibition Service of the National Collection of Fine Arts, 375 shows, mainly in the field of the fine arts, have been organized and circulated in over 500 different museums throughout America, as well as in museums in many foreign countries. Almost 4,500 showings have been made possible in this period by this service.

The greatest event in the decade 1953–63 was the act passed by Congress in 1958 authorizing the transfer to the Smithsonian Institution of the historic and beautiful old Patent Office Building for conversion to art galleries. Plans are well underway for the establishment in this building of public galleries, study rooms, and restoration laboratories that will allow the National Collection of Fine Arts to display its great collections of American and other paintings in a manner that could never have been achieved in its present borrowed and incongruous space in the Natural History Building of the Smithsonian Institution.

Freer Gallery of Art, 1953–63

The period 1953–63 is the fourth decade in the history of the Freer Gallery of Art. This unit of the Smithsonian Institution was established by the late Charles Lang Freer as a gallery for the display of great collections of art and as a center for the study especially of the art of the Far East and the Middle East.

The annual attendance of the Gallery during the decade has grown from approximately 70,000 to 183,000 per year. The collections have also developed in notable ways. Additions to the collections, as provided in Mr. Freer's will and purchased with the income from his bequest, have included over 450 major objects of art. The most significant of these additions have been in the fields of Ming porcelains and in Japanese painting. Mrs. Eugene Meyer, the one survivor of the three persons permitted by Mr. Freer's will to make gifts to the collection, generously has given in this period three Chinese bronzes and one Chinese painting. Members of the professional staff of the Freer during the decade have published research on the collections in 16 books and over 100 articles.

The Freer Gallery has continued during this decade its world-famous studies of the scientific composition of metallic, ceramic, and other objects of art, and the development of new preservation techniques. The Gallery during these years has been the base for the publication, under the auspices of the International Institute for Conservation of Historic and Artistic Works, of the *I.I.C. Abstracts* (commonly called the *Freer Abstracts*). The current number of this journal shows that almost 4,000 abstracts of published works on conservation have so far been made available to the whole museum world through this medium.

National Gallery of Art, 1953–63

The National Gallery of Art resulted from Andrew W. Mellon's munificent gift to the American people of his great collection of art and a splendid building in which to house it.

Although a bureau of the Smithsonian Institution, the Gallery is largely under the direction of a separate Board of Trustees of which the Secretary of the Smithsonian is an ex officio member.

In the decade under consideration, 4,220 works of art were acquired by the Gallery, including outstanding gifts from the Samuel H. Kress Foundation, Horace Havemeyer, William Nelson Cromwell, Syma Busiel, the Fuller Foundation, Inc., Mrs. Mellon Bruce, Mrs. P. H. B. Frelinghuysen, and many others.

During the period 45 temporary loan exhibitions were held and the annual series of lectures (A. W. Mellon Lectures in the Fine Arts) was delivered. These lectures are in the process of being published in a notable series. Many articles and books by staff members have also been published during this time.

The annual number of visitors to the National Gallery of Art has more than doubled in the past 10 years, with an attendance of 1,793,500 in fiscal year 1963 compared with 887,213 in fiscal year 1954.

Funds appropriated by Congress for maintenance of the Gallery have increased from $1,274,473 in fiscal year 1954 to $2,100,769 for fiscal year 1964.

National Air Museum, 1953–63

This bureau of the Smithsonian Institution has made significant progress during the decade 1953–63.

One measure of this progress is the increase in public interest in the small exhibit (less than 5 percent of its collection) which the Air Museum now has on display. For example, its old Aircraft Building, now called the Air and Space Building (a small metal building erected in 1917 as a test center for Liberty motors), had a visitor count of 237,446 in fiscal year 1953. In fiscal year 1963 the count was 2,673,618.

The greatest need of the National Air Museum has been for a suitable building in which to display its great collection of the history of manmade flight. Progress has been made toward achieving this objective. In 1958 the Congress authorized the preparation of plans and specifications for a new National Air Museum Building and designated a beautiful Mall site for it. In 1963 planning funds were appropriated by the Congress and planning will now begin.

Very important progress has been made during the decade in the techniques of storage, preservation, and restoration. In 1953 most of the collection of historic aircraft, engines, and other aeronautical materials were stored in an Air Force hangar at Park Ridge, Ill.

Space requirements of the Air Force made it necessary to move the collection. An area at Silver Hill, Md., close to Washington, was acquired by transfer, and temporary storage buildings were erected. The transfer of storage was completed in 1956.

One of the buildings at Silver Hill was constituted as a restoration and preservation facility. With the congressional authorization of the new National Air Museum Building in 1958, this work was accelerated, and creditable shop facilities have been established, together with the completion of connecting roadways between storage buildings and shop. By the end of the decade under consideration, this facility was engaged in the restoration and preservation of historic aircraft and engines in anticipation of the increased display requirements of the new Air Museum Building.

The decade marked a very large increase in the collection of the Museum. A total of 3,424 historic specimens were added, including many full-size aircraft and, during the recent years, spacecraft. Notable among these accessions were: a Douglas DC airplane, No. 164; the "Excalibur" airplane which made the first nonstop solo flight over the North Pole; a Boeing 247–D airplane; a 1929 Link Trainer; a Pitcairn Autogyro of 1929; the "Ole Miss" Curtiss airplane; a "Vanguard" launch vehicle; a Verville-Sperry "Messenger" airplane of 1920; a bronze statue of Brig. Gen. William Mitchell; the "First Recovered Nose Cone" from space; a "Jupiter C" launch vehicle; a collection of original records and memorabilia of Dr. Robert H. Goddard, given by Mrs. Robert H. Goddard; an original holograph manuscript of "Soaring Flight" by John J. Montgomery; a Ryan X–13 "Vertijet" airplane; the Lockheed "Sirius" airplane flown by Charles A. and Anne Morrow Lindbergh; an "Atlas" launch vehicle; the "Able-Baker" spacecraft; a McDonnell FH–1 "Phantom" carrier-based aircraft; the first "space" camera; the "Que Sera Sera," first airplane to land at the South Pole; "Freedom 7," America's first manned spacecraft; the "Sacred Cow," a Douglas C–54, the first Presidential airplane; an early Bellanca airplane; an original oil portrait of Gen. Claire Chennault and a number of his medals; a "Polaris" rocket; "Friendship 7," America's first manned orbital spacecraft; gear worn and used by Astronaut John Glenn on his historic flight in "Friendship 7"; and an original painting of Astronaut Alan B. Shepard, Jr., by artist James Scalese from the Honorable James G. Fulton.

One of the most important areas of progress during the past 10 years has been the increase in the study library and reference files. This collection now numbers more than 12,000 books, more than 300 file cabinets of reference material, and approximately 100,000 photographs.

The research work of the Museum has increased along with the increase in public interest in its exhibits. Most of the time of the professional staff is taken up with historical, technical, and biographical research to provide a service to authors, publishers, historians, engineers, teachers, and students seeking authentic information.

In addition, a considerable increase in historical and technical research is required in connection with the accelerated restoration program of aircraft and engines.

For the National Air Museum the decade has been a transition period. It has changed from a collecting and storing agency to a full museum operation that is commensurate with its world-renowned collection and its responsibilities to the public. It has developed new displays, research, studies, preservation and restoration techniques, and publications in a field of great American patriotic and historical interest—manmade flight.

National Portrait Gallery, 1961–63

In 1961 Congress provided for the establishment of the National Portrait Gallery. This gallery will be housed, together with the National Collection of Fine Arts, in the old Patent Office Building which, as noted above, has been transferred to the Smithsonian Institution.

The Congress in 1962 provided for the establishment of a National Portrait Gallery Commission to advise the Smithsonian Institution in organizing and developing this new and important unit.

National Cultural Center, 1958–63

The National Cultural Center was established by an act of Congress in 1958, and the new unit was designated as a bureau of the Smithsonian Institution. Like the National Gallery of Art, the National Cultural Center is largely administered by its own special Board of Trustees.

Since the establishment of the bureau the principal function has been connected with raising the funds to erect a suitable building in the Nation's Capital to provide halls for the presentation of opera, symphonic concerts, dramatic performances, ballet, and other fields of the performing arts.

Financial Resources, 1953–63

During the decade many generous gifts of funds have come to the Smithsonian from private individuals and from foundations. Most of these gifts are for very specific purposes. The most notable of these private benefactions is the receipt of a legacy which, when finally settled, will be in excess of $1½ million from the late Robert Lee Forrest. Another important benefaction came from the estate of

Atherton Seidell. Laura D. Barney has also been most generous to the Institution during this period, and she and her sister, Natalie C. Barney, gave the Smithsonian the Barney Studio House in Washington.

At the beginning of this period (June 30, 1952) the book value of the unexpended funds and endowments of the Smithsonian was $11,138,392. As indicated in the financial statement on a later page of this report, this sum has now reached a total of $22,534,920. The market value of the securities and assets of the endowment funds of the Smithsonian at the end of the period is in excess of $25,000,000. The income from the many funds that make up this total is expended according to the directions of the donors of the funds.

During the decade Federal funds for building and for planning buildings have been provided to the Smithsonian to a total of $61,012,000. At the beginning of the period the annual appropriation for the basic expenses of the operation of all the bureaus of the Smithsonian Institution (except the National Gallery of Art and the National Zoological Park, which have separate budgets) was $2,553,200. The appropriation for these same parts of the Institution for the fiscal year 1964 is $13,124,000. At the start of the decade the annual operating appropriation for the National Zoological Park was $620,800. The appropriation for this part of the Institution for fiscal year 1963 was $1,470,200. Capital appropriations for the National Zoological Park in this period, in addition to operating funds, have been $2,550,000. The budget of the National Gallery of Art, which is administered separately from the Smithsonian Institution as a whole, was $1,240,000 at the start of the decade, and the appropriation for 1964 for this unit was $2,138,000. Gifts and grants for research projects and other specific purposes, exclusive of appropriated funds and all for the particular purposes specified by donors or grantors, have totaled $32,489,471 in the decade under consideration.

It can be said with assurance, as the progress of the decade 1953–63 is reviewed, that the Smithsonian's donor, James Smithson, planned well when he directed that his Institution should concern itself with the great and related humanitarian functions of *the increase and the diffusion of knowledge among men.*

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 appointment to the vacancy in the class of citizen regent was effected by the approval on July 2, 1963, of a joint resolution of Congress designating Dr. William A. M. Burden of New York to succeed the late Dr. Arthur H. Compton as a Regent for the statutory term of 6 years.

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 Lyndon B. Johnson; members from the Senate: Clinton P. Anderson, J. William Fulbright, Leverett Saltonstall; members from the House of Representatives: Frank T. Bow, Clarence Cannon, Michael J. Kirwan; citizen members: John Nicholas Brown, William A. M. Burden, Robert V. Fleming, Crawford H. Greenewalt, Caryl P. Haskins, and Jerome C. Hunsaker.

The customary informal dinner meeting, preceding the annual meeting, was held in the Great Hall of the Smithsonian Building on January 23, 1963. Exhibits showing some of the recent work of the Smithsonian bureaus were in place in the hall at the time of the dinner to apprise the Regents of current Smithsonian research developments. Dr. Richard S. Cowan spoke on "Research for a Tropical American Rain-Forest Exhibit"; Dr. Robert P. Multhauf on "History of the Measurement of Gravity in the 19th Century"; Dr. John A. Pope on "The Freer Gallery of Art Research Project on Ancient Chinese Ceremonial Bronzes"; and Dr. Fred L. Whipple on "Scientific Study of Recovered Parts of Russian Sputnik IV."

The annual meeting was held on January 24, 1963. The Secretary presented his published annual report on the activities of the Institution. The Chairman of the Executive and Permanent Committees of the Board, Dr. Robert V. Fleming, gave the financial report for the fiscal year ended June 30, 1962.

The spring meeting of the Board of Regents was held at 5 o'clock in the Regents Room. A financial report was presented by the chairman of the Executive Committee. The Regents then adjourned to the hall of fossil mammals for an informal dinner.

RETIREMENT OF DR. KELLOGG

On October 31, 1962, Dr. A. Remington Kellogg, Assistant Secretary of the Smithsonian Institution and Director of the United States National Museum, retired and assumed the status of honorary re-

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search associate of the Smithsonian. During Dr. Kellogg's service as Director, beginning in 1948, the National Museum experienced a remarkable growth. The collections grew from 25 million specimens in 1948 to 56 million in 1962. A renovation of exhibits programs revitalized more than 20 exhibition halls in the National Museum. A wing was added to the Natural History Museum, and a new Museum of History and Technology was built. Dr. Kellogg directed the programs that resulted in these achievements and participated strongly in their execution.

Prior to becoming Director of the National Museum, Dr. Kellogg had served in the division of mammals, beginning in 1928 as assistant curator and becoming curator of the division in 1941. His main scientific interest has been, and continues to be, the biology of whales, in which field he is one of the world's foremost authorities. His research on the paleontology of whales has been widely acclaimed. It is altogether fitting, therefore, that he should now be conducting his scientific investigations in a workroom on the vertebrate paleontology floor of the museum wing which he helped to create. He is continuing to publish his excellent scientific reports.

On November 1, 1962, following Dr. Kellogg's retirement, Dr. Albert C. Smith, who had been Director of the Museum of Natural History since 1958, became an Assistant Secretary of the Institution.

NATIONAL PORTRAIT GALLERY

On April 27, 1962, Public Law 87–443 established the National Portrait Gallery as a bureau of the Smithsonian Institution to "function as a free public museum for the exhibition and study of portraiture and statuary depicting men and women who have made significant contributions to the history, development, and culture of the people of the United States and of the artists who created such portraiture and statuary."

This act of Congress also authorized the establishment of a National Portrait Gallery Commission, to serve as an advisory body to the Board of Regents in regard to programs, methods of operation, and selections of appropriate displays for the new Gallery. The members of the Commission, as announced on June 21, 1963, by the Chancellor of the Board of Regents, the Honorable Earl Warren, are as follows:

Catherine Drinker Bowen, author and historian, of Bryn Mawr, Pa.

Julian P. Boyd, author and historian, of Princeton, N.J.

John Nicholas Brown, Regent of the Smithsonian Institution, of Providence, R.I.

Lewis Deschler, Parliamentarian of the House of Representatives of the United States Congress, of Bethesda, Md.

David E. Finley, former Director of the National Gallery of Art, of Washington, D.C.

Wilmarth Sheldon Lewis, historian and biographer, of Farmington, Conn.

Richard H. Shryock, author and historian, of Philadelphia, Pa.
Col. Frederick P. Todd, Director of the U.S. Military Academy Museum, of West Point, N.Y.

Ex officio:

The Chief Justice of the United States.
The Secretary of the Smithsonian Institution.
The Director of the National Gallery of Art.

NATIONAL ARMED FORCES MUSEUM ADVISORY BOARD

Public Law 87–186 (August 30, 1961) established a National Armed Forces Museum Advisory Board in the Smithsonian Institution to provide advice and assistance to the Smithsonian Board of Regents on matters concerning the portrayal of the contributions which the Armed Forces of the United States have made to American society and culture, the investigation and survey of lands and buildings in and near the District of Columbia suitable for the display of military collections, and the preparation of recommendations to the Congress with respect to the acquisition of lands and buildings for such purposes.

This law additionally provides that the Smithsonian Institution shall (1) commemorate and display the contributions made by the military forces of the Nation toward creating, developing, and maintaining a free, peaceful, and independent society and culture in this country; (2) portray the valor and sacrificial service of the men and women of the Armed Forces as an inspiration to the present and future generations of America; (3) demonstrate the demands placed upon the full energies of our people, the hardships endured, and the sacrifice demanded in our constant search for world peace; (4) graphically describe the extensive peacetime contributions the Armed Forces have made to the advance of human knowledge in science, nuclear energy, polar and space exploration, electronics, engineering, aeronautics, and medicine; (5) interpret through dramatic display significant current problems affecting the Nation's security; and (6) provide a study center for scholarly research into the meaning of war, its effects on civilization, and the role of the Armed Forces in maintaining a just and lasting peace by providing a powerful deterrent to war.

Members of the National Armed Forces Museum Advisory Board will serve 6 years, except for the initial Board which was appointed by the President in April 1962 to serve for terms of 2, 4, and 6 years:

John Nicholas Brown, Regent of the Smithsonian Institution
Rufus E. Clement, President of Atlanta University
Fred Korth, Secretary of the Navy
David L. Kreeger, Vice President of Government Employees Insurance Co.
Cyrus B. Vance, Secretary of the Army
Earl Warren, Chief Justice of the United States

Henry B. Washburn, Jr., Director of the Boston Museum of Science
William W. Whiteman, Jr., lawyer and financier, Oklahoma City
Eugene M. Zuckert, Secretary of the Air Force

The Advisory Board has held two meetings, during which it selected a chairman, John Nicholas Brown, adopted bylaws for its operation, considered the scope and extent of the Board's functions, and proposed areas of study. A number of potential Museum sites in the Greater Washington area have been considered, and several have been examined by the Advisory Board.

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 261. Funds appropriated to the Institution for its regular operations for the fiscal year ended June 30, 1963, totaled $11,060,550. Besides this direct appropriation, the Institution received funds by transfer from other Government agencies as follows: From the District of Columbia for the National Zoological Park, $1,504,997; from the National Park Service, Department of the Interior, for the River Basin Surveys, $271,000.

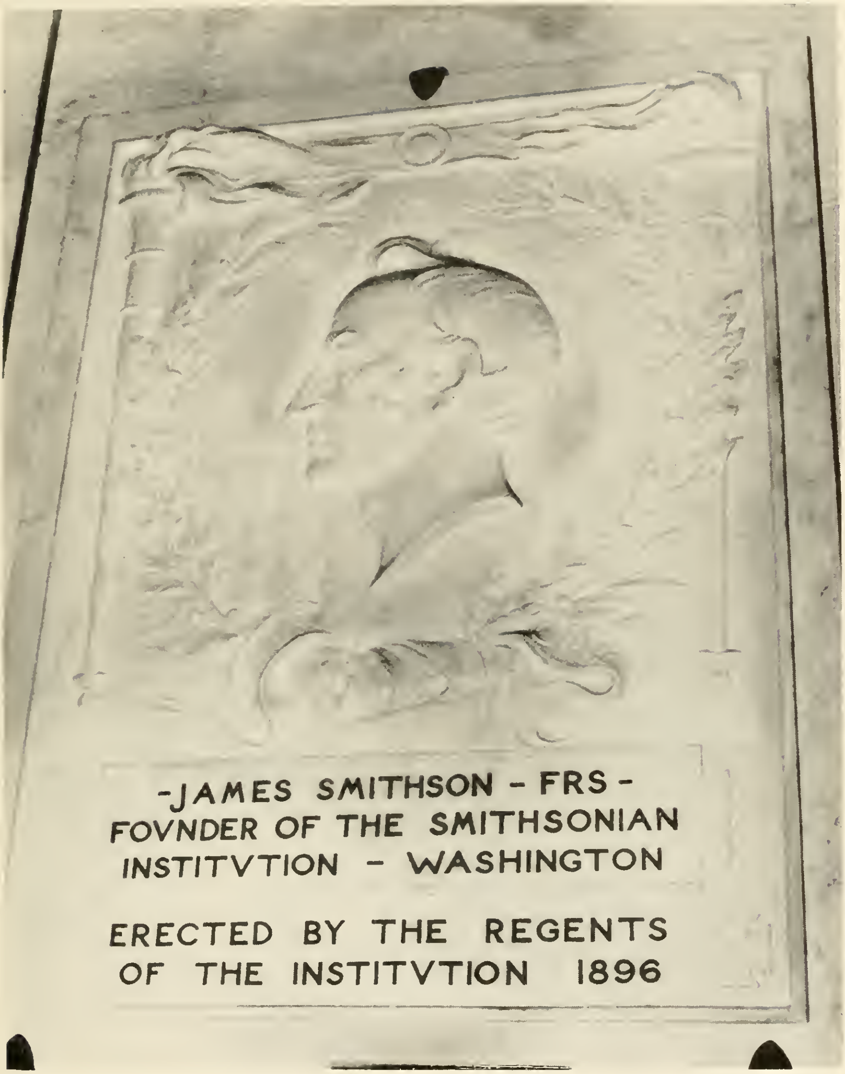
VISITORS

Visitors to the Smithsonian buildings on the Mall again surpassed all records with a total of 10,309,836, which was 1,386,705 more than for the previous year. April 1963, with 1,720,716, was the month of largest attendance; August 1962 second, with 1,616,360; July 1962 third, with 1,612,452. Table 1 gives a summary of the attendance records for the five buildings; table 2, groups of schoolchildren. A new method adopted for estimating the number of visitors at the National Zoological Park showed a total of 3,200,000 for the year. When this figure is added to the attendance in the Institution's buildings on the Mall, and to the 1,793,500 recorded at the National Gallery of Art, the total Smithsonian attendance for 1962 may be set at 15,303,336.

REPLACEMENT OF SMITHSON PLAQUE

In 1896 the Smithsonian Board of Regents caused to be erected a handsome marble memorial to James Smithson in the English Church of the Holy Ghost in Genoa, Italy, where he died on June 26, 1829. During World War II the church was gutted by fire following Allied bombardments and stripped of all fittings by looters. Following the war the church was restored, but all trace of the Smithson cenotaph had disappeared.

It seemed appropriate and desirable that this memorial to the founder of the Smithsonian Institution be replaced, and in 1960 the Board of Regents so authorized. The new plaque, sculptured by Raf-



Smithson plaque as restored in English Church of the Holy Ghost, Genoa, Italy, 1963

faello Romanelli, of Florence, is a facsimile of a replica of the original which is erected adjacent to the Smithson tomb in the Smithsonian Building in Washington. In May 1963 the Institution was notified by the American Consul General at Genoa that installation of the new memorial had been completed (pl. 1).

Thanks are due particularly to the following individuals for their interest and cooperation in helping to initiate or complete this project: John LePelley, of Paris, assistant vice president of the First National City Bank of New York; David Balfour, former British Consul General at Genoa; S. A. H. Eley, Lord Bishop of Gibraltar; F. J. Bailey, the Archbishop of Malta; Stephen P. Dorsey, American Consul General at Genoa; and to sculptor Romanelli for his faithful creation.

TABLE 1.—*Visitors to certain Smithsonian buildings during the year ended June 30, 1963*

Year and month	Smithsonian Building	Arts and Industries Building	Natural History Building	Air and Space Building	Freer Building	Total
1962						
July	258, 510	555, 775	267, 106	502, 686	28, 375	1, 612, 452
August	264, 448	595, 337	282, 016	443, 142	31, 417	1, 616, 360
September	79, 136	200, 639	119, 261	116, 104	14, 267	529, 407
October	64, 169	159, 731	120, 189	101, 711	11, 169	456, 969
November	55, 136	159, 100	121, 763	92, 541	10, 846	439, 386
December	34, 400	73, 199	70, 306	45, 726	5, 940	229, 571
1963						
January	39, 430	96, 555	114, 159	64, 642	6, 558	321, 344
February	51, 528	114, 532	106, 570	75, 033	7, 098	354, 761
March	76, 916	165, 820	154, 488	120, 853	10, 901	528, 978
April	298, 248	692, 693	337, 878	370, 947	20, 950	1, 720, 716
May	210, 378	352, 299	283, 510	325, 157	15, 574	1, 186, 918
June	197, 981	368, 502	311, 151	415, 076	20, 264	1, 312, 974
Total	1, 630, 280	3, 534, 182	2, 288, 397	2, 673, 618	183, 359	10, 309, 836

TABLE 2.—*Groups of schoolchildren visiting the Smithsonian Institution during the year ended June 30, 1963*

Year and month	Number of children	Number of groups	Year and month	Number of children	Number of groups
1962			*1963*		
July	12, 810	348	July	23, 808	629
August	6, 991	208	August	17, 124	493
September	4, 797	146	September	41, 888	1, 046
October	25, 970	698	October	77, 770	1, 726
November	32, 495	818	November	165, 384	3, 428
December	12, 946	368	December	53, 065	1, 174
			Total	475, 048	11, 082

Report on the United States National Museum

Sir: I have the honor to submit the following report on the condition and operations of the U.S. National Museum for the fiscal year ended June 30, 1963:

COLLECTIONS

During the year 1,723,830 specimens were added to the national collections and distributed among the 8 departments as follows: Anthropology, 11,993; zoology, 1,361,586; botany, 69,642; geology, 80,414; science and technology, 2, 588; arts and manufactures, 2,910; civil history, 191,753; and Armed Forces history, 2,944. The largest divisional acquisition was in the division of insects, which accessioned a total of 1,209,339 specimens. Most of this year's accessions were acquired as gifts from individuals or as transfers from Government departments and agencies. The complete report on the Museum, published as a separate document, includes a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 57,541,770.

Anthropology.—The division of archeology received as its largest accession a lot of 8,431 specimens from Alaska collected for the Museum by Dr. James A. Ford. His published monograph, "Eskimo Prehistory in the Vicinity of Point Barrow," made it possible to accession the specimens according to the published types and illustrations. James P. Mandaville, Jr., donated a well-documented collection of 185 specimens from northern Arabia, including potsherds, terra-cotta figurine fragments, and an inscribed copper hoe blade. Three important collections of Iranian artifacts were presented by Mr. and Mrs. Anthony Cuomo, Mr. and Mrs. Daniel F. Magner, and C. Edward Wells. Represented among the 160 specimens are pottery, bronze weapons, inscribed mud bricks, and glazed architectural fragments, ranging in dates from 2000 B.C. to the third century A.D. A group of five Korean bronze weapons of the Han Dynasty was donated by Gen. George H. Decker. A rare anthropomorphic pottery figure from the Bahía culture of the Esmeraldas region was acquired from Mrs. Erika Burt.

The division of ethnology received a collection of 25 items of traditional court costume from Indonesia, presented by His Highness Sri

Paku Alam VIII, through the American Embassy in Djakarta. The Government of Vietnam, through its embassy in Washington, D.C., presented 67 specimens comprising a carved wooden chest, bronze vessels, and textiles. For use in the preparation of new exhibits, 103 ornaments, household items, and weapons of the people of Burundi were obtained from David W. Doyle, American Vice Consul at Usumbura, Burundi. Also for exhibition, a Chinese collection of 365 specimens was acquired from Taiwan with the assistance of the National Historical Museum and the Provincial Museum, under the direction of the Ministry of Education and Academia Sinica.

The division of physical anthropology received, from the U.S. Army Research Institute of Enviromental Medicine, a collection of 50,000 somatotype negatives. These were made during the U.S. Army survey of male body build in 1945–46 under the direction of E. A. Hooton and form the basis for the Harvard system of rating body build. Largest of its kind, the collection will be available for study by qualified professionals. Received for study and exhibit purposes is a new set of casts of the original Neanderthal skeleton, gift of the Rheinisches Landesmuseum, Bonn, Germany, and excellent casts of *Oreopithecus* from central Italy, received from the Natural History Museum in Basle, Switzerland. Other accessions include human skeletal materials from Mexico, Alaska, and various parts of the United States.

Zoology.—Staff members and cooperating agencies contributed approximately 9,200 specimens to the division of mammals, most of these being collected by Dr. Charles O. Handley, Jr., and Francis M. Greenwell in Panama. Others were collected by Naval Medical Research Unit No. 2, in Formosa; by Dr. Dale Osborn in Turkey; by Gary L. Ranch in Libya and Iran; by the department of microbiology of the University of Maryland, in West Pakistan and Mexico; and by Kenneth I. Lange and James H. Shaw in the Malagasy Republic. Dr. Henry W. Setzer of the Museum staff participated in the last three projects. Other valuable collections were made as follows: by Miss Alena Elbl of the University of Maryland, in Ruanda Urundi; by Dr. L. G. Clark of the University of Pennsylvania, in Nicaragua, and by William J. Schaldach, Jr., in southern Mexico. Important specimens obtained for the exhibition series include a large male walrus, collected by Hugh H. Logan, and two paratypes of the bat *Philippinopterus lanei*, presented by Dr. Edward H. Taylor.

To the collections of the division of birds, 2,259 bird skins, 1,011 anatomical specimens, and 1 egg from Panama and 198 skeletons from Kenya were received through Dr. Alexander Wetmore; 642 skins, 128 skeletons, and 9 alcoholic specimens from the U.S. Fish and Wildlife Service; 198 skins from Formosa transferred from the U.S. Department of the Navy, U.S. Naval Medical Research Unit No. 2, through

Dr. Robert E. Kuntz; and a collection of wooden game-bird calls, together with tape recordings demonstrating their use, from Dr. Augusto Ruschi, director, Museu de Biologia Prof. Mello Leitao, Brazil.

In the division of reptiles and amphibians, several additions to the collections are noteworthy: a gift of 325 Colombian frogs, including types and paratypes, from Brother Hermano Nicéforo María, Bogotá, Colombia; a gift of 162 reptiles and amphibians collected in Mexico and Central America from Elkan J. Morris, Fairbanks, Alaska; 71 reptiles and amphibians obtained for the Museum in South America and Panama by Dr. Charles O. Handley, Jr., and Francis M. Greenwell; 70 amphibians acquired for the Museum from South America and Panama by Mrs. Doris H. Blake and Dr. Doris M. Cochran; an exchange of 27 Colombian frogs with the Chicago Natural History Museum; and an exchange of 21 Brazilian frogs with Werner C. A. Bokermann, São Paulo, Brazil.

Exchanges of specimens netted the division of fishes the major portion of the current year's new accessions. Received on exchange was the holotype of a new *Dascylus* from D. Wolfgang Klausewitz, Frankfurt, Germany. Horace Loftin and Dr. R. W. Yerger sent, on exchange, 10,000 fresh-water fishes from the Canal Zone, Panama, collected by Mr. Loftin. Other contributors of holotypes include Drs. Giles W. Mead and Henry B. Bigelow, Museum of Comparative Zoology, Harvard University; Dr. George S. Myers, Stanford University; and Loren P. Woods, Chicago Natural History Museum. Among the contributors of paratypes were Dr. C. Richard Robins, University of Miami, Marine Laboratory; Dr. Norman J. Wilimovsky, University of British Columbia; Dr. Jacques R. Géry, Laboratoire Arage, France; and Dr. José Alvarez del Villar, Instituto Politécnico Nacional, Mexico.

The division of mollusks added a total of 23,967 specimens to its collections. Dr. Joseph Rosewater of the Museum staff collected 1,194 marine and land mollusks on Eniwetok Atoll. Mr. and Mrs. Delmas H. Nucker donated 699 specimens of marine mollusks from the Caroline Islands, and Dr. Tadashige Habe added 120 specimens, of which 28 are paratypes, of recently described mollusks from Japan. Holotypes of molluscan species and subspecies were received from Dr. Raul Guitart, Dr. Harry W. Wells, Messrs. Leslie Hubricht, Thomas L. McGinty, and William G. Pearcy, and from the U.S. Fish and Wildlife Service Laboratory, Pascagoula, Miss., through Harvey R. Bullis, Jr.

A total of 1,257 helminthological specimens, among which were many types of new species, were added to the collection housed in the Parasitological Laboratory of the Animal Disease and Parasite Research Branch of the U.S. Department of Agriculture, Beltsville, Md.

The division of marine invertebrates acquired a number of important collections. Leslie Hubricht of Meridian, Miss., presented his personal collection of 32,327 fresh-water invertebrates, containing what is probably the largest and most valuable series of American fresh-water isopod crustaceans ever assembled. A total of 33,177 specimens were received from the Fourth Smithsonian-Bredin Caribbean Expedition, 1960. Through Dr. Harry S. Ladd, the Paleontology and Stratigraphy Branch of the U.S. Geological Survey contributed 1,079 corals from the Marshall Islands, including 217 type and figured specimens described by Dr. J. W. Wells in his comprehensive monograph on Indo-Pacific reef corals. Through Dr. Arthur G. Humes, Boston University donated 852 copepod and isopod crustaceans. Approximately 974 isopod and 322 amphipod crustaceans were received from the Beaudette Foundation for Biological Research, through Dr. J. Laurens Barnard. Included in this group are 198 paratypes of 4 species of isopods described by Dr. Robert J. Menzies.

The U.S. Department of Agriculture, through Dr. William H. Anderson, transferred to the division of insects the largest single accession ever received: a collection of Coccidae (scale insects) conservatively estimated to contain 1 million specimens. Additional important accessions include the Harold E. Box collection of 5,000 Neotropical cane-boring moths of the genus *Diatraea;* a donation of 8,000 North American butterflies and moths by Dr. George W. Rawson; the J. C. Hopfinger collection of butterflies and moths; 6,741 specimens, mostly Coleoptera, from William W. Pinch; 805 Brazilian insects from Dr. C. M. Biezanko; 6,543 British Columbian insects from C. Garrett; 6,612 specimens from N. L. H. Krauss, who has been a devoted contributor for many years; and 2,000 specimens from Guatemala from Dr. Thomas H. Farr.

Noteworthy contributions to the collections by staff members include 900 specimens, mostly European centipedes, from Dr. Ralph E. Crabill, Jr.; 41,110 specimens collected in Puerto Rico, Virgin Islands, and North America from Dr. Paul J. Spangler; 400 specimens of butterflies from the eastern United States from William D. Field; 1,192 miscellaneous insects, chiefly caddisflies, from Dr. Oliver S. Flint, Jr.; 7,826 specimens, mostly Microlepidoptera, from the northwestern United States from Dr. J. F. Gates Clarke; and 285 specimens, chiefly Orthoptera, from Dr. Ashley B. Gurney, U.S. Department of Agriculture. Others making important donations were Drs. Nell B. Causey, G. E. Ball, W. L. Brown, Richard L. Hoffman, and Bernard Feinstein.

Botany.—A fine lot of 4,143 herbarium specimens and 480 wood samples from Brazil, presented by Boris A. Krukoff, Smithtown, N.Y., adds appreciably to the national collections. Among them was a group of woods from laticiferous plants on which anatomical research was planned by Mr. Krukoff. Dr. José Cuatrecasas gave 3,200 specimens which he collected in Colombia. Other gifts included 620 excellent specimens of Pennsylvania plants from Muhlenberg College, Allentown, Pa.; 850 cryptogams, mostly mosses, from Dr. F. J. Hermann, Adelphi, Md.; and 504 specimens from the University of Alaska.

Several large collections were received in exchange. A group of 845 slides of pollen of African plants was received from Duke University through Mrs. Shirlee Cavaliere and 765 slides from the Pan American Petroleum Corp. of Tulsa, Okla., through Dr. Donald W. Engelhardt. Gray Herbarium of Harvard University sent 1,037 specimens collected by Dr. L. J. Brass on the Fourth Archbold Expedition to New Guinea. Other exchanges included 845 specimens of Asia and eastern Europe from the V. L. Komarov Institute of Botany of the Academy of Sciences, Leningrad, U.S.S.R.; 888 specimens collected in Mexico by Dr. Faustino Miranda from the Instituto de Biología, Universidad Nacional de México; and 392 plants of Australia from the Commonwealth Scientific and Industrial Research Organization, Melbourne.

Dr. John J. Wurdack collected for the Museum 9,258 specimens in Peru; Dr. R. S. Cowan and Dr. Thomas R. Soderstrom, 3,370 specimens in British Guiana; and Dr. William L. Stern, 439 specimens in Oregon, Wyoming, and Colorado.

From the U.S. Geological Survey were transferred 801 specimens collected on the Pacific islands by Dr. F. R. Fosberg; from the U.S. Fish and Wildlife Service, 420 plants collected in Alaska by Frank Beals; and from the Agricultural Research Service, Department of Agriculture, 235 specimens collected in Iran and Mexico by Dr. Howard Scott Gentry.

Geology.—A total of 3,885 specimens was received in the division of mineralogy and petrology. Among the important gifts are a very fine specimen of legrandite, Mapimi, Mexico, from Bernard T. Rocca, Sr., and an exceptional specimen of fairfieldite, Kings Mountain, N.C., from Carter Hudgins. Outstanding among specimens received by exchange was a collection of cerussite, azurite, and associated minerals from Tsumeb, South West Africa; a crystal of vivianite, 31 inches in length from the Cameroons; and a fine piece of malachite, from the Congo. New species received in exchange were: calumetite, Michigan; angelellite, Argentina; arsenate-belovite, fersmanite, gerasimovkite, kupletskite, lomonossovite, and vinogradovite, from the U.S.S.R.; bafertisite, Inner Mongolia; bergenite, East Germany; bonattite, Canada; carobbiite, Italy; cuprorivaite, Italy; hydroamesite, Hungary; reinerite, stranskite, and gallite, South West Africa; and schuetteite and wightmanite, California.

A total of 815 specimens was added to the Roebling collection by purchase or by exchange. Among these are outstanding specimens of wulfenite, calcite, and agate from Mexico. Gem specimens include a 17-carat greenish-yellow brazilianite, from Brazil; a 30-carat cat's-eye cerussite, from South West Africa; and a 9.35-carat axinite from Baja California, Mexico. Acquired by purchase through the Canfield fund is a magnificent group of amethyst quartz crystals from Guerrero, Mexico. The largest crystal measures 4 by 18 inches, and each is tipped by white quartz.

New acquisitions to the gem collection include a 2.86-carat deep-pink diamond, Tanganyika, from S. Sydney De Young; a 235.5-carat morganite, Brazil, from Mr. and Mrs. Frank Ix, Jr.; a 277.9-carat citrine, Brazil, from Albert Cutter; and a 177-carat kunzite, California, from the American Gem Society. Gem specimens acquired by purchase through the Chamberlain fund for the Issac Lea collection include a 17.5-carat pink tourmaline cat's-eye and a 4,500-carat faceted smoky quartz egg, both from California; and a 9-carat axinite, from Baja California, Mexico.

During the year 20 meteorites were added to the collection, of which 11 were not previously represented. The Bogou meteorite was of special interest. This 8.8-kilogram coarse octahedrite, which came to the Museum through the generous cooperation of the Government of Upper Volta and the U.S. Atomic Energy Commission, was observed to fall in Upper Volta on August 14, 1962. It is being extensively studied in several laboratories because observed falls of iron meteorites are extremely rare.

In the division of invertebrate paleontology and paleobotany, a number of important collections of invertebrate fossils were acquired. Among transfers of type specimens from the U.S. Geological Survey were: 68 Permian pelecypods described by K. Ciriaks of Columbia University; 369 specimens of Upper Cretaceous oysters from the western interior; 40 Permian corals from Nevada with thin sections; and 33 specimens and 87 thin sections of Middle Silurian corals from Quebec, described by W. A. Oliver, Jr.

Funds from the Walcott bequest were used to purchase the Hughes collection of Tertiary invertebrates from Florida, numbering more than 50,000 specimens. The Walcott fund also provided means for staff collections which included 4,000 Upper Cretaceous mollusks from the western interior; 5,000 Tertiary invertebrates from Hampton, Va.; and 2,000 fossil echinoids from southwestern Florida. The Springer fund made possible the purchase of 210 Triassic echinoids and 72 Paleozoic echinoids from the western United States.

Gifts from collectors outside the Smithsonian Institution include: 221 type specimens of planktonic Foraminifera from Recent bottom sediments of the Pacific Ocean from Miss Frances Parker of the Scripps Institution of Oceanography; 1,000 Upper Cretaceous mollusks from Tennessee and Mississippi arranged by Margaret J. Hall through Mid-South Earth Science Club; 6,000 Silurian brachiopods from Czechoslovakia collected by Dr. A. J. Boucot of the California Institute of Technology; 134 type specimens of Foraminifera from the Cretaceous Adelphia Marl of Arkansas from Dr. H. C. Skinner, Tulane University; 500 specimens of Middle Devonian brachiopods and corals from northern Ohio from Bernard Keith; 100 Early Devonian invertebrates from Flute Cave, W. Va., from the Potomac Speleological Club; 50 specimens of early Ordovician brachiopods from Kielce, Poland, from Dr. R. B. Neuman; 23 rare and unusual Miocene mollusks from Virginia from Mr. and Mrs. W. M. Rice; and 52 thin sections of type Foraminifera from the Mississippian of southern Illinois and Kentucky from Mrs. D. E. N. Zeller of the University of Kansas.

Outstanding specimen exchanges brought 76 specimens of Pliocene mollusks from the Scaldesian formation of Belgium, through Dr. S. Amelinckx; 99 specimens of fossil invertebrates from Argentina through Dr. A. J. Amos; 13 ammonites from the Cretaceous of Russia through Dr. D. P. Naidin; and the Harris collection of type specimens of fossil crinoids, from the University of Houston.

In the division of vertebrate paleontology, the major specimens of fossil vertebrates accessioned this year consist of two skulls and a skeleton of three different tetrapods from the Permian of Texas, and two partial skeletons of Mississippian amphibians, probably new to science, from West Virginia. The Texas material is of superior quality and will be most useful in morphological work. These specimens were collected by associate curator Nicholas Hotton III and James Kitching of the University of the Witwatersrand, Johannesburg, South Africa.

A remarkably good collection comprising remains of a variety of Eocene mammals found by W. L. Rohrer in the Big Horn Basin of Wyoming was transferred from the U.S. Geological Survey. Noteworthy are skull portions of the large pantodont *Coryphodon*, jaws and maxillae of the early horse *Hyracotherium* and the lemuroid primate *Pelycodus*, and the greater part of a skull of a rare leptictid insectivore.

Science and technology.—The division of physical sciences received from the Bell Telephone Laboratories the apparatus used by Dr. Clinton T. Davisson in his 1927 investigations of interference phenomena in crystals irradiated by electrons, for which he received the Nobel prize in physics in 1936. Received also was a full-scale reproduction of an observational armillary, one of the large astronomical instruments used by Tycho Brache, from L. S. Eichner. A sectioned model of a 1962 microscope showing its optical system was given by the E. Leitz Co. A large collection representing the history of the water meter was donated by A. A. Hirsch.

The division of mechanical and civil engineering received an important early (1905) example of steam turbine power, a Parsons turbine with direct-connected direct-current generator. The machine was presented by the Department of the Navy, San Francisco Naval Shipyard, through Eduardo Magtoto, General Superintendent; Varadero de Manila, Republic of the Philippines; and Rear Adm. Charles A. Curtze. Of a number of bridge models received is one of the famed bridge "Colossus." The original was the longest timber span for a century following its construction in 1812. The section of tools received the Rogers Bond Comparator No. 2 from the Pratt & Whitney Co. This was the first instrument in this country used to transfer the length of a standard by microscopic measurement and to subdivide it directly, converting line-standard to end-standard measurement. The section of light machinery acquired, from the American Watchmakers Institute, the James Ward Packard collection of complex watches.

Senator Leverett Saltonstall, Regent of the Smithsonian, presented a piano-box buggy and a fine set of silver-mounted coach harnesses to the section of land transportation. A beautifully restored and fully documented farm wagon of 1860 was donated by Don H. Berkebile. The section of marine transportation acquired several fine ship models, including a downeaster, the *Emily F. Whitney*, and a Pittsburgh & Cincinnati steam packet, the *Buckeye State*.

The division of medical sciences lists as its most important acquisition a 17th-century Lambeth Delft pill tile bearing the coats of arms of the City of London and of the Worshipful Society of Apothecaries. This was received through the generosity of Charles Pfizer & Co., Inc. Other gifts include the first ionization X-ray condenser dosimeter, developed and donated by Dr. Otto Glasser, and a Cambridge indicator dye-dilution curve apparatus, from Dr. Alfred Henderson.

Through the generosity of Franklin Wingard, the division of electricity acquired a large collection of radio material which greatly strengthens its holdings in this field.

Arts and manufactures.—The division of textiles received an especially well-executed 19th-century appliqué and stuffed-work quilt from Stewart Dickson. A very early silk throw, made for an ante-Civil War bride, was presented by Commander and Mrs. James P. Oliver, John P. Oliver, and their aunt, Mrs. Ruth P. Hall. A very fine

Brussels needlepoint and bobbin appliqué lace collar and Gros Point de Venice lace cape were presented by Mrs. Herbert May. An additional group of seven beautiful oriental rugs was presented by Mrs. Clara W. Berwick. These included examples of wool and silk rugs, which are in both the Sehna and Ghiodes knot techniques.

The division of ceramics and glass acquired, from Mrs. Ellouise Baker Larsen, of Lima, Ohio, her entire collection of Staffordshire ware. Consisting of about 900 pieces, this is the most important assembly of these ceramics in America. Mrs. Larsen has spent more than 30 years compiling data and gathering the representative pieces, many of which are extremely rare. Hugh D. Auchincloss, McLean, Va., donated five pieces of ancient glass illustrative of the high degree of artistic skill of the glassmakers when Rome dominated the Mediterranean. Dr. Hans Syz, Westport, Conn., presented another group of 18th-century German porcelains including fine pieces from Meissen, Hochet, Ludwigsburg, Nymphenburg, and Furstenberg.

An important accession of the division of graphic arts was the color aquatint *La Promenade Publique*, by Philibert-Louis Debucourt, generally considered to be the finest example of French color printing of the last quarter of the 18th century. Other outstanding accessions were a chiaroscuro woodcut, *The Death of Ananias*, after Raphael, executed about 1530, by Ugo de Carpi, who is usually accepted as the first and most important Italian chiaroscuro woodcutter; and *The Fountain of Trevi*, one of the most desirable subjects from Giovanni Battista Piranesi's great series of etchings, *Veduta di Roma*, published in 1765.

The eminent Hungarian artist Joseph Domjan, now an American citizen, donated his highly original woodcuts *Starlit Night*, *Peacock of the Carnations*, and *Moon-Shine Peacock*. Through its president, Prentiss Taylor, the Society of Washington Printmakers presented the color lithograph *Black Fire*, by Jack Perlmutter. Mr. Taylor, a well-known Washington artist, also donated a print of his lithograph *La Presa-Marfil*, together with the original preliminary drawing of the subject, the transfer drawings, and the zinc plate used in printing.

The section of photography acquired some notable additions to its historical collections as well as items representative of significant current developments. The Eastman Kodak Co. presented a matchbox camera developed during World War II for the Office of Strategic Services, a 1922 cine-camera, Model-A, their first motion picture camera, and several cutaway cameras illustrative of design changes. Dr. Harold E. Edgerton donated a pair of deep-sea stereo cameras of his design. These were first used in 1954 by Capt. Jacques Yves Cousteau and by the Woods Hole Oceanographic Institution.

Noteworthy donations to the division of manufacturing and heavy industries include a collection of more than 300 tinware items, covering the entire range of the 19th-century tinsmith's art, from Kenneth Jewett. President John F. Kennedy, through the U.S. Atomic Energy Commission, transferred a cube of uranium fuel used by Enrico Fermi in the world's first controlled neutron chain reaction (December 2, 1942). Obtained from the Army Nuclear Power Program was a model of the first land-based nuclear power plant (SM-1), the prototype of small reactors being developed for the use of the U.S. Army in the field, and the Oak Ridge National Laboratory provided a display showing the method of fabrication of the fuel elements used therein. The section of iron and steel was successful in locating the original Ajax-Wyatt electric induction furnace which was transferred by the Ajax Magnethermic Corp.

The division of agriculture and forest products received, from Minneapolis-Moline, Inc., a 1918 Moline Universal Model D tractor with a two-bottom plow attached. The tractor is notable for its use of electrically operated accessories. Another historical item acquired by the division is an 1869 portable steam engine, the first made by the J. I. Case Co. and donated by that firm.

Civil history.—Among the important accessions received in the division of political history is Mrs. John F. Kennedy's gift of her inaugural-ball gown and cape, made of peau d'ange covered with several layers of white silk chiffon. Mrs. Kennedy also presented her dress of white ottoman silk worn at the inaugural gala on January 19, 1961. Items of clothing worn by Presidents William Howard Taft, Theodore Roosevelt, Calvin Coolidge, and Woodrow Wilson were presented by Charles R. Taft, Ralph E. Becker, John Coolidge, and the National Trust for Historic Preservation, respectively. A handsomely bound book presented to Theodore Roosevelt by the Faculty Club of the University of California, *The Silva of California*, was given by his grandson, Cornelius Van S. Roosevelt. A number of items, including a fan, a brown satin apron, and other articles of the clothing which belonged to Dolley Madison, were donated by her great-great-great-grandniece, Miss Barbara Donald. Mrs. Herbert A. May donated the famous Napoleon diamond necklace presented by the Emperor to his wife, the Empress Marie-Louise, on the occasion of the birth of their son, the King of Rome.

To the collections of the division of cultural history were added an important block-front tall clock from Rhode Island, a Philadelphia "pie crust" table, and other significant items, donated by Mrs. Francis P. Garvan. Mrs. Harry T. Peters and her children, Harry T. Peters, Jr., and Mrs. Charles D. Webster, presented 11 large folio lithographs by Currier and Ives and others, a valuable addition to the nearly 2,000 prints given by this family. Mr. and Mrs. A. Philip Stockvis gave a varied group which includes an American Chippendale armchair. For the musical instruments collection, the Le Blanc Corp. presented a basset horn, contra-bass clarinet, bass clarinet, and two alto clarinets.

The division of philately and postal history added 178,626 specimens to its collections. One of the most significant of the recent gifts came from Bernard Peyton of Princeton, N.J., who presented a Confederate States cover, to which is affixed a block of twelve 2-cent Jackson Confederate stamps. This is the largest known block of these stamps on a cover. Funds donated by the Charles and Rosanna Batchelor Memorial, Inc., made possible valuable additions to the Emma E. Batchelor Air Mail Collection.

The division of numismatics received significant contributions of rare half dollars from R. E. Cox, Jr., of Fort Worth, Tex. Extensive donations of the Messrs. Stack of New York City included original drawings for U.S. patterns and medals, and Harvey Stack gave a hitherto unknown variety of the extremely rare Indian Peace Medal dated 1843, portraying President George Washington and distributed by one of the fur-trading companies in the Missouri Territory. To our holdings in modern coins the Honorable R. Henry Norweb of Cleveland, Ohio, contributed a virtually complete collection of Newfoundland issues dating from 1865–1947. Willis H. du Pont of Wilmington, Del., added to his previous donations of Russian coins and medals formerly owned by the Grand Duke Mikhailovitch a group of 778 coins struck during the reigns of Peter III and Catherine II up to 1774, and medals struck during the period from 1762–94. Mrs. Wayte Raymond of New York City contributed 620 important modern coins of the world, and Mrs. F. C. C. Boyd of New York City gave 572 Mexican coins comprising many issues of the Revolutionary Period. Philip H. Chase of Wynnewood, Pa., donated a very rare album, *The Currency of the Confederate States of America*, prepared by Raphael P. Thian about 1880 and containing 286 notes and their descriptions. Mr. and Mrs. Isadore Snyderman of New York City presented to the Smithsonian a unique gold plaquette of 1906, made by Victor D. Brenner in commemoration of the removal of the remains of John Paul Jones from Paris to Annapolis in 1905.

Armed Forces history.—The collections of the division of military history were enriched by a unique Henry rifle once presented to President Lincoln and given to the Museum by Robert Lincoln Beckwith. The William De Laney Travis Civil War panorama "The Army of the Cumberland" was received from C. C. Travis and Mrs. Hattie Kidd. A fine group of decorations awarded to Capt. C. H. Huntington was presented by Mrs. Huntington. A rare Medal of Honor and associated Civil War medals awarded Lt. Edward B. Williston were received from the Department of the Navy.

The division of naval history acquired, from Capt. P. V. H. Weems, the Weems Memorial Library and its associated collection of navigational instruments illustrative of the progressive solution of problems posed by aerial navigation from its earliest days. The collection includes a notably fine run of Bowditch's *The New American Practical Navigator* from the 1st to 15th editions. Also included are navigation instruments used in the polar flights of Richard E. Byrd and Lincoln Ellsworth.

The division's uniform collection has been greatly enhanced by the gift of Mrs. Ernest J. King, widow of Fleet Adm. Ernest J. King, which included a number of her late husband's uniforms, orders, and decorations.

Philip Wrigley presented rare and interesting naval uniforms including the period of World War I, and an extensive collection of contemporary naval uniforms was presented by the Department of the Navy and Jacob Reed & Sons of Philadelphia.

The U.S. Coast Guard transferred a wide selection of objects pertaining to the history of that service. These included items of ordnance, two sets of gangway headboards, a first order catadioptric lens, original drafts of a wide variety of lighthouse lenses, a lifeboat and fully equipped beach cart, and, most important, eight extremely handsome models of revenue cutters. Floyd D. Houston of New Suffolk, N.Y., presented his finely executed model of the submarine *Holland*, first submarine in the Navy.

Through the courtesy of M. E. Tucker and the government of Bermuda, head curator Mendel L. Peterson and museum technician Alan B. Albright collected a significant number of artifacts from underwater sites in the Bermuda reefs. These included materials of glass, ceramics, and metal from sites dating from 1595 through 1838.

EXPLORATION AND FIELDWORK

Dr. R. S. Cowan, assistant director of the Museum of Natural History, conducted a 5-week expedition to Baja California, Mexico, in February and March, primarily to collect data and materials for constructing a desert-life group in the future hall of plant life. With the assistance of modelmaker Paul Marchand and sculptor-artist Vernon R. Rickman, fiber-glass models and plaster models were prepared of several cacti and other plants characteristic of the desert. Dr. Cowan also made a systematic collection of wood specimens, almost half of which are new to the Smithsonian Institution wood collection.

During November and December, Dr. I. E. Wallen, assistant director for oceanography, visited institutions specializing in marine sciences in England, Denmark, Sweden, Holland, France, Monaco, and Italy. He obtained information which has been useful in the planning of the Smithsonian Oceanographic Sorting Center. The establishment and functioning of this Center constitute perhaps the most important single accomplishment of the first year of the oceanography program. At the close of the year Dr. Wallen was in East Pakistan on a temporary assignment as visiting professor of zoology for the Asia Foundation.

During September and October Dr. T. D. Stewart, then head curator of anthropology (now director of the Museum of Natural History), was in Baghdad, Iraq, reconstructing and studying the remains of Neanderthal skeletons IV and VI recovered in Shanidar Cave in 1960. The results of this year's work, embodied in a manuscript scheduled to be published in *Sumer*, the Journal of Archaeology and History in Iraq, led Dr. Stewart to the conclusion that the Shanidar Neanderthal population remained fairly homogeneous throughout the estimated 15,000 years during which their skeletons accumulated in the cave.

The investigation of the late Pleistocene bone bed near Littleton, Colo., was underway again at the beginning of the year. Dr. Waldo R. Wedel, then curator of archeology (now head curator of anthropology), museum specialist George Metcalf, and exhibits specialist Peter W. Bowman continued to work until late in August, by which time some 2,400 square feet of deposits around an ancient spring had been excavated to depths up to 11 feet and extensive additional collections made of mammoth, bison, and other mammal bones. Although conclusive evidence of man's association with the mammoth was not obtained, a stratified section of the deposit and recovery of several key artifact types in situ established man's presence here at least as far back as 7,000 years ago.

From January to March Dr. Saul H. Riesenberg, curator of ethnology; Dr. Clifford Evans, curator of archeology; and Dr. Betty J. Meggers, honorary research associate, were on the island of Ponape in the Caroline Islands of the Trust Territory in the Pacific studying ancient megalithic structures and the traditions relating thereto. Just off the eastern end of Ponape is a complex of artificial islets, known as Nan Madol, on which are structures made of columnar basalt. By using 25 workmen to clear the areas to be investigated, Drs. Evans and Meggers were able to excavate and map eight distinct parts of the complex. In the process they collected typical artifacts and a sequence of carbon samples which may yield reliable dates. The team spent 6 weeks at the site, Dr. Riesenberg collecting the traditions related to the structures and Drs. Evans and Meggers investigating the archeological clues and interpretations provided by these traditions and, consequently, offering new leads for ethnological explorations. As a result of this unusual approach, they concluded that orally transmitted tradition has greater historical validity, at least in this area, than is generally recognized by most anthropologists.

After finishing their work on Ponape, Drs. Evans and Meggers went to Japan and Taiwan to consult with Japanese and Chinese archeologists and to examine sites and collections of the Early-Middle Jomon Culture of Japan in order to determine the relationship between that pottery complex and the pottery complexes relating to the early Valdivia Culture of coastal Ecuador. The Valdivia Culture has yielded the earliest dated pottery in the New World (5,000–4,050 years before the present, as determined by carbon-14 tests). Not only is this pottery unexpectedly early for the New World, but also it indicates no relationship with any known New World culture. Since the Jomon pottery shows suprisingly similar features, and is of about the same antiquity, the records obtained during this trip open up many doors to research on the problem of transpacific movements of early populations.

While in Japan, Drs. Evans and Meggers examined the collections made by staff members of the University of Tokyo during two archeological expeditions to the northern Andes of Peru. Here also the pottery was found to bear directly upon some of the cultures of Ecuador. These rewarding contacts between American and Japanese archeologists having mutual interests promise to open up a fruitful era of cooperation.

Late in August Drs. Evans and Meggers, together with Dr. William H. Crocker, associate curator of ethnology, attended the 35th International Congress of Americanists in Mexico City, after which they examined collections and sites in various parts of Mexico, giving particular attention to those in Yucatán.

Dr. Henry W. Setzer, associate curator of mammals, was engaged during much of the year in organizing and supervising field parties operating in Asia, Madagascar, and Mexico with the objective of making collections of small mammals and their ectoparasites. Late in August he went to London to study type and other specimens of mammals in the British Museum (Natural History). After this he spent brief periods with field parties in West Pakistan and along the Afghanistan border in Iran, consulted with American officials in Cairo, Egypt, and helped the Madagascar field party initiate work in the vicinity of Ihosy. Another trip late in February and early in March took him to Mexico, where he joined a field party on the Mexican plateau.

Col. Robert Traub, who in January was appointed honorary research associate, worked closely with Dr. Setzer in organizing and participating in fieldwork in widely separated areas. During most of September and October he collected small mammals and their ectoparasites in West Pakistan, particularly in the Kagan Valley and in the vicinity of Lahore and Sialkot. From there he went to northern Thailand for 4 weeks. Then, late in February, he spent a month in Mexico collecting in the States of Veracruz, Guerrero, México, Nuevo León, and Tamaulipas.

From January to April Dr. Charles O. Handley, Jr., associate curator of mammals, with the assistance of Frank M. Greenwell of the Smithsonian's office of exhibits, continued his major project of studying the mammals of Panama. The areas investigated this year were the San Blas coast in extreme eastern Panama and the Bocas del Toro Archipelago and adjacent mainland near the Costa Rican boundary. The resulting mammal collection amounted to 1,914 specimens.

In order to study the relationship of birds to arthropod-borne virus diseases, especially eastern equine encephalitis, Dr. Philip S. Humphrey, curator of birds, collected extensively in the vicinity of Belém and in Bragança, Brazil, from the end of January to the end of April. In this work he had the cooperation of the Belém Virus Laboratory, Fundaçao Serviço Especial de Saúde Pública, and the Museu Paraense "Emilio Goeldi," all of Belém. In addition to 986 skins and 1,035 anatomical specimens, he took over 1,100 liver and 788 blood samples. Since three or four different habitats are represented, Dr. Humphrey hopes that the serological findings can be subjected to ecological analysis.

Field studies concerned with the birdlife of the Isthmus of Panama, under Dr. Alexander Wetmore, honorary research associate and retired Secretary of the Smithsonian Institution, covered the period from early in January to late in March. The first work of the season centered on the white-winged dove colonies found last year in the extensive mangrove swamps along the lower Río Pocrí, below Aguadulce in the Province of Colcé. These colonies were especially interesting, since elsewhere the doves inhabit drier upland localities. Traveling by dugout canoe along the river channels during these investigations, Dr. Wetmore found also the rare rufous-crowned wood rail, *Aramides axillaris*, known previously in Panama only from a few reports around Almirante Bay on the Caribbean coast. In addition, he obtained information on wintering dowitchers among the many sandpipers, and on gull-billed terns, all migrants from the north.

Late in January Dr. Wetmore was a guest on the small motor vessel *Pelican* engaged in a study of the distribution of the spiny lobster, a cooperative project between the Bureau of Commercial Fisheries of the U.S. Fish and Wildlife Service and agencies concerned with assistance to the Panamanian Government. Their route through the

Canal and along the Pacific coast to islands off western Chiriquí gave opportunity for daily work ashore on Isla Parida and Isla Bolaños, in continuation of the island survey of last year on the launch *Barbara II.*

On his final fieldwork of the season Dr. Wetmore arranged a charter flight on a small plane east to Puerto Obaldía on the San Blas coast near the boundary with Colombia. After a few days' work near the town, he established a camp, in company with mammalogist Dr. Charles O. Handley, Jr., in the high forest back of Armila, the easternmost village of the Cuna Indians. Three pairs of the rare antbird *Xenornis setifrons*, known previously from five specimens, were special prizes here.

As last year, the Gorgas Memorial Laboratory of Panama provided Dr. Wetmore with one of their technicians, Rudolfo Hinds, to serve as field assistant.

Dr. Doris M. Cochran, curator of reptiles and amphibians, in company with entomologist Mrs. Doris H. Blake, honorary research associate, was in South and Central America from the beginning of December through February visiting museums and making collections. The countries visited included Brazil (Brasilia, Rio de Janeiro, São Paulo, Santos, and Curitiba); Argentina (Foz de Iguassu, Buenos Aires, La Plata, Vila Bela); Peru (Lima, Pachacamac, Río Blanco, and Río Rimac); Colombia (Cali, Palmyra, Bogotá, and Medellín); and the Canal Zone (Barro Colorado Island). As a result of the information and specimens obtained, Dr. Cochran expects to complete reports on the frogs of central Brazil and of Colombia, the latter in collaboration with Dr. C. J. Goin of Gainesville, Fla.

Two associate curators of the division of fishes, Dr. Victor G. Springer and Dr. William R. Taylor, participated in oceanographic expeditions during the year. Dr. Springer was on the oceanographic vessel *Geronimo*, operated by the Fish and Wildlife Service, when she left Boston for West Africa on March 5. Unfortunately, 4 days later the vessel malfunctioned and had to be towed into Bermuda for repairs, but again departed for Africa on March 12. During the 3 days in Bermuda Dr. Springer was able to make only night-light collections. After leaving Bermuda the vessel again malfunctioned and had to be towed back to port. Thereupon the cruise was canceled, and Dr. Springer, after further attempts at shore collecting, left for Washington by air. In spite of limited collecting opportunities and unfavorable weather conditions, he returned with about 300 specimens.

Dr. Taylor joined the *Anton Bruun* of the International Indian Ocean Expedition when she left Bombay, India, early in March on her first cruise designed to obtain physical data and biological material from the Andaman Sea and Bay of Bengal. Malfunction of the electrical equipment, winches, etc., and difficulties in obtaining fresh water caused changes in schedules and restricted the activities of the biologists aboard. As a result, Dr. Taylor late in April left the ship at Vizagapatam. The collections obtained were limited to the Andaman Sea and offshore areas west of Burma.

From early in March to late in May Dr. J. A. F. Garrick, research associate in the division of fishes, visited several museums and other institutions in Europe and Africa primarily to examine type material of the shark genus *Carcharhinus* for his revision of the group. He also wished to obtain additional locality records and to ascertain if any species had been overlooked or are not represented in the collections of U.S. museums thus far seen. Dr. Garrick's findings show that much of the current nomenclature for the group is in error, particularly in regard to species of the Indo-Pacific, based primarily on the literature rather than on examination of types. As a result of this fieldwork, locality records for many species were greatly extended, and in several cases species thought to be restricted to one ocean were found to occur in other oceans or to be worldwide in distribution. The number of recorded species was increased by two. Because of the value of vertebral counts in identifying shark species, Dr. Garrick X-rayed critical specimens whenever possible. About 90 specimens were so examined. In this and all other respects he received the fullest cooperation from the staffs of the institutions visited.

From the middle of July through August Dr. J. F. Gates Clarke, curator of insects, conducted extensive field studies in Oregon and Washington. While in Oregon he had the company of a colleague, James Baker, of Burns, Oreg. From numerous stations set up for collecting purposes at various altitudes, they obtained over 7,000 specimens, including many novelties, which eventually will contribute much to our knowledge of the ecology and distribution of Microlepidoptera of the Pacific Northwest.

From the beginning of June until the end of September Dr. Ralph E. Crabill, Jr., associate curator of insects, conducted further studies of myriapods, particularly in museums in Munich, Vienna, Hamburg, Copenhagen, and London. He was able to locate and examine previously unknown material. He also spent a couple of weeks in the Bavarian Alps collecting topotypical specimens of centipedes for the national collections.

Since joining the staff as associate curator of the division of insects this year, Dr. Paul J. Spangler, a specialist in aquatic beetles, has made several collecting trips, the longest of which, December 15–January 26, took him to Puerto Rico and the Virgin Islands. Although the insect fauna from Puerto Rico is better known than that from other Caribbean islands, he found numerous new records and new species and collected approximately 14,000 insects. Although this material has as yet been examined only cursorily, 1 family (Isometopidae), 12 genera previously unknown from the island, and numerous new species have been identified. The number of species of aquatic beetles known from Puerto Rico has been increased from approximately 40 to 75, and larvae of about 35 of these have been established by rearing or association. The number of aquatic beetle species known from the Virgin Islands has been tripled.

During 2 weeks in August Dr. Spangler collected also in South Dakota, Wyoming, and Montana, concentrating in the numerous and unusual habitats in Yellowstone National Park and vicinity. He collected approximately 10,000 insects during this trip. Although this material has not yet been thoroughly examined, several new species of water beetles have been found. In several rare genera the number of specimens present in the national collection has been doubled. In addition, rare and undescribed larvae of several species have been found and associated with their adults.

At the beginning and end of the year Dr. Spangler in company with other members of the staff made day-long trips to collecting areas in Maryland and West Virginia. A trip to the vicinity of Oakland in Garrett County, Md., yielded several rare species for the first time and one apparently new species.

Dr. Oliver S. Flint, Jr., associate curator of insects, continued his research on caddisflies. This year his major collecting effort came during the latter part of July when he went to Jamaica and again to Puerto Rico. On the island of Jamaica he obtained well over 1,000 specimens of caddisflies belonging to about 20 species. Almost all these species are new to science, and one represents a genus new to the Antilles. The collection of nearly 5,000 specimens from Puerto Rico included an undescribed caddisfly belonging to a genus unrecorded from that island.

During the latter part of May, Dr. Flint, accompanied by William D. Field, made a 12-day trip through the Jefferson and Monongahela National Forests in Virginia and West Virginia to Bluestone State Park in West Virginia. Little collecting of aquatic insects has been done in this area.

A 12-day collecting trip for butterflies was made late in August by William D. Field, associate curator of insects, along the Blue Ridge Parkway in Virginia, North Carolina, South Carolina, and Tennessee to the Great Smoky Mountains National Park. The 392 specimens obtained include species which contribute importantly to knowledge of these insects. As mentioned above, Mr. Field also accompanied Dr. Flint on a trip into the mountains of western Virginia and eastern West Virginia in the vicinity of Lewisburg, W. Va. Here he found a specimen of *Pieris virginiensis* Edwards, one of the rarest of eastern butterflies. Over 100 mature larvae of *Euphydryas phaeton* Drury and a good series of *Glaucopsyche lygdamus* Dbldy., another early spring rarity, also were collected.

During the latter part of August Dr. Donald R. Davis, associate curator of insects, conducted studies on Microlepidoptera in the Tenkiller Lake district of Oklahoma. As this is an area practically unknown entomologically, these studies were particularly significant in producing information on distribution, ecology, and new species. Prior to this, in July, on a visit to the Dismal Swamp area of Virginia in company with Dr. Flint, Dr. Davis collected 300 specimens of Microlepidoptera, along with a sizable sample of leaf miners. Three species of leaf miners were reared, and leaves mined by several additional species were collected.

Associate curator O. L. Cartwright, who in May accompanied Dr. Spangler to the vicinity of Oakland in Garrett County, Md., collected specimens of seven species of Scarabaeidae, including three rare species, the basis for new Maryland State records, and one species (nine specimens) apparently new to science.

During July Dr. Donald F. Squires, associate curator (now curator) of marine invertebrates, was in New Zealand conferring with officers of the New Zealand Oceanographic Institute regarding the identification and study of deep-water coral banks, and with the New Zealand Geological Survey staff regarding the occurrence of such banks as fossils. At the Auckland Museum and Institute he studied recent collections of corals, particularly those made by fisheries research vessels. He also examined outcroppings of fossil deep-water coral banks at two localities in Wairarapa.

In November, while participating in the annual meetings of the Bahamas National Trust, Dr. Squires conducted preliminary explorations, with other members of the Trust, of the reef tracts at Lyford Cay, New Providence Island.

From late in March to early in May, Dr. Squires carried out field work on R/V *Chain* of the Woods Hole Oceanographic Institution, as part of the international Equivalent I operation, in the area from Recife, Brazil, to Trinidad and east to longitude 25° W. He collected samples and made numerous bathymetric observations on the structures known as shelf-edge prominences off the Orinoco River Delta. Also, he made collections of corals from 40 to 200 fathoms in the vicinity of St. Paul's Rock and in the approaches to Paramaribo, Surinam.

As a participant in the International Indian Ocean Expedition from the middle of January to the middle of March, Charles E. Cutress, Jr., associate curator of marine invertebrates, visited the Indian Museum at Calcutta and studied sea anemones at Port Canning, the University of Madras, the Central Marine Fisheries Research Institute at Mandapam Camp, the Porto-Novo Marine Biological Station, and the Institute of Science of the University of Bombay. En route to India Mr. Cutress examined anemone types at the British Museum (Natural History) and, on the way home, studied and collected anemone material at the Stazione Zoologica di Napoli. These studies will contribute to the solution of major problems of long standing in the classification of the sea anemones.

As biological consultant of the National Science Foundation, Dr. Waldo L. Schmitt, honorary research associate, late in November joined an expedition to the Palmer Peninsula, Antarctica, to survey possible sites for a scientific station in that area. Delays in obtaining transportation on an icebreaker afforded Dr. Schmitt the opportunity to visit institutions and consult with biologists in New Zealand, particularly at Christchurch, and to visit the USARP McMurdo Station on the shores of the Ross Sea ice shelf. He finally sailed on the U.S.S. *Staten Island* on January 5. During the ensuing 2½ months before returning to the Museum, he examined 20 possible sites for a station from the point of view of logistics, engineering problems, meteorological conditions, and biological potential. At the same time he made land, shore, and offshore collections by various means, including hook and line, traps, tow nets, and dredges.

Continuing his work on the marine mollusks of the Indo-Pacific region, Dr. Harald A. Rehder, curator of mollusks, collected on the island of Tahiti from mid-January to mid-March. Here he concentrated efforts in the coastal area immediately to the east of Papeete but also made several trips around the island, obtaining a good representation of mollusks from numerous localities in almost all districts. Dr. Rehder also gathered fresh-water mollusks at the mouths and along the courses of the three principal streams that traverse the Districts of Pirae, and examined the area for land snails. The results of this trip will assist in planning for future fieldwork in the southern Polynesian area.

In connection with his studies on the families Tridacnidae and Littorinidae of the Indo-Pacific region, Dr. Joseph Rosewater, associate curator of mollusks, spent 6 weeks during February and March on Eniwetok Atoll in the Marshall Islands utilizing the excellent facilities of the Eniwetok Marine Biological Laboratory of the Atomic Energy Commission. Representatives of all four species of Tridacnidae living around the atoll were collected and maintained in the laboratory. The brightly hued mantles of these specimens provided valid distinguishing differences, and dissection of the animals yielded additional valuable information regarding their anatomical distinctions. Although a spawning reaction was induced in two individuals of one species by the introduction of the sex products of a third, no development of possible fertilized eggs could be noted. It is theorized that natural spawning in this group may occur during the warmer summer months and that the event is initiated by the occurrence of a particular water temperature. Similar studies were carried out on specimens of Littorinidae.

In connection with her research on Leguminosae, Dr. Velva E. Rudd, associate curator of phanerogams, joined a group of botanists from the University of California and the University of Mexico during December in a 10-day field trip in the region of San Blas, Mexico. En route she spent 2 days in Mexico City at the Instituto de Biología, University of México, examining plant specimens. The collections and field experience will be helpful in planning more intensive future work in the area.

Dr. John J. Wurdack, associate curator of phanerogams, returned in December from Peru where he had continued on the field trip reported last year. Most of his collecting centered around Chachapoyas in the northern highlands, with the last few months spent along the Río Marañón from below Pongo de Rentema to Pongo de Manseriche in the tropical rainforest. Total specimens exceed 12,000. Dr. Wurdack attributes much of the success of the trip to the help received from the staff of the Museo de Historia Natural "Javier Prado" in Lima, where one complete set of his specimens has been deposited.

Dr. Harold Robinson, associate curator of cryptogams, spent most of May collecting bryophytes in Mexico. The work centered in the Valle Nacional area of northern Oaxaca, with short visits to Chiapas and Guerrero. Dr. Robinson estimates that about 300 specimens from the collection will be retained.

Early in December, an algologist, Dr. Richard Norris, was added to the staff as associate curator. He left Washington almost immediately to join the first and some of the subsequent cruises of the *Anton Bruun* of the International Indian Ocean Expedition.

While in Trinidad attending the Neotropical Botany Conference early in July, Dr. William L. Stern, curator of plant anatomy, gathered a small group of wood specimens from the northern part of the island. In the latter part of August, while on his way to attend the meetings of the American Institute of Biological Sciences in Corvallis, Oreg., he collected wood specimens in the Rocky Mountains of Colorado and in the Cascade and Coast Ranges of Oregon.

During February and March, Dr. Stern, accompanied by two other members of his division, Dr. Richard H. Eyde, associate curator, and Edward S. Ayensu, research assistant, conducted fieldwork in Panama, collecting not only specimens of fossil woods but also conventional herbarium specimens and associated wood samples in the fossil localities for comparison with the fossil flora. An abundance of fossil woods was found on the Azuero Peninsula, particularly in the environs of the village of Ocú. Two other localities for fossil woods, both on the isthmus proper, were discovered, one near the town of La Mesa and the other near Colorado, a tiny settlement southwest of Calobre. Petrifactions from the two new areas superficially resemble those from Ocú.

Dr. G. A. Cooper, head curator of geology, in company with Drs. Thomas G. Gibson and Druid Wilson of the U.S. Geological Survey, in October visited a fossil site near Hampton, Va., known as Rice's Pit. Although this has become a very popular place for collecting, Dr. Cooper and his party obtained some good material, especially of the smaller fossils. Mr. and Mrs. William M. Rice, who own the pit, and Mrs. George Webb, a neighbor, donated examples of the rarer species.

For a month beginning late in April, Dr. Cooper was occupied in a revisionary study of the stratigraphy of the Glass Mountains in the vicinity of Marathon, Tex. He was assisted by Dr. Richard Grant, of the U.S. Geological Survey, and John L. Carter, museum technician. The trip took them to a number of places not heretofore visited by geologists and accessible only with great difficulty. The objective was to verify new views on Glass Mountains stratigraphy which had been developed as a result of work done on the brachiopods therefrom.

Dr. Cooper and his party spent a day at the end of May in the Chinati Mountains south of Marfa, Tex., looking for certain types of fossils reported to occur in that locality. From here they went to Van Horn, Tex., which they used as a base for forays into the Sierra Diablo, Guadalupe, and Apache Mountains.

Early in September, Edward P. Henderson, associate curator of mineralogy and petrology, and Roy S. Clarke, Jr., analytical chemist, attended an informal conference in the British Museum (Natural History) on methods of chemical analysis of meteorites. Before and after the meeting they inspected the museum's collections of meteorites and tektites and conferred with staff members about problems of organization, equipment, and scientific procedure.

In the Netherlands, Messrs. Henderson and Clarke visited the University of Utrecht and Prof. G. H. R. von Koenigswald, who has one of the world's finest tektite collections. Arrangements were made with him for an exchange. In Mainz, Germany, they discussed mutual problems with the staff of the Max Planck Institute. Dr. H. Wänke of the institute showed them a new shipment of tektites from which he generously proffered a selection of interesting and unusual specimens. A visit also was made to the University of Heidelberg.

Mr. Clarke then returned home by way of England, stopping again at the British Museum, while Mr. Henderson continued on to Copenhagen, where he studied the meteorite collection in the Danish National Museum and arranged to exchange Philippine tektites for much-needed moldavites. He also spent 2 days with Dr. Vagn Buchwald, metallurgist with the Laboratory of Metals in Copenhagen, who is working on some specimens that were described from Smithsonian collections.

Back in England early in October, Mr. Henderson visited Dr. H. J. Axon of the department of metallurgy, University of Manchester, who also is working on specimens that have been studied in our laboratory. Next, he called on the York firm of Cooke, Troughton & Simms which made the metallograph used in our laboratory. Besides giving Mr. Henderson expert advice on the care and use of the instrument, members of the firm offered to make pictures of one of the meteorites he had with him.

A collecting party from the division of invertebrate paleontology, consisting of Dr. R. S. Boardman, curator; Dr. F. M. Hueber, associate curator; Dr. J. Utgaard, research associate; and F. J. Collier, museum specialist, went to western New York State for 3 weeks late in May. Following a reconnaissance of the Hamilton strata in the Cayuga Lake region, Drs. Boardman and Utgaard and Mr. Collier went on to Lockport, leaving Dr. Hueber at Cornell University to study paleobotanical collections housed there. In the Lockport area they obtained large numbers of Silurian Bryozoa which will enable reevaluation and statistical analysis of many species. Dr. Hueber rejoined the group at Batavia, where detailed collecting of the Hamilton strata was undertaken. As the party moved eastward to the Finger Lakes region, they made extensive collections of Bryozoa from many localities at several stratigraphic intervals. A few fossil plant specimens were obtained which are considered especially important in taxonomic and morphologic interpretations. After Dr. Boardman returned to Washington, the rest of the party continued the stratigraphic reconnaissance and detailed collecting eastward to the Ithaca area. The entire trip resulted in approximately half a ton of specimens, most of which fall into groups previously poorly represented in the collections.

Late in October, Dr. Richard Cifelli, associate curator of invertebrate paleontology, obtained material for his study of the distribution of planktonic Foraminifera in the North Atlantic during the 2-week cruise of the R/V *Crawford* from Woods Hole, Mass. He collected

28 plankton samples on a track from Cape Cod to the vicinity of Puerto Rico to Bermuda.

For another scientific cruise beginning late in March, Dr. Cifelli joined the R/V *Chain* at Recife, Brazil, as a participant in the International Tropical Atlantic Ocean Expedition. Of particular interest to Dr. Cifelli were the nearly 100 plankton hauls collected which he will examine for Foraminifera in connection with his long-range program to study the relationship between the distribution of surficial planktonic Foraminifera and oceanic circulation in the North Atlantic. Also of importance for the study of Foraminifera were the 12 piston long-cores and numerous bottom sediment samples collected from the abyssal plain, continental slope, Orinoco shelf, and the Gulf of Paria.

In June and July Dr. Erle G. Kauffman, associate curator of invertebrate paleontology, and F. J. Collier, museum specialist, spent 6 weeks completing a biostratigraphic study of the lower Colorado group along the Front Range of the Colorado Rockies, tracing faunal zones, refining the zonation by use of ammonites and pelecypods, and tracing disconformities and facies change. They were able to tie in 60 detailed stratigraphic sections along the Front Range and to correlate them with others in northern New Mexico and southern Wyoming, as well as with others in the intermontane parks of the middle Rockies. Approximately 4,000 specimens were collected, predominantly pelecypods and ammonites.

While studying at the U.S. Geological Survey offices in Denver, Colo., during October, Dr. Kauffman spent two weekends in the vicinity of Colorado Springs collecting from previously measured Upper Cretaceous sediments. This resulted in the addition of approximately 300 well-preserved pelecypods and ammonites to the collections.

A number of short excursions to the Upper Cretaceous outcrops of Maryland were undertaken by Dr. Kauffman and Dr. Norman Sohl, of the U.S. Geological Survey, as part of a continuing restudy of this rich but incompletely known fauna. Large collections from near Brightseat, Md., include many species, particularly gastropods, never before reported in the Middle Atlantic Coast Cretaceous.

Late in August Dr. Nicholas Hotton III, associate curator of vertebrate paleontology, and James W. Kitching, research associate on leave from the Bernice Price Institute in Johannesburg, South Africa, journeyed to the Appalachian Mountains in search of field occurrences of middle and late Paleozoic vertebrate-bearing deposits. In quarries of the Greer Limestone Co., at Greer, W. Va., they collected partial skeletons, including one skull, of at least two amphibians from outcrops of the Greenbriar limestone (Mississippian). While in this area they examined beds above and below the Greenbriar outcrop along the valley of Stranger Creek but found no fossils. A Greenbriar quarry at Terra Alta, W. Va., also yielded no results, but one at Fairchance, Pa., yielded scraps of fossil fishes.

On September 6, Dr. Hotton, Mr. Kitching, and Gerald R. Paulson, museum technician, went to Chalk Point, in nearby Maryland, to collect the skeleton of a whale discovered during excavation for a facility of the Potomac Electric Power Co. The deposits at Chalk Point are assigned to the Calvert formation, of late Miocene age. The specimen turned out to be a squalodont whale that was about 15 feet long during life; the amount of wear shown by the teeth indicates that the individual was very old when it died. As recovered, the specimen consists of a large part of the lower jaw, a number of vertebrae, ribs, loose teeth, a scapula, and a complete flipper in good articulation. The find is significant as a locality record, and anatomically because of the excellent preservation of the flipper. The degree of wear on the teeth is interesting from the viewpoint of function.

Dr. Hotton and Mr. Kitching conducted October fieldwork in several western States and in a variety of formations ranging in age from Permian to Oligocene. These include the White River Oligocene and Pierre Cretaceous of South Dakota and Wyoming; the Permian, Triassic, and Paleocene of New Mexico; and the Permian and Triassic of Texas. The most spectacular result of the trip was the discovery of an untouched pocket of vertebrates in the lower Permian along West Coffee Creek, Baylor County, Tex., which yielded four complete skeletons and five additional skulls of various amphibians and reptiles, plus a considerable amount of material of an as yet undetermined nature. These specimens represent a good portion of the fauna of the lower Permian of the United States. Most of them have been forwarded to the Bernard Price Institute for Paleontological Research, in Johannesburg, South Africa, in partial reciprocity for the excellent Beaufort material from South Africa that Mr. Kitching's help and the good offices of the institute enabled Dr. Hotton to collect.

Howard I. Chapelle, curator of transportation in the Museum of History and Technology, made brief trips to Madrid and Barcelona, Spain, during December and May to examine the construction of a full-size replica of Columbus's flagship *Santa Maria* and to check the progress of a scale model to be donated to the Smithsonian. The research for this project of reconstruction has been carried on by Captain de Corbita J. M. Marinez-Hidalgo, S.N., director of the Maritime Museum in Barcelona, who previously had done similar research on a Spanish galley of the post-Lepanto period and for a caravel, specifically the *Pinta*. The Maritime Museum is located in an ancient galley yard built before the battle of Lepanto (1571). The original stone galley slips and sheds remain and are restored and utilized for museum halls. Interestingly, the launching ends of the slips are now about a block from the water.

On his way to attend the 18th International Congress of the History of Medicine, held in Warsaw and Krakow, Poland, during September, Dr. Sami Hamarneh, acting curator of medical sciences, sought information in his fields of interest through visits to the British Museum, the Wellcome Medical Library and Museum, the British Pharmaceutical Society, and a number of institutions in Poland.

In order to collect further data on the life of Frederick Carder, the Englishman who came to America early in this century and established the Steuben Glass Works, Paul V. Gardner, curator of ceramics and glass, made several visits to Corning, N.Y., where Mr. Carder is living, and to various institutions where examples of Carder's work are preserved.

From mid-August to mid-October Jacob Kainen, curator of graphic arts, was in Europe gathering material for an exhibition on typography and doing research for his study of the Dutch engraver Hendrick Goltzius (1558–1617). He obtained typographical material from Monotype House, Ltd., London, and consulted with technicians and historians in London, Haarlem, and Brussels. Also he conducted research in various museums in London, Amsterdam, Rotterdam, Utrecht, Brussels, Paris, Venice, Florence, Rome, Milan, Parma, and Madrid.

John N. Pearce, assistant curator of cultural history, with Richard J. Muzzrole, archeological aide, in October, participated in a 10-day archeological investigation of the site of John Frederick Amelung's "New Bremen Glass Manufactory." This, the first major glassmaking enterprise in the American Republic, was operated between 1785 and 1795 in Frederick County, Md. The excavations were sponsored by the Corning Museum of Glass with the collaboration of the Smithsonian Institution. Ivor Noël Hume, honorary research curator, who is chief archeologist of Colonial Williamsburg, Inc., was director of excavations, and Paul N. Perrot, director of the Corning Museum, was executive director of the project. With the evidence of structures and artifacts thus far revealed, it is expected that the results will contribute significantly to knowledge of 18th-century glassmaking in America as well as yielding particular information about this influential primary source of American glassmaking skills.

In November and again in December Mr. Pearce worked with members of the Maryland Archeological Society in excavations on the Morgan pottery site in Baltimore, a site which dates from the late colonial period. They were fortunate to find in one pit a layer rich with pottery sherds (possibly a working floor) between the undisturbed subsoil and a sealing layer of relatively clean sand, presumably fill. Very few pottery fragments other than those of local stoneware were found in the test-hole portion of this layer, but all of those which were found were datable as within the period of operation of the pottery (1794–1837).

Mr. Pearce and Mr. Muzzrole also conducted archeological excavations during May on the site of the early 18th-century City Tavern building in Annapolis. In locating the major foundation they identified four (possibly five) periods of building and found builder's trenches of about 1780 containing cultural materials which after study will make quite accurate dating possible.

At the beginning of the year, through the courtesy of E. B. Tucker and the government of Bermuda, Mendel L. Peterson, head curator of Armed Forces history, and Alan B. Albright, museum technician, collected a number of significant artifacts from underwater sites in the Bermuda reefs dating from 1595 through 1838. The earliest site yielded a rare pewter porringer. The site of the *San Antonio*, a Spanish ship which sank in 1621, yielded more ordnance materials and traces of trade goods. The site of the *Eagle*, a Virginia Company ship which went down in 1658, produced clay pipes, a soapstone bullet mold, and a solid iron shot for the ship's main battery. The site of *L'Herminie*, a French frigate which sank in 1838, was extensively explored, and from it were collected glass and unmarked porcelain from the wardroom services and a collection of perfect bottles, including those for brandy, wine, oil, and clarified olive oil, with the seal of the merchant.

Frank A. Taylor, director, attended the Sixth General Conference of the International Council of Museums at The Hague, July 2–11, 1963, where he was elected president of the International Committee of ICOM for Museums of Science and Technology. He visited museums in Italy, Switzerland, Germany, Holland, and England.

EXHIBITIONS

Highlights in the exhibits program during the year were the reopening of three large halls of modernized exhibits in the Museum of Natural History and the beginning of the installation of exhibits in the new Museum of History and Technology. With the opening of the second hall of North American archeology, the hall of life in the sea, and the hall of dinosaurs and fossil reptiles, all but three of the galleries on the first floor of the Museum of Natural History have now been modernized. At the end of the year installation of exhibits in four halls of the new Museum of History and Technology began while the construction of exhibits continued. Exhibit units for 15 of the halls in the new museum were prepared.

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The new hall of North American archeology includes 38 modernized displays. An introductory section of several units explains the objectives and dating methods of systematic archeology; most of the rest of the hall is devoted to displays of the cultures of Indian groups in various regions of the United States. Curator Waldo R. Wedel prepared the scripts and selected the specimens for this hall with the expert assistance of Dr. C. G. Holland and Dr. W. A. Ritchie. The hall was designed by Ray Hayes and Mrs. Barbara Craig.

Plans for the layout of the new hall of Old World archeology were completed by associate curator Gus Van Beek and exhibits designer R. O. Hower. This gallery will present a synopsis of Old World cultural history from earliest times to the end of the Roman Era.

Contract renovation for the new hall of physical anthropology began on March 30. Exhibits designer Joseph Shannon and director T. D. Stewart, while still head curator of the department of anthropology, completed the plan for the new hall layout and the arrangement of cases. Dr. Stewart prepared detailed scripts for 14 of the exhibits and Dr. Angel completed the specifications for a large map of the peoples of the world.

The new hall entitled "Life in the Sea" was officially opened to the public in February. The most impressive single exhibit here is the life-size blue whale prepared under the direction of Dr. Remington Kellogg, recently retired Assistant Secretary of the Smithsonian Institution. Other mammals depicted include the sea otter, several kinds of porpoises, and five other species of whales. A group of six jellyfishes and comb-jellies is shown by means of eight superimposed reverse-carved sheets of Plexiglas; side lighting provides very lifelike qualities. A central alcove in the hall will eventually display deep-sea views, but an exceptionally fine temporary exhibit now occupies this space. In each of the openings in the alcove, shells are presented in a gemlike display which attracts much favorable attention. Among the other temporary installations is an exhibit of 137 species of mollusks found in Polynesia, the Eastern Pacific region, and along our Atlantic coast. This and the other temporary exhibits in the hall will be replaced as rapidly as the permanent exhibit materials can be installed. The hall has been developed under the direction of Dr. Fenner A. Chace, Jr., in cooperation with exhibits designers Thomas Baker, Chris Karras, and Gorman Bond.

Construction in the halls of comparative osteology and cold-blooded vertebrates was virtually completed at the end of the year. Most of the bird and small-mammal skeletons to be exhibited in the hall of osteology were cleaned and restored by Leonard Blush of the taxidermy staff. Dr. Leonard P. Schultz is directing the development of the hall of cold-blooded vertebrates, and scripts for more than half of the units have been prepared. Several casts of fishes were repaired, and one cast of a record-size 12-foot white sturgeon was produced by John Widener for the case on ancient fishes. This cast was prepared from a specimen obtained through the cooperation of Dr. Murray A. Newman, curator of the Vancouver Public Aquarium.

All curators in the department of zoology participated in the planning and development of a temporary exhibit entitled "Zoology in the Smithsonian Institution" for viewing during the XVI International Congress of Zoology, meeting in Washington during August 1963.

A detailed statement of the purpose and scale for each unit in the future hall of plant life was prepared as a basis for more precise planning of the exhibits in this large gallery. Specifications for models in the rainforest life group were prepared and some of the models made. Early in 1963 a field party spent 5 weeks in the desert of Baja California, Mexico, collecting data and materials for the construction of a desert life group. Dr. R. S. Cowan, assistant director for the Museum of Natural History, led the party and served as technical adviser and photographer; Paul Marchand and Vernon R. Rickman worked together to prepare models, molds, sketches, and other exhibit items. The work of the field party was greatly facilitated by the use of the Vermilion Sea Field Station maintained on the east coast of the peninsula by the San Diego Natural History Museum.

The large modernized hall of dinosaurs and other fossil reptiles was opened to the public in June. The dominance of the dinosaurs in the terrestrial fauna of the Age of Reptiles is illustrated by displays representing all major groups of dinosaurs. Examples range in size from one which had an arm bone 6 feet long to a tiny beast with a thigh bone smaller than that of a chicken. Many of the specimens were collected during the early U.S. Geological Survey explorations associated with the opening of the West between 1870 and 1895. Also displayed in this hall are reptiles from which mammals evolved. These animals apparently were never abundant in the United States, and the exhibited fossils were collected recently in South Africa. The displays of fossil reptiles are related to exhibits of fossil invertebrates, fishes, and mammals in adjoining halls, so that the visitor can follow the history of life from its earliest traces almost to the present. Dr. Nicholas Hotton III, associate curator of vertebrate paleontology, planned the exhibits for the hall with the assistance of exhibits designers Ann Karras and Barbara Craig. Preparation has begun on four dioramas for exhibit on the balcony in the hall of dinosaurs. Using the scale of 1 inch to 1 foot, Jay N. Matternes and Norman Deaton will prepare these dioramas to depict land vertebrates of the

Upper Triassic, the Upper Jurassic, and the Upper Cretaceous, and the sea vertebrates of the Upper Cretaceous. Mr. Matternes completed the third mural painting, for the age of mammals hall, which depicts terrestrial life during the Oligocene in North America. Specifications were prepared for the fourth mural in the hall which will represent animal assemblages in the Pliocene Epoch.

Eight new exhibits to be displayed in the halls of medicine, dentistry, and pharmacy in the new Museum of History and Technology were temporarily installed in the gallery of medical sciences in the Arts and Industries Building; these include units on the development of the microscope, medical and dental equipment, and crude drugs. Exhibits planned or prepared to portray various phases of the history of medicine include a diorama showing the performance of an operation in about the year 1805, the corner of a ward in the Massachusetts General Hospital as it appeared in 1875, and a dental office in Illinois during the period 1912–20. Most of the units have now been designed and produced for these halls under the direction of Dr. Sami K. Hamarneh.

Exhibits for the hall of tools, planned by curator Silvio A. Bedini in cooperation with exhibits designer Harry Hart, neared completion in the exhibits laboratory. Displays of the handtools of the blacksmith, cooper, wheelwright, pump log maker, and woodworking trades were in the designing stage. In mid-June artist R. McGill Mackall of Baltimore installed the first unit in the new hall of tools—a large background painting showing skilled workmen fabricating marine propellers. An exhibit of a mid-19th-century machine shop was moved to the new building and will be erected early in the summer.

The production of exhibits for the civil-engineering hall neared completion with the construction of a series of wooden arches illustrating the American, Austrian, and English systems of tunnel timbering. The Bethelhem Steel Co. fabricated especially for this hall a cast-iron tunnel segment 10 feet in diameter, such as is used for lining tunnels through soft soil. The technical direction of this hall is the responsibility of associate curator Robert M. Vogel, with exhibits designers John Brown and Harry Hart providing the design of individual exhibits.

In preparation for developing the exhibits in the future hall of electricity, associate curator Bernard Finn made a study of the electrical exhibits in the museums of Europe. Substantial progress was made in the design of exhibits in the first third of the hall, devoted to wired communications and power.

At the end of the year, the Pioneer locomotive of 1851 joined the historic engines, coaches, and streetcars now assembled in the railroad hall in the new Museum of History and Technology. These large, full-scale exhibits will be complemented by a series of models and specimens of equipment which will trace the history of railroads and street railways in the United States. Associate curator John H. White and exhibits designer Virginia Mahoney collaborated in the development and design of this hall.

Curator Paul V. Gardner is revising his plans for the hall of ceramics in order to include important specimens received during the year. Recently acquired 18th-century German and English porcelains, from several donors, were placed on exhibition in the Museum of Natural History.

The American Petroleum Institute continued to render valuable assistance in the planning of exhibits for the new hall of petroleum. A model of the first fluid catalytic cracking plant, which began operation at Baton Rouge, La., in May 1942 to produce high-octane gasoline for the United States and its allies in World War II, was placed on exhibit in the present petroleum hall.

The 50th anniversary of the establishment of the collection of dresses of the First Ladies of the White House was marked by the installation of the Inaugural Ball gown and cape of Mrs. John F. Kennedy. The project of making the mannequins of the First Ladies appear more lifelike has continued. The application of natural flesh tints to the features of more than half of the group has been completed.

Exhibits for the hall of historic Americans, planned by curator Wilcomb E. Washburn in cooperation with exhibits designer Robert Widder, were nearing completion at the end of the year. Assistant curator Anne W. Murray continued to direct the fitting of historic women's dresses and men's suits on the mannequins to be exhibited in the hall of American costume. A series of 4 introductory panels has been designed and 15 exhibits completed for this hall.

The exhibits in the cultural history hall in the Museum of Natural History were dismantled for transfer to the new Museum of History and Technology. The woodwork and fireplaces of the period rooms were carefully disassembled and moved to the new building. Twenty-five exhibits have been produced for the new hall of everday life in the American past, among them a series of units illustrating the influences upon early American home furnishings of cultural elements imported by Spanish, French, British, Dutch, Flemish, German, and Scandinavian settlers. Installation of this hall is under the direction of curator C. Malcolm Watkins, and exhibits chief John E. Anglim designed the exhibits with the assistance of Deborah Bretzfelder.

A difficult operation was successfully accomplished with the removal of Horatio Greenough's statue of George Washington from the chapel of the Smithsonian Building to the central corridor of the second floor of the Museum of History and Technology, where it stands at the entrance to the series of halls which will interpret the growth of the United States. Exhibits scripts for three of the five halls illustrating this growth were prepared by associate curator Peter Welsh in collaboration with Dr. Anthony N. B. Garvan, chairman of the Department of American Civilization, University of Pennsylvania. Exhibits designers Robert Widder and Nadya Kayaloff prepared detailed designs for many of the units in the two halls of this series. George Watson restored an 18-century Pennsylvania waterwheel and gear-train which will illustrate the ingenuity and skill of the colonial millwright and demonstrate the use and transmission of power in his time.

The production of exhibits for the hall of philately was begun, and 18 units have been completed. Associate curator Francis J. McCall and assistant curator Carl H. Scheele prepared the scripts for several series of exhibits in the hall devoted to the history of postal services in this country and abroad, methods of postal transportation, mail metering devices, and the design and production of U.S. stamps. Exhibits designer John Clendening is preparing the detailed layouts for these units.

The history of the Armed Forces of the United States in war and peace is the subject of a series of exhibits in the new Museum of History and Technology; curator of military history Edgar M. Howell, curator of naval history Philip K. Lundeberg, and associate curator of naval history Melvin H. Jackson continued to write scripts and provide technical supervision for the design and production of these exhibits. A striking series of models of militarily historic ships was produced during the year. Other exhibits produced depict the role of the Army in the Mexican War, in frontier service during the middle 19th century, and in the Civil War, and the service of the Navy in the Mexican and Civil Wars. Exhibits designer Fred Craig designed the units for these halls.

Design and production of exhibit units for the hall of ordnance are largely completed. Associate curator Craddock H. Goins supplied technical direction for the exhibits, the design of which was contributed by exhibits designer John Brown. Among these is included an interpretation of the interchangeable-parts system of manufacturing, a significant development in the history of firearms. Other units trace the development of naval artillery and naval guns and relate the history of tanks and armored warfare. Dr. Lundeberg prepared detailed specifications for those units concerned with the original Continental gunboat *Philadelphia*, which include original items of equipment recovered with the gunboat itself from the waters of Lake Champlain and graphic materials which help to explain the battle of Valcour Island on October 11, 1776, in which this gunboat participated.

Mr. Howell continued supervision of the preparation of the Star-Spangled Banner for exhibition in the central rotunda of the new building. Skilled seamstresses have sewed tapes to the flag backing to support this great national treasure in its new location.

Following his appointment to the directorship of the Museum of Natural History, Dr. T. Dale Stewart assumed the chairmanship of the committee coordinating and supervising the modernization of exhibits in natural history; he also continued planning and development of the new hall of physical anthropology. In addition to planning for the future hall of plant life, Dr. R. S. Cowan, assistant director, coordinated the work of the curators and the exhibits staff involved in preparing exhibits for the Museum of Natural History.

Exhibits chief John E. Anglim continued in charge of the planning and preparation of all exhibits and directly supervised the operation of the exhibit laboratory in the Natural History Building. In June, A. Gilbert Wright joined the staff of that laboratory to assist in its supervision. Julius Tretick supervised the production and installation of natural history exhibits.

The installation of exhibits in four halls of the Museum of History and Technology was initiated late in the year. Exhibit units were prepared for 15 of the halls in the new museum during the past year, and 2 other halls were in the design stage. Assistant director John C. Ewers continued to coordinate the work of curators and exhibits staffs for the new museum. Benjamin W. Lawless supervised the design and production of exhibits for this museum, as well as the preparation of additional displays for the Air and Space Building. He was assisted by Bela S. Bory in production, Robert Klinger in the model shop, and Robert Widder in design. Carroll Lusk entered on duty as exhibits lighting specialist in January. The editing of the curators' drafts of exhibits scripts was continued by George Weiner, with the assistance of Constance Minkin and Edna Wright.

DOCENT SERVICE

For the ninth consecutive year the Junior League of Washington continued its volunteer docent program, conducting school classes from the greater Washington area through the Smithsonian museums. The program was carried out through the cooperation of curator G. Carrol Lindsay, Smithsonian Museum Service, with Mrs. Vernon Knight, chairman of the League's docent committee, and Mrs. Dickson R. Loos, cochairman. Mrs. Loos will serve as chairman for the forthcoming year, with Mrs. Arnold B. McKinnon as cochairman.

During the 1962–63 school year 22,393 children were conducted on 783 tours, representing an increase of 8 percent over the previous year's participation. Since the beginning of the tour program in 1955, more than 100,000 schoolchildren have been guided through Smithsonian museum halls by the Junior League docents.

Tours were conducted in the halls of everyday life in America, Indians of the Americas, the world of mammals, and textiles, for grades 3 through 6; and in the halls of gems and minerals, and power machinery, for grades 5 through junior high school. Tours in the everyday life in early America hall stopped at the end of November so that the exhibit could be moved to the new Museum of History and Technology. The Junior League has guided approximately 22,500 schoolchildren through this hall since it opened in 1957. To replace the early America tour, a new tour through the hall of the world of mammals was offered beginning January 14, 1963. Four tours each day, 5 days a week, were offered every half hour from 10 through 11:30 a.m. in the halls of everyday life in early America, Indians of the Americas, and the world of mammals. Tours in the halls of gems and minerals, textiles, and power machinery were conducted on Monday through Friday at 10 and 11 a.m.

Tours were conducted from October 1, 1962, through May 28, 1963, with the exception of the month of April 1963, when, as usual, tours were suspended because of the exceedingly heavy visitor traffic in all museum halls during the Easter and cherryblossom seasons. The great number of visitors to the Smithsonian museums during the early spring so overcrowd the exhibition halls that the school tours cannot be conducted satisfactorily.

In addition to Mrs. Knight and Mrs. Loos, the members of the League's docent committee were:

Mrs. A. Stuart Baldwin, Mrs. Thad H. Brown, Jr., Mrs. Challen E. Caskie, Mrs. Thomas R. Cate, Mrs. Dean B. Cowie, Mrs, Henry M. deButts, Mrs. Lee M. Folger, Mrs. Rockwood Foster, Mrs. Clark Gearhart, Mrs. George Gerber, Mrs. Gilbert Grosvenor, Mrs. Robert H. Harwood, Mrs. Walter M. Johnson, Jr., Mrs. Charles J. Kelly, Jr., Mrs. Lansing Lamont, Mrs. J. H. Lasley, Mrs. Peter Macdonald, Mrs. John Manfuso, Jr., Mrs. Samuel D. Marsh, Mrs. Earnest May, Mrs. Alexander McClure, Mrs. Robert McCormick, Mrs. Arnold B. McKinnon, Mrs. H. Roemer McPhee, Jr., Mrs. William Minshall, Jr., Mrs. L. Edgar Prina, Mrs. Arthur W. Robinson, Mrs. Donald M. Rogers, Mrs. Robert E. Rogers, Mrs. W. James Sears, Mrs. Walter Slowinski, Mrs. Joseph Smith, Jr., Mrs. James H. Stallings, Jr., Mrs. E. Tilman Stirling, Mrs. William R. Stratton, Mrs. Richard Wallis, and Mrs. Mark A. White.

The Institution deeply appreciates the able and devoted efforts of these volunteers, whose services to the schools of the Washington area encourage effective use of the Smithsonian museum exhibits by teachers and students alike.

BUILDINGS AND EQUIPMENT

During the year the new east wing of the Natural History Building was completed, and the department of geology and the divisions of birds and mollusks moved into their new quarters. For the first time in many years these units have adequate workrooms and laboratories as well as sufficient space in which to arrange the systematic reference collections for the most effective service to the scientists who employ these unduplicated materials in essential research. The contract for the construction of the west wing and the remaining required renovation of the existing building had not been awarded at the close of the year.

In May 1963, the General Services Administration accepted a limited area of the new Museum of History and Technology Building from the general contractor. Exhibits for a number of halls in this area have been moved to the building, and at the end of the year installations were proceeding in several halls concurrently. At the close of the year the construction of the building was estimated to be 98 percent complete.

CHANGES IN ORGANIZATION AND STAFF

Upon the retirement of Dr. A. Remington Kellogg on October 31, 1962, as director of the United States National Museum and as Assistant Secretary of the Smithsonian Institution, Dr. Albert C. Smith, then director of the Museum of Natural History, was appointed Assistant Secretary. Frank A. Taylor became the director of the United States National Museum in addition to being director of the Museum of History and Technology.

On March 26, 1963, Mr. Taylor received one of the 10 National Civil Service League's career service awards for 1963.

On November 1, 1962, Dr. T. Dale Stewart, head curator of anthropology, became director of the Museum of Natural History. On December 9, 1962, Dr. Richard S. Cowan was appointed assistant director of the Museum of Natural History. Dr. I. E. Wallen, formerly associated with the Atomic Energy Commission, was appointed assistant director for oceanography on August 5, 1962.

During the fiscal year 1963, the following appointments were made to the scientific staff of the Museum of Natural History: Dr. Paul J. Spangler, associate curator of insects, on July 8; George E. Watson, assistant curator of birds, on August 6; Dr. Donald Duckworth, associate curator of insects, on August 19; Dr. Victor G. Springer, associate curator of fishes, on August 28; Dr. J. Lawrence Angel, curator of physical anthropology, on September 4; Stanywn G. Shetler, assistant curator of phanerogams, on September 4; Dr. Harold E. Robinson, associate curator of cryptogams, on October 15; Dr. Richard H. Eyde, associate curator of plant anatomy, on October 18; Dr. Francis M. Hueber, associate curator of invertebrate paleontology and paleobotany, on November 1; Dr. Richard E. Norris, associate curator of cryptogams, on December 4; Dr. Stanley H. Weitzman, associate curator of fishes, on January 2; Dr. Robert H. Gibbs, Jr., associate curator of fishes, on January 30; Dr. Marian H. Pettibone, associate curator of marine invertebrates, on March 4; Dr. Martin A. Buzas, associate curator of invertebrate paleontology and paleobotany, on June 5; Dr. Herman A. Fehlmann, supervisor of the Smithsonian Oceanographic Sorting Center, on June 17; Dr. Raymond B. Manning, associate curator of marine invertebrates, on June 24.

Dr. David H. Dunkle was reinstated in his position of associate curator of vertebrate paleontology on December 16, 1962, after an absence of 2 years with the U.S. Geological Survey on assignment to Pakistan.

Dr. Marshall T. Newman, associate curator of physical anthropology since 1942, resigned on July 6, 1962, to accept a teaching position at Portland State College in Oregon.

Dr. Robert E. Snodgrass, honorary collaborator since 1953 and one of the world's leading scholars in insect anatomy and morphology, died September 4, 1962, at the age of 87. At the time of his death he was preparing a handbook of insect morphology for students. His major work, *Principles of Insect Morphology*, published in 1935, stands as a basic text in the field. On the occasion of his 84th birthday in 1959 a special volume of the Smithsonian Miscellaneous Collections, entitled *Studies in Invertebrate Morphology*, was published in his honor. In 1961 he was awarded the Leidy Medal by the Academy of Natural Sciences of Philadelphia.

Among the additions to the staff of the Museum of History and Technology were the appointments of Dr. Bernard S. Finn as associate curator in charge of the division of electricity on August 20, 1962, and J. Jefferson Miller II as assistant curator in the division of ceramics and glass on September 17, 1962. Miss Barbara F. Bode was appointed junior curator in the division of numismatics on September 24, 1962. A. Gilbert Wright became assistant chief of the Natural History Exhibits Laboratory on June 2, 1963, coming to the Smithsonian Institution from the National Park Service.

George T. Turner, associate curator in the division of philately, left the Museum of History and Technology on March 1, 1963, and Dr. Charles O. Houston, Jr., associate curator in the division of manufactures and heavy industries, on March 8. Dr. Lester C. Lewis, curator of the division of physical sciences, resigned on April 12, 1963. Joseph E. Rudmann of the office of head curator, department of science and technology, transferred to a position elsewhere, effective May 10, 1963.

Respectfully submitted.

FRANK A. TAYLOR, *Director*.

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the International Exchange Service

Sir: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1963:

The original plan of organization of the Smithsonian Institution, presented to the Board of Regents by Joseph Henry in 1847, provided for a system of exchange of current Smithsonian publications which would afford the Smithsonian Institution the most ready means of entering into friendly relations and correspondence with all the learned societies in the world and of enriching the Smithsonian Library with the current transactions and proceedings of foreign institutions.

When the first of the Smithsonian's long series of scientific publications was published, copies were sent to scientific and learned institutions in foreign countries. In return, the Smithsonian Institution received many valuable publications from foreign institutions. To continue this desirable international exchange of scientific information, the Smithsonian Institution appointed agents in a number of foreign countries to distribute the Smithsonian publications. In return, these agents received publications from foreign organizations which were forwarded to the Smithsonian Institution.

In 1851 the privilege of transmitting publications through the Smithsonian Institution to other countries, and to receive in return publications from foreign institutions, was offered to governmental agencies, learned societies, and individuals in the United States. This opportunity for wide distribution of scientific publications was eagerly grasped and the system grew rapidly. Thus began a Smithsonian service that has increased steadily in usefulness, and the quantity of material handled has increased from a few hundred packages of publications transmitted in 1849 to more than a million packages during the last fiscal year.

In 1867 Congress provided that copies of all documents thereafter printed by order of either House be placed at the disposal of the Joint Committee on the Library to be exchanged through the agency of the Smithsonian Institution. This was the first official recognition of the Smithsonian exchange system. In 1875 there began a series of international meetings which led to the adoption, in 1886, of the Brussels Convention for the international exchange of literary and scientific publications, as well as for the exchange of governmental documents. The State Department requested the Smithsonian Institution to assume the responsibility of establishing in the United States a bureau of exchange to carry out the purposes of the Brussels Convention. The Board of Regents of the Smithsonian Institution agreed to accept this responsibility, and the Smithsonian Institution has continued to carry out these functions up to the present time.

The work of the International Exchange Service serves as a means of developing and executing, in part, the broad and comprehensive objective of the Smithsonian Institution, "the diffusion of knowledge." Over the years the operations of the Service have affected most beneficially the libraries of all learned institutions in the United States and have helped to promote the rapid growth of science through facilitating the international exchange of ideas. Libraries throughout the world have been enriched by the publications received through the Service from many institutions in the United States and, in turn, the libraries of the United States have benefited from the publications received from the institutions in foreign countries.

The Service operates in this manner: Libraries, scientific societies, educational institutions, and individuals in the United States who wish to transmit their publications through the Service to foreign countries, on exchange or as gifts, advise the International Exchange Service of the names and addresses of the foreign organizations to which they wish to transmit their publications, and the general character and approximate weight of the publications they wish to send. If the publications are accepted for transmission, packing and shipping instructions are furnished the sender. The transportation charges to the Smithsonian Institution must be prepaid, but there is no charge to the sender for the cost of transportation from the Smithsonian Institution to the intended addressees. Publications transmitted through the Service must be packaged and addressed by the senders.

Shipments of addressed packages of publications are received by the International Exchange Service from foreign exchange bureaus for distribution in the United States. These packages are forwarded to the domestic addressees whose names and addresses appear on the packages. Addressed packages of publications weighing 111,609 pounds were received during the past year from foreign sources for distribution in the United States.

Publications weighing 796,622 pounds were received by the International Exchange Service during the year from approximately 250 domestic sources for transmission to intended recipients in over 100 foreign countries.

Packages of publications are mailed directly to the addressees in the countries that do not have exchange bureaus. During the past fiscal year the International Exchange Service mailed directly to the intended recipients in foreign countries addressed packages of publications weighing 225,689 pounds, or 28 percent of the total poundage received, at a cost to the Smithsonian Institution of $51,604.18, or approximately 23 cents per pound.

The Service transmitted by ocean freight addressed packages of publications weighing 562,301 pounds, or 71 percent of the total poundage received, to foreign exchange bureaus for distribution in their respective countries. The cost to the Smithsonian Institution for forwarding these publications was $33,843.44, or approximately 6 cents per pound. Listed below are the names of the foreign exchange bureaus to which the International Exchange Service forwards addressed packages of publications for distribution.

LIST OF EXCHANGE SERVICES

AUSTRIA: Austrian National Library, Vienna.

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

CHINA: National Central Library, Taipei, Taiwan.

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

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

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

FINLAND: Library of the Scientific Societies, Helsinki.

FRANCE: Service des Échanges Internationaux, Bibliothèque Nationale, Paris.

GERMANY (Eastern): Deutsche Staatsbibliothek, Berlin.

GERMANY (Western): Deutsche Forschungsgemeinschaft, Bad Godesberg.

HUNGARY: Service Hongrois des Échanges Internationaux, Országos Széchenyi Konyvtár, Budapest.

INDIA: Government Printing and Stationery Office, Bombay.

INDONESIA: Minister of Education, Djakarta.

ISRAEL: Jewish National and University Library, Jerusalem.

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

JAPAN: Division for Interlibrary Services, National Diet Library, Tokyo.

KOREA: Korean Library Association, Seoul.

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: Servico Português de Trocas Internacionais, Biblioteca Nacional, Lisbon.

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

RUMANIA: International Exchange Service, Biblioteca Centrala de Stat, Bucharest.

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, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

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

TASMANIA: Secretary of the Premier, Hobart.

TURKEY: National Library, Ankara.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town.

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

VICTORIA: State Library of Victoria, Melbourne.

WESTERN AUSTRALIA: State Library, Perth.

YUGOSLAVIA: Bibliografski Institut FNRJ, Belgrade.

FOREIGN EXCHANGE OF GOVERNMENTAL DOCUMENTS

In accordance with treaty stipulations, conventions, and other agreements made between the United States and various foreign countries for the mutual exchange of official publications, the Smithsonian Institution transmits to the foreign recipients the official U.S. Government publications. The libraries that receive copies of all of the official publications are the recipients of the full sets of Government documents. The libraries that receive a selected list are the recipients of the partial sets of Government documents. During the fiscal year 632,922 pieces weighing 220,700 pounds were received by the Smithsonian Institution for transmission to the recipients of the full sets, and 74,951 pieces weighing 34,834 pounds were received for transmission to the recipients of the partial sets.

RECIPIENTS OF THE FULL SETS

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

AUSTRALIA: Commonwealth 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: State Library of Victoria, Melbourne.
- WESTERN AUSTRALIA: State Library, Perth.

AUSTRIA: Administrative Library, Federal Chancellery, Vienna.

BELGIUM: Service Belge des Échanges Internationaux, Bruxelles.[1]

BRAZIL: Biblioteca Nacional, Rio de Janeiro.

BURMA: Government Book Depot, Rangoon.

See footnotes, p. 72.

CANADA: Library of Parliament, Ottawa.
- MANITOBA: Provincial Library, Winnipeg.
- ONTARIO: Legislative Library, Toronto.
- QUEBEC: Library of the Legislature of the Province of Quebec.
- SASKATCHEWAN: Legislative Library, Regina.[1]

CEYLON: Department of Information, Government of Ceylon, Colombo.
CHILE: Biblioteca Nacional, Santiago.
CHINA: National Central Library, Taipei, Taiwan.
- National Chengchi University, Taipei, Taiwan.

COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Biblioteca Nacional, San José.
CUBA: Dirección de Organismos Internacionales, Ministerio de Relaciones Exteriores, Habana.
CZECHOSLOVAKIA: University Library, Prague.
DENMARK: Institut Danois des Échanges Internationaux, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Staatsbibliothek, Berlin.
- Free University of Berlin, Berlin-Dahlem.
- Parliamentary Library, Bonn.

GREAT BRITAIN:
- British Museum, London.
- London School of Economics and Political Science. (Depository of the London County Council.)

INDIA: National Library, Calcutta.
- Central Secretariat Library, New Delhi.
- Parliament Library, New Delhi.

INDONESIA: Ministry for Foreign Affairs, Djakarta.
IRELAND: National Library of Ireland, Dublin.
ISRAEL: State Archives and Library, Hakirya, Jerusalem.
ITALY: Ministero della Pubblica Istruzione, Rome.
JAPAN: National Diet Library, Tokyo.[2]
MEXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, México, D.F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Utenriksdepartmentets Bibliothek, Oslo.
PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.
PORTUGAL: Biblioteca Nacional, Lisbon.
SPAIN: Biblioteca Nacional, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: National Library, Ankara.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow.
UNITED NATIONS: Library of the United Nations, Geneva, Switzerland.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Bibliografski Institut FNRJ, Belgrade.[2]

See footnotes, p. 72.

RECIPIENTS OF THE PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.
BELGIUM: Bibliothèque Royale, Bruxelles.
BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.
BRAZIL: MINAS GERAIS: Departmento Estadul de Estatística, Belo Horizonte.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
CAMBODIA: Les Archives et Bibliotheque Nationale, Phnom-Penh.[1]
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.
DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Santo Domingo.
ECUADOR: Biblioteca Nacional, Quito.
EL SALVADOR:
  Biblioteca Nacional, San Salvador.
  Ministerio de Relaciones Exteriores, San Salvador.
GREECE: National Library, Athens.
GUATEMALA: Biblioteca Nacional, Guatemala.
HAITI: Bibliothèque Nationale, Port-au-Prince.
HONDURAS:
  Biblioteca Nacional, Tegucigalpa.
  Ministerio de Relaciones Exteriores, Tegucigalpa.
ICELAND: National Library, Reykjavik.
INDIA:
  BOMBAY: Sachivalaya Central Library, Bombay.[3]
  BIHAR: Revenue Department, Patna.
  KERALA: Kerala Legislature Secretariat, Trivandrum.
  UTTAR PRADESH:
    University of Allahabad, Allahabad.
    Secretariat Library, 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, Valletta.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
PAKISTAN: Central Secretariat Library, Karachi.
PANAMA: Ministerio de Relaciones Exteriores, Panamá.
PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.
PHILIPPINES: House of Representatives, Manila.
SCOTLAND: National Library of Scotland, Edinburgh.

See footnotes, p. 72.

SINGAPORE: Chief Secretary, Government Offices, Singapore.
SUDAN: Gordon Memorial College, Khartoum.
THAILAND: National Library, Bangkok.
VIETNAM: Direction des Archives et Bibliothèques Nationales, Saigon.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNALS

There are being sent abroad through the International Exchange Service 87 copies of the daily issues of the Federal Register and 105 copies of the daily issues of the Congressional Record. The names and addresses of the recipients of the official journals are listed below:

RECIPIENTS OF THE CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:
- Biblioteca del Poder Judicial, Mendoza.[5]
- Dirección General del Boletin Oficial e Imprentas, Buenos Aires.
- Cámara de Diputados Oficina de Información Parliamentaria, Buenos Aires.

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

BASUTOLAND: Clerk to the Legislative Council, Maseru.[1,4]
BELGIUM, Bibliothèque du Parlement, Palais de la Nation, Brussels.[4]

BRAZIL:
- Biblioteca da Câmara dos Deputados, Brasília, D.F.[4]
- Secretaria da Presidencia, Rio de Janeiro.[4]

BRITISH HONDURAS: Colonial Secretary, Belize.
CAMBODIA: Ministry of Information, Phnom Penh.
CAMEROON: Imprimerie Nationale, Yaoundé.[1,5]

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

CEYLON: Ceylon Ministry of Defense and External Affairs, Colombo.[4]
CHILE: Biblioteca del Congreso Nacional, Santiago.[4]

CHINA:
- Legislative Yuan, Taipei, Taiwan.[4]
- Taiwan Provincial Government, Taipei, Taiwan.

CUBA:
- Biblioteca del Capitolio, Habana.
- Biblioteca Pública Panamericana, Habana.[5]

CZECHOSLOVAKIA: Ceskoslovenska Akademie Ved. Prague.[4]
EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.[4]
FINLAND: Library of the Parliament, Helsinki.[4]

FRANCE:
- Bibliothèque Assemblée Nationale, Paris.
- Bibliothèque Conseil de la République, Paris.
- Library, Organization for European Economic Cooperation, Paris.[4]
- Research Department, Council of Europe, Strasbourg.[4]
- Service de la Documentation Étrangère Assemblée Nationale, Paris.[4]

GABON: Secretary General, Assemblée Nationale, Libreville.[1,4]

See footnotes, p. 72.

GERMANY:
Amerika Institut der Universität München, München.[4]
Archiv, Deutscher Bundestag, Bonn.
Bibliothek des Instituts für Weltwirtschaft an der Universität Kiel, Kiel-Wik.
Bibliothek Hessischer Landtag, Wiesbaden.[4]
Deutsches Institut für Rechtswissenschaft, Potsdam-Babelsberg II.[5]
Deutscher Bundesrat, Bonn.[4]
Deutscher Bundestag, Bonn.[4]
Hamburgisches Welt-Wirtschafts-Archiv, Hamburg.
Westdeutsche Bibliothek, Marburg, Hessen.[4, 6]
GHANA: Chief Secretary's Office, Accra.[4]
GREAT BRITAIN:
Department of Printed Books, British Museum, London.
House of Commons Library, London.[4]
N.P.P. Warehouse, H.M. Stationery Office, London.[5, 6]
Printed Library of the Foreign Office, London.[4]
Royal Institute of International Affairs, London.[4]
GREECE: Bibliothèque Chambre des Députés, Hellênique, Athens.
GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.
HAITI: Bibliothèque Nationale, Port-au-Prince.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Országos Széchenyi Konyvtár, Budapest.
INDIA:
Civil Secretariat Library, Lucknow, United Provinces.[5]
Indian Council of World Affairs, New Delhi.[4]
Jammu and Kashmir Constituent Assembly, Srinagar.[4]
Legislative Assembly, Government of Assam, Shillong.[4]
Legislative Assembly Library, Lucknow, United Provinces.
Kerala Legislature Secretariat, Trivandrum.[4]
Madras State Legislature, Madras.[4]
Parliament Library, New Delhi.
Gokhale Institute of Politics and Economics, Poona.[4]
IRELAND: Dail Eireann, Dublin.
ISRAEL: Library of the Knesset, Jerusalem.
ITALY:
Biblioteca Camera dei Deputati, Rome.
Biblioteca del Senato della Republica, Rome.
International Institute for the Unification of Private Law, Rome.[5]
Periodicals Unit, Food and Agriculture Organization of the United Nations, Rome.[5]
JAPAN:
Library of the National Diet, Tokyo.
Ministry of Finance, Tokyo.
JORDAN: Parliament of the Hashemite Kingdom of Jordan, Amman.[4]
KOREA: Library, National Assembly, Seoul.
LUXEMBOURG: Assemblée Commune de la C.E.C.A., Luxembourg.
MEXICO:
Dirección. General Información, Secretaría de Governación, Mexico, 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.

See footnotes, p. 72.

MEXICO—Continued

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutiérrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.[5]

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, Palacio de Gobierno, Oaxaca.[5]

PUEBLA: Secretaría General de Gobierno, Puebla.

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

SINALOA: Gobernador del Estado de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

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

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NETHERLANDS: Koninklijke Bibliotheek, The Hague.[5]

NEW ZEALAND: General Assembly Library, Wellington.

NIGERIA: Office of the Clerk of the Legislature, Enugu.[1,4]

NORWAY: Library of the Norwegian Parliament, Oslo.

PAKISTAN: Secretary, Provincial Assembly West Pakistan, Lahore.[1,4]

PANAMA: Biblioteca Nacional, Panama City.[4]

PHILIPPINES: House of Representatives, Manila.

POLAND: Kancelaria Rady Panstwa, Biblioteka Sejmowa, Warsaw.

PORTUGUESE TIMOR: Repartição Central de Administração Civil, Dili.[5]

RHODESIA AND NYASALAND: Federal Assembly, Salisbury.[5]

RUMANIA: Biblioteca Centrala de Stat RPR, Bucharest.

SPAIN: Boletin Oficial del Estado, Presidencia del Gobierno, Madrid.[5]

SWEDEN: Universitetsbiblioteket, Uppsala.[4]

SWITZERLAND:

International Labour Office, Geneva.[5,7]

Library, United Nations, Geneva.

TANGANYIKA: Library, University College, Dar es Salaam.[1,4]

TOGO: Ministère d'État, de l'Interieur, de l'Information et de la Presse, Lome.

UNION OF SOUTH AFRICA:

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

TRANSVAAL: State Library, Pretoria.

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

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

YUGOSLAVIA: Bibliografski Institut FNRJ, Belgrade.[7]

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[1] Added during the year.
[2] Receives two sets.
[3] Change in name.
[4] Congressional Record only.
[5] Federal Register only.
[6] Three copies.
[7] Two copies.

The International Exchange Service accepts publications for transmission to addressees in all countries except to the mainland of China, North Korea, and Communist-controlled areas of Vietnam but will not accept packages of publications from domestic sources intended for addressees in the United States or in a territory subject to the jurisdiction of the United States.

The number and weight of the packages received from sources in the United States for transmission abroad, and the number and weight of packages received from foreign sources intended for domestic addressees, are classified in the accompanying table.

Classification	Received by the Smithsonian Institution for transmission			
	For transmission abroad		For distribution in the United States	
	Number of packages	Weight in pounds	Number of packages	Weight in pounds
U.S. parliamentary documents received for transmission abroad	715, 347	287, 664		
Publications received from foreign sources for U.S. parliamentary addressees			12, 568	14, 124
U.S. departmental documents received for transmission abroad	235, 396	253, 131		
Publications received from foreign sources for U.S. departmental addressees			4, 553	12, 090
Miscellaneous scientific and literary publications received for transmission abroad	191, 187	255, 827		
Miscellaneous scientific and literary publications received from abroad for distribution in the United States			47, 069	85, 395
Total	1, 141, 930	796, 622	64, 190	111, 609
Total packages received	1, 206, 120			
Total pounds received				908, 231

Respectfully submitted.

J. A. Collins, *Chief.*

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, 1963, conducted in accordance with the act of Congress of April 10, 1928, as amended August 22, 1949, which directs the Bureau "to continue independently or in cooperation anthropological researches among the American Indians and the natives of lands under the jurisdiction or protection of the United States and the excavation and preservation of archeologic remains."

SYSTEMATIC RESEARCHES

Dr. Frank H. H. Roberts, Jr., director of the Bureau, devoted most of the fiscal year to office duties and to general supervision of the activities of the Bureau and the River Basin Surveys.

Early in August, at the invitation of the Czechoslovak Academy of Sciences, Dr. Henry B. Collins, anthropologist, attended a meeting of the Permanent Council of the International Congress of Anthropological and Ethnological Sciences in Prague. Following the meetings the delegates were taken on a week's tour to visit ethnographic museums and inspect paleolithic and neolithic sites being excavated by Czech archeologists in Bohemia, Moravia, and Slovakia.

On November 9–10 Dr. Collins participated in a symposium on Prehistoric Man in the New World held at Rice University, Houston, Tex., in celebration of the 50th anniversary of the university. His paper, discussing the present status and problems of archeological research in the American Arctic and subarctic, together with those of the 16 other participants in the symposium, will appear in a volume to be published by the University of Chicago Press. Dr. Collins's paper "Bering Strait to Greenland," evaluating the results of recent archeological discoveries in the American Arctic and their bearing on the problem of the origin and relationships of Eskimo culture, was published in December 1962 in *Technical Paper No. 11, Arctic Institute of North America.* Another paper, "Stefansson as an Anthropologist," was published in the Stefansson memorial issue of *Polar Notes, No. 4.*

In December Dr. Collins was reelected to a 3-year term on the board of governors of the Arctic Institute of North America. He continued to serve as a member of the Institute's publications committee and as chairman of the directing committee which is responsible for preparation of the *Arctic Bibliography*, a reference work which summarizes and indexes the contents of scientific publications in all fields, and in all languages, pertaining to the Arctic and subarctic regions of the world. The material for Volume 11 of the bibliography, edited by Marie Tremaine, was delivered to the Government Printing Office in October 1962. Approximately 1,500 pages in size, it will contain abstracts in English of 6,607 publications, of which 2,990 are of books, monographs, and papers published in Russian, 2,638 in English, and 979 in Scandinavian, German, French, and other languages. American scientists and others interested in following the course of scientific research and economic and social developments in the northern parts of the Soviet Union find the bibliography a valuable source of information, including as it does English abstracts of Soviet publications on such widely varied subjects as acclimatization, acculturation, administration and government, aerial mapping and reconnaissance, agriculture, archeology, botany and zoology, construction, economic conditions, education, electric power, fishes and fisheries, forestry, geology and geophysics, hydrology, ice navigation, maps and mapping, meteorology, mineral resources, mines and mining, oceanography, paleontology, public health and medicine, petroleum, petrology, railroads, transportation, wildlife conservation and management, etc. Abstracts of anthropological publications have formed a substantial part of the *Arctic Bibliography* from the beginning of the project. An attempt has been made, with considerable success, to summarize and index the contents of every paper that has been written on the Eskimos of Siberia, Alaska, Canada, and Greenland; the Tlingit, Haida, and Tsimshian Indians of the Northwest Coast; the northern Athapaskans and Algonkians; and the native peoples of northern Eurasia.

The Arctic Institute's Russian translation project—*Anthropology of the North: Translations from Russian Sources*—which Dr. Collins organized in 1960, continued its operations under a renewed grant from the National Science Foundation and the editorship of Dr. Henry N. Michael. The third volume of the series, an English translation of the late M. G. Levin's definitive work on the anthropology of northeastern Asia (*Ethnic Origins of the Peoples of Northeastern Asia*), was published by the University of Toronto Press in May 1963. Additional translations of Russian publications on Arctic anthropology are in the course of preparation.

Dr. William C. Sturtevant attended the 35th International Congress of Americanists (Mexico City, August 19–25), the joint annual meetings of the American Indian Ethnohistoric Conference and the Conference on Iroquois Research (Albany, October 12–14), the 61st annual meeting of the American Anthropological Association (Chicago, November 15–18), and the annual meeting of the Central States Anthropological Society (Detroit, May 16–18). At the last he participated in a symposium on primitive art.

Dr. Sturtevant's time in Washington was devoted to continuing research on the Iroquois and Seminole, to preparation of a paper titled "Studies in Ethnoscience" which he presented at the Social Science Research Council's Conference on Transcultural Studies of Cognitive Systems (Mérida, Yucatán, April 17–20), and to his duties as book-review editor of the *American Anthropologist.* Papers by him were published in the *Florida Anthropologist* and in *Ethnohistory.*

In July Dr. Sturtevant spent about 2 weeks continuing ethnographic fieldwork among the Seneca-Cayuga of Oklahoma, which he had begun the previous summer. This research, supported by a grant from the American Philosophical Society, is providing data on the most extreme variant of Iroquois culture, particularly on religion and ceremonial aspects, which casts a new light on the relatively well-known culture of the modern Iroquois communities in New York and Ontario. In October Dr. Sturtevant spent a few days on the Six Nations Reserve in Ontario, observing an important Iroquois religious ceremony and making inquiries for comparison with his Oklahoma data. In addition to this fieldwork, Dr. Sturtevant conducted archival research on the Oklahoma Seneca-Cayuga in the Indian Archives Division of the Oklahoma Historical Society in Oklahoma City (July 23–24) and museum research on Florida Seminole and other eastern Indian material in the Milwaukee Public Museum (November 19–21) and in the College Museum of Hampton Institute, Hampton, Va. (June 8–9).

In November Dr. Robert M. Laughlin, ethnologist, began fieldwork in Chiapas, Mexico, where he collected and recorded ethnographic and linguistic materials, particularly myths and dreams, as well as numerous prayers, from the Tzotzil Indians of Zinacantan, Chiapas, and surrounding areas. A vocabulary of 2,200 items of the dialect of Zinacantan collected by Lore M. Colby in 1960 has been expanded to 4,000 by Dr. Laughlin. He recorded a series of 26 dreams in Tzotil from a Zinacantan informant. Because specific dream experiences determine the selection of shamans from the community and also provoke new religious feasts, it is expected that dreams will illuminate many aspects of Zinacantan world view. This material is being prepared for publication.

Dr. Laughlin utilized the results of a week of ethnographic research in the Huastec area of the States of San Luis Potosí and Veracruz, Mexico, in January 1963, to supplement library research for the preparation of the chapter "Huastec" for the *Handbook of*

Middle American Indians. Another chapter for the *Handbook*, entitled "Tzotzil," is in preparation. Dr. Laughlin returned to Washington in mid-May to check on data he had obtained in the field and to consult references in various libraries, and on June 14 left again for Mexico to continue his field studies.

RIVER BASIN SURVEYS

The River Basin Surveys, the unit of the Bureau of American Ethnology organized to cooperate 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 State and local institutions in the program for salvage archeology in areas to be flooded or otherwise destroyed by the construction of large dams, continued its activities. An increase in funds made possible an expansion of the program throughout the Missouri Basin. The investigations during 1962–63 were supported by a transfer of $271,000 from the National Park Service, a carryover of $64,498 Missouri Basin money, a grant of $7,285 from the Appalachian Power Co., and a carryover of $4,080 from an earlier contribution by the Idaho Power Co. The National Park Service funds were to support the investigations in the Missouri Basin, and the grant from the Appalachian Power Co. was to provide for archeological excavations along the Roanoke River in southern Virginia where the Smith Mountain Project is nearing completion. The balance from the Idaho Power Co. came from a grant originally made to conduct researches in the Hells Canyon Reservoir area along the Snake River, Idaho-Oregon, and the work this year was a continuation of that project. This particular investigation was carried on as a cooperative project between the River Basin Surveys and the Museum of Idaho State College at Pocatello. The grand total of funds available for the River Basin Surveys in 1962–63 was $346,863.

Activities in the field pertained, in large part, to surveys and excavations. Most of the work was concentrated in the digging or testing of sites but surveys were made in six new reservoir basins. Five of the new reservoirs were in Kansas; the sixth was in Nebraska. At the beginning of the fiscal year, nine excavating parties were in the field in the Missouri Basin and one survey party was operating in Montana. In September, digging was started in the Smith Mountain Reservoir area in southern Virginia, and in October a small group collected pollen samples from areas in western Nebraska. During February and early March one party excavated a site along the Chattahoochee River in Georgia. In May, a small group worked for a short period in South Dakota, while another made the reconnaissance of the six reservoirs previously mentioned. Also during May a party returned to the Smith Mountain area. During June, 11 parties began operations in the Missouri Basin and were fully occupied in the excavation program at the end of the fiscal year.

As of June 30, 1963, archeological surveys and excavations had been made, since the start of the salvage program, in a total of 264 reservoir areas located in 29 different States. Furthermore, two lock projects, four canal areas, and two watershed areas had also been examined. Since 1946, when the program got underway, 5,009 sites have been located and recorded; of that number, 1,175 were recommended for excavation or limited testing. Because of the conditions under which the salvage operations need to be conducted, complete excavations, except in the case of a few small sites, are rarely possible. Consequently, when the term "excavation" is used, it generally implies that only about 10 percent of a site was dug.

By the end of the year, 484 sites in 54 reservoir basins and one watershed area had either been tested or excavated to the degree where good information about them had been obtained. It has been the policy of the River Basin Surveys to dig in at least one example of the various kinds of sites reported in the preliminary surveys. The sites range in nature from those which were simple camping areas, occupied by early hunting and gathering Indians of about 10,000 years ago, to village remains left by historic Indians of the mid-19th century. In addition, the remains of frontier trading posts of European origin and of Army installations have also been examined. The results of the investigations have been incorporated in reports which have been published in various scientific journals, in the Bureau of American Ethnology Bulletins, and in the Miscellaneous Collections of the Smithsonian Institution. *River Basin Surveys Paper No. 25*, which constitutes *Bureau Bulletin 182*, pertaining to the work done in the John H. Kerr Reservoir Basin on the Roanoke River, Virginia-North Carolina, was published in October. *River Basin Surveys Papers Nos. 26–32*, which report on investigations in North Dakota, Montana, and Kansas, and comprise *Bulletin 185*, were released during June. Reports on other investigations in the two Dakotas and Kansas, consisting of *River Basin Surveys Papers 33–38*, constituting *Bulletin 189*, were sent to the Printing Office early in the fiscal year and will be ready for distribution shortly after the beginning of the new year. Various members of the staff cooperated with representatives of other Federal agencies in the preparation of short popular pamphlets about some of the major reservoir projects. These pamphlets were published by the cooperating agency and are distributed at the visitors' center for the reservoir concerned.

As in previous years, the River Basin Surveys received helpful cooperation from the National Park Service, the Bureau of Reclamation, the Corps of Engineers, the Geological Survey, and numerous State and local institutions. The party leaders were assisted in many ways by the field personnel of all the cooperating agencies, and the relationship was excellent in all areas. The National Park Service continued to serve as liaison between the various agencies, both in Washington and in the field. The Park Service also prepared the budget estimates and justifications for the funds needed to support the salvage program.

General direction and supervision of the program were continued by the main office in Washington. Work in the Missouri Basin was directed by the field headquarters and laboratory at Lincoln, Nebr. The projects in southern Virginia and Georgia were supervised by the Washington office.

Washington Office.—Dr. Frank H. H. Roberts, Jr., continued the direction of the main headquarters of the River Basin Surveys in the Bureau of American Ethnology throughout the year. Harold A. Huscher and Carl F. Miller, archeologists, were based at that office. Mr. Huscher had just returned from the Walter F. George Dam and Lock area on the Chattahoochee River below Columbus, Ga., at the beginning of the fiscal year. He remained in the office during the summer and fall months, working on the accumulating records and collections from the 4 preceding years. In November he attended the Southeastern Archeological Conference and the Conference on Historic Site Archeology at Mound State Park, Moundville, Ala., reading a report on the "Archaic of the Walter F. George Reservoir Area." On November 10 and 11, he attended the Eastern States Archeological Conference at Athens, Ga., reading a paper on "Generic Western Names Identifiable in the Southeast." On November 22–24, he participated in the 20th Annual Plains Conference at Lincoln, Nebr., where he discussed "Southern Athapaskan Names in Early Spanish Records." Early in February he returned to Georgia and completed emergency excavations at a site just south of the City of Columbus. In May he attended the joint meeting of the Society for American Archeology and the American Association of Physical Anthropologists at Boulder, Colo., reading a paper on "Intermontane Athapaskan Continuities." At the close of the fiscal year he was working on his materials from the Walter F. George Reservoir area.

At the beginning of the fiscal year Mr. Miller was in charge of an excavating party at the Tuttle Creek Reservoir area in northern Kansas. The results of his activities there are covered in the following section on the Missouri Basin. On September 10 he left for the Smith Mountain and Leesville Reservoir area in southern Virginia and carried on excavations there until November 18, when weather conditions made it advisable to terminate digging until spring.

While in the Washington office he worked on materials he had previously collected in Georgia and also started detailed studies on the ceramic material he had obtained while digging at Russell Cave in Alabama. He also examined numerous archeological specimens sent to the Washington office by private collectors. In January he assisted in setting up a series of archeological exhibits at one of the schools in Newport News, Va. He also completed two short papers for publication, one describing certain polyhedral cores found in Kansas, the other discussing *Chenopodium* weeds as a source of food for Southeastern Indians. On May 15, Mr. Miller left Washington for Rocky Mount, Va., to resume his investigations in the Smith Mountain Reservoir Project area, and at the end of the year he and his small field party were digging in one of the best sites found in that locality.

Alabama-Georgia.—Harold A. Huscher spent the week of November 4–10 at the Walter F. George Reservoir, checking and photographing sites as they were being progressively flooded by the rising waters of the reservoir. At the upper end of the reservoir the historically important Coweta Town House site, 1 RU 9, where Oglethorpe held a peace conference with the Creek chiefs in 1739, was being destroyed by grading for the new Phoenix City dock development.

The Walker Street site (Key School site), 9 ME 60, reported by David W. Chase, Fort Benning Infantry Museum, was being destroyed by an eroding drainage ditch and immediate salvage operations were recommended. Huscher returned to Georgia on February 7, 1963, and, working under an emergency grant, investigated this site, which proved to be an Early Woodland occupation level buried in a natural levee of the Chattahoochee River south of Columbus. With the assistance of David W. Chase of the Infantry Museum, power equipment was used in stripping the overburden from 1,600 square feet of the site. The exposed camp layers were then excavated using power-screening techniques. Post holes in linear and curvilinear arrangements were recorded, but no complete house patterns were worked out. Twenty occupational features, including pits and hearths, were recorded. Over 3,000 sherds and stone artifacts were recovered, of which 1,000 were sherds of the sand-tempered fine-checked (Cartersville Check Stamped) types. There were 40 examples of the tetrapodal pot-base and 9 examples of the subrectangular flat pot-base, characteristic of the late Deptford Period. Minority pottery types were, in descending frequency, large check stamped, complicated stamped, linear check stamped, and simple stamped. A few sherds showed combinations of check stamped and complicated stamped, possibly transitional Deptford-Swift Creek forms belonging with Willey's New River Complicated Stamped. The characteristic point is triangular, thick cross-section, slightly excurvate sides, with baseline either straight, slightly concave, or slightly convex. The assemblage, seemingly a manifestation late in the Deptford Period, with some early traits of the Swift Creek complex appearing, most closely parallels that found in the submound and primary mounds at the Stark's Clay Landing site, 9 CLA 1 ("Mandeville Mound," University of Georgia), and the Mound at the Upper Francis Landing, 1 BR 15 ("Shorter Site," University of Alabama), and the Early Woodland level at the Russell Cave.

Idaho-Oregon.—Under an agreement with the Smithsonian Institution, the Idaho State University Museum undertook archeological reconnaissance and excavations in the Hells Canyon Reservoir on the Snake River between Idaho and Oregon. Fieldwork began on March 25, 1963, and concluded June 20, 1963. The project was under the general supervision of Dr. Earl H. Swanson, director of the museum. Max G. Pavesic, a graduate student at the University of Colorado, directed the fieldwork and was assisted by Roger Nance, Washington State University, and by David Wyatt, University of Washington.

Field headquarters were maintained at Oxbow Dam, where the Idaho Power Co. generously made available a trailer for residence and for laboratory work. Additional assistance during the excavation was given by the Morrison-Knudsen Corp., which provided the field party with a bulldozer. Grateful acknowledgment is also due to Jess Smith, Mr. and Mrs. Amos Camp, Dan Cole, Ross Parker, Ralph Page, and Rudy Lanning for the help they gave.

The field studies were conducted throughout by three men whose work included intensive reconnaissance and excavation at an important village site (No. 10–AM–1). Ten archeological sites were located which were not reported in the original survey of Hells Canyon (Columbia Basin Project, River Basin Surveys, Smithsonian Institution, 1951). These include three rockshelters, seven camp sites, and numerous rock cairns. Five cairns were excavated. The first was excavated entirely by hand because these appear to be a type of archeological feature. Cairns of this nature are constructed of large boulders, which sometimes weigh several tons and which are covered by earth. Reports of burials beneath the cairns were given to the crew, but no archeological materials or data were obtained from them and they remain unexplained at this time.

An important village site was given careful attention by the field party. Two adjacent housepits, as well as the area between, were intensively examined by excavation. These lie on a north-south axis parallel to the river. The largest structure is approximately 25 feet in diameter, while the smaller measures approximately 12 feet across.

It could not be determined whether there was any superimposition of the structures. Stratigraphically, and by the artifact inventory, the housepits appear to be contemporaneous. In both, the house fill is not more than 3½ feet in depth. Little soil change was found in the fill, which was a dark loam near the top but became sandier with depth. Above the sterile soil, yellow sand and gravel, an ash layer is found throughout the limits of the housepits. Stratigraphically, there appears to be only one cultural occupation.

Large quantities of tools, flakes, and bones were recovered, which indicate both intensive occupation and use of the area for hunting purposes. Preliminary examination of the artifacts suggests that occupation was late in prehistoric time, possibly early historic, and similarities can be seen with the Camas Prairie Phase reported at the Weis Rockshelter on Camas Prairie (B. Robert Butler, Contributions to the Prehistory of the Columbia Plateau, *Occasional Papers No. 9* of the Idaho College Museum).

Missouri Basin.—At the beginning of fiscal year 1947 the Missouri Basin Project of the River Basin Surveys began its operations from the field headquarters and laboratory in Lincoln, Nebr. The Project has carried on its activities for 17 consecutive years from that location. The office and laboratory were at first housed with the Laboratory of Anthropology in the basement of the Social Sciences Building. They were then moved to a basement hallway of the University of Nebraska Library. Shortly thereafter much more space was made available in the basement of the just-completed Burnett Hall on the University campus, and the Laboratory of Anthropology and the project again joined forces. By 1950, both the project and the Laboratory of Anthropology had outgrown this space, and the Missouri Basin Project rented a building at 1517 O Street. The project laboratory was transferred to the new location, but offices were maintained in Burnett Hall. In 1953 the offices were moved to O Street and the entire project operated from that location for the following 10 years. During the present fiscal year expansion of the project and deterioration of the upper floors of the building at 1517 O Street made new quarters an absolute necessity. On May 1, 1963, the Missouri Basin Project rented a one-story building at 1835 P Street in Lincoln and moved to that location. It is a relatively new, fireproof building of 14,000 square feet, with all laboratory, storage, and office facilities on one floor.

Activities during the current fiscal year, as in past years, included surveys, excavations, analyses of materials, and reporting of results of the salvage of archeological remains being destroyed by dam and reservoir construction within the Missouri Basin. Dr. Robert L. Stephenson served as chief of the project, except for approximately 3 months when he was on leave and Dr. Warren W. Caldwell functioned as acting chief. During the summer months the work consisted mainly of excavations. Analyses and preparation of reports received the major attention throughout the remainder of the year. The special chronology program, begun in January 1958, was continued throughout fiscal 1963.

At the beginning of the year the permanent staff, in addition to the chief, consisted of five archeologists, one administrative clerk, one administrative assistant, one secretary, one clerk-typist, one scientific illustrator, one photographer, and four museum aides. The temporary staff included 4 archeologists, 5 field assistants, 3 cooks, and 83 field crewmen.

During July and August seven field crewmen were added to the temporary staff. By the end of the first week in August, the employment of all the field crewmen and cooks had been terminated. Other terminations of temporary employees were made shortly thereafter. Four of the temporary archeologists and field assistants were transferred to the permanent staff as archeologists.

At the end of the fiscal year the permanent staff consisted of 21 persons. These were, in addition to the chief, nine archeologists, one administrative assistant, one secretary, one administrative clerk, two clerk-typists, one scientific illustrator, one photographer, and four museum aides. The temporary staff consisted of 71 persons: 3 archeologists, 2 physical anthropologists, 4 cooks, and 62 field crewmen.

During the year there were 25 Smithsonian Institution River Basin Surveys field parties at work in the Missouri Basin. During July and August four parties were working in the Oahe Reservoir area and four parties were working in the Big Bend Reservoir area of South Dakota; two parties were working in the Yellowtail Reservoir area of Montana and Wyoming; one crew was working in the Tuttle Creek Reservoir area in Kansas; and one party was surveying the Missouri Breaks area between Fort Peck and Fort Benton in Montana. In October a small crew was collecting pollen samples in western Nebraska. In May, a small crew worked in the Fort Randall Reservoir area of South Dakota and a survey party conducted a reconnaissance of six proposed reservoirs in Kansas and Nebraska. During June, a crew was excavating in the Pony Creek area of Iowa; another crew had begun work on the James Diversion Project in South Dakota; one crew was at work in the Yellowtail Reservoir of Montana and Wyoming; three parties were working in the Oahe Reservoir; and four groups were excavating in the Big Bend Reservoir, South Dakota. One special crew was not in the field but was at work during June in the laboratory at Lawrence, Kans., studying the skeletal remains from sites in the Oahe Reservoir.

Other fieldwork in the Missouri Basin during the year included 14 parties from State institutions operating under cooperative agreements with the National Park Service and in cooperation with the Smithsonian Institution in the Inter-Agency Archeological Salvage Program.

At the beginning of the year Robert W. Neuman, assisted by John J. Hoffman and a crew of 10, was at work on the excavation of an early village of circular houses known as the Molstad site (39DW234),[1] about 8 miles south of Mobridge, S. Dak., on the right bank of the Missouri River in Dewey County. This site will be subject to wave cutting at maximum pool level of the Oahe Reservoir. Artifacts and architectural details recovered indicate that the site had been a small, fortified village of the very early period of circular house occupation often referred to as the La Roche. There were five houses within an oval stockade and one larger house outside the stockade. The stockade was surrounded by a dry moat 2.6 feet deep and had a single large loop bastion on one side. The entire stockade line and five of the houses were excavated, as well as the bastion and two cross sections of the moat. The people who occupied this site during the 15th or 16th centuries were culturally very closely related to those who occupied the Potts Village, some 2 miles upstream, which had been excavated previously by crews from the Missouri Basin Project.

A second field party in the Oahe Reservoir, also directed by Robert W. Neuman with the assistance of James J. Stanek and a crew of 10, was at work at the beginning of the year excavating the Swift Bird site (39DW233), half a mile downstream from the Molstad site. This site comprised a group of two burial mounds of the Plains Woodland Period and a circular house depression that appears to belong to the La Roche Period. The burial mounds date from a period of some 1,500 or so years ago, while the house dates from about 500 years ago. Mound 1 was a dome-shaped tumulus 75 feet in diameter and 4 feet high. Several articulated bison skeletons lay on the mound floor as did numerous large, charred timbers. Below these was a burial pit containing several secondary human interments. Artifacts were few and largely found within the burial pit. In most respects this mound resembled those excavated at the Boundary Mounds site at the North Dakota-South Dakota State line. Mound 2 was slightly smaller and had articulated bison skeletons, secondary

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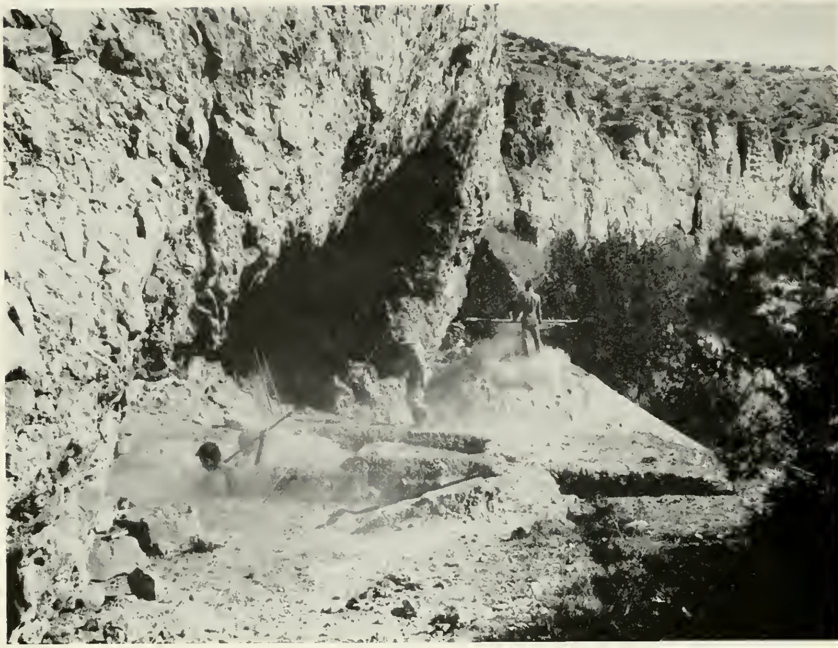
[1] Site designations used by the River Basin Surveys are trinomial in character, consisting of symbols for State, county, and site. The State is indicated by the first number, according to the numerical position of the State name in an alphabetical list of the United States; thus, for example, 32 indicates North Dakota, 39 indicates South Dakota. Counties are designated by a two-letter abbreviation; for example, ME for Mercer County, MN for Mountrail County, etc. The final number refers to the specific site within the indicated State and county.

Walker Street site (Key School site), 9ME60, a buried Deptford camp on the Chattahoochee River, Ga. Overburden has been removed and the underlying camp levels are being excavated by units 10 feet square. River Basin Surveys.

Probable house pattern showing at bottom of Deptford level. Shown here are indications of a subrectangular structure with supporting wall posts set in trenches. River Basin Surveys.



Close-up view of the Sorenson site (24CB202) in the Big Horn Canyon within the Yellowtail Reservoir area during excavation. Evidence of more than 7,000 years of occupation were uncovered in this small rock shelter. River Basin Surveys.

View of the site (24CB203) at the confluence of Dry Head Creek with the Big Horn River within the Yellowtail Reservoir area. Smithsonian Institution field camp can be seen adjacent to the excavation area. River Basin Surveys.

human burials, and a very few artifacts on the mound floor, but no burial pit. The circular house provided a minimal floor pattern without center posts and a small quantity of artifacts. This party also excavated Mound 3 of a series of five burial mounds at the Grover Hand site (39DW240). That mound resembled Mound 1 at the Swift Bird site, including the burial pit. Remains of 17 bison were recovered from the mound fill and floor. A new site, the Stelzer (39DW242), was tested. It is situated about a mile downstream from 39DW240. Occupational levels and artifacts indicate that this may be a substantial camp site of Plains Woodland times. Neuman's two crews shared a single camp and completed their fieldwork on September 2 after 12 weeks in the field.

A third field crew in the Oahe Reservoir was directed by Dr. William M. Bass, assisted by Jon Muller and a crew of six. Based in Pierre, this party utilized a caterpillar tractor and scraper to excavate large sections of the burial areas at the Sully site (39SL4), which is located approximately 20 miles northwest of Pierre, on the left bank of the Missouri River. It comprises the largest prehistoric village remains in the Missouri Basin and was excavated in previous years by Smithsonian Institution field crews. The large burial areas were not exhausted and, in order to get a sufficiently large sample of the physical remains of the people who had lived there some 250–400 years ago, the current season's work was directed toward exhausting the burial areas. The heavy equipment was used to remove the overburden above the graves. Each grave was then excavated by hand. During the first three seasons of work, 264 burials were excavated. This season an additional 293 were recovered, making a total of 557 burials from this one village. Brief investigations at other sites provided additional burials. At the Swan Creek site (39PO1), excavated during a previous season by a cooperating institution, a single burial was obtained. At the Bleached Bone site (39HU48), 20 burials were recovered and 8 were taken from the Second Hand site (39PO207). In addition, a good quantity of burial artifacts was recovered, correlating the burials directly with the village areas and providing cultural meaning for the skeletal remains. This party completed its fieldwork on August 30 after a season of 12 weeks.

The fourth Oahe Reservoir party was directed by Dr. Alfred W. Bowers, assisted by William B. Colvin and a crew of 10. Based at Mobridge, S. Dak., this crew excavated 14 circular earth lodges in the Red Horse site (39CO34) just west of the bridge from Mobridge and at the mouth of the Grand River. This was a moderately large, fortified earth-lodge village of the late period and probably dates in the 18th century. A large artifact yield as well as good architectural details resulted from the excavations. Bowers's crew also exca-

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vated a portion of the Davis site (39CO14), some 200 yards west of the Red Horse site. There, a complex defensive system and a series of long rectangular houses were partly uncovered. Apparently there were at least two, and perhaps three, occupation periods represented, but time did not permit sufficient excavation to recover the whole story. The earliest occupation of the Davis site was several centuries earlier than that at the Red Horse site. Continuation of the work was planned for the next season.

In the Big Bend Reservoir area, three field parties were at work at the beginning of the year and a fourth party was added during July. One of the parties was directed by Dr. Warren W. Caldwell, assisted by Richard E. Jensen and a crew of 11. They excavated at two sites. The Langdeau site (39LM209) had been a village of long-rectangular houses and 15 depressions were visible. Four of these house remains were excavated, and three long trenches were dug in an unsuccessful attempt to find a fortification system. The houses were 30–40 feet wide with no small structural posts at the ends. Entrances were to the south or southwest and floors were compact and stained with red ochre. Pottery found there is of the Anderson and Foreman types, suggesting relationship to the early rectangular-house period at the Dodd site near Pierre, but other artifacts were extremely exotic, including copper, shell, bone, and stone tools and ornaments. This crew's second excavation was at the Jiggs Thompson site (39LM208), located 9 miles north of Lower Brule in the loop of the Big Bend. This site had been a small village of 17 long-rectangular houses situated on a high terrace finger that was separated from the rest of the terrace by a moat 4.5 feet deep and 11 feet wide. Two houses were excavated, the moat was sampled, and numerous other test trenches were dug. The houses had been about 30 by 20 feet with entrances to the south. They did not have end posts, but there were massive central support posts. Architecture and artifacts suggest a close relationship to the Langdeau site; both are in the Anderson-Foreman and Swanson traditions of early rectangular-house culture. This party completed its work on August 26 after 11 weeks in the field.

The second Big Bend party was also directed by Dr. Caldwell, with the assistance of Richard E. Carter. It consisted of a crew of nine. Excavations were carried out at a two-component site (39LM2) overlooking Medicine Creek some 8 miles northwest of Lower Brule. This had been a village of small, rectangular houses with ramp entrances to the south, minimal end support posts, and many cache pits. The remains of the first occupation were overlain by those of a village of square (or subrectangular) houses, 35 feet in diameter, which had four central support posts of the kind usually found in late circular houses in the area. One house of each component, many cache pits, and several midden areas were excavated. Abundant pottery and other artifacts suggest that the earlier component relates to the Anderson and Over foci, while the later component was of the period of the Shannon Focus and similar to component C at the Talking Crow site. This party also sampled the Jandreau site (39LM221), 3 miles east of Medicine Creek in the same general area. Portions of two long-rectangular houses were excavated as were cross sections of the fortification moat. Ceramics recovered there suggest that the village may have been transitional between the Anderson Focus and the Thomas Riggs Focus and will date toward the latter part of the long-rectangular house period. In addition, minor tests were made at the Gilman site (39LM226) and at site 39LM228 in the Medicine Creek Bottoms. The latter proved to have been a rectangular-house village of Over Focus affiliation, while the former was a circular-house village of the Shannon Focus. After 11 weeks in the field this crew completed its assignment on August 26.

A third party in the Big Bend Reservoir area, sharing a joint camp with Caldwell's two crews, was directed by Vernon R. Helmen. This crew of three was frequently assisted by members of Caldwell's parties during the 2 weeks of its work (July 16–27). Helmen and his associates provided their services on a volunteer basis, and Mrs. Helmen made a useful study of the microecology of the flora of one earth lodge. The Helmen crew excavated one house in site 39LM223, a small village of the Shannon Focus. The circular house and several cache pits yielded Talking Crow and Iona pottery.

The remaining field party in the Big Bend Reservoir area was at work at the beginning of the year excavating the remains of Fort George (39ST202), a historic fur-trading post built in 1842 and operated briefly in opposition to the trading post of Fort Pierre Chouteau. The crew of eight was directed by G. Hubert Smith, assisted by Lee G. Madison, and was based in Pierre with the Bass party. Fort George was located on the right bank of the Missouri River some 15 miles downstream from Pierre. Remains of the log stockade, two blockhouses, and the interior buildings of timber were excavated and recorded. Artifacts were abundant and will, along with the architecture, provide a substantial picture of life at this early post, of which so little contemporary record remains.

Two Missouri Basin Project field parties were at work at the beginning of the year in the Yellowtail Reservoir area in the Big Horn Canyon in Montana and Wyoming. Lionel A. Brown, with a crew of five, operated in the lower end of the reservoir from the Yellowtail Dam south to the mouth of Dry Head Creek, a distance of some 25 miles upstream from the dam. They excavated three large, diffuse, occupation sites and tested numerous rock shelters. Site 24BH215 at the mouth of Black Canyon, 6 miles above the dam, was a stratified campsite with three levels of occupation. Artifacts were moderately abundant and included a few nondescript potsherds, corner-notched projectile points, and many scrapers, blades, and bone tools, but no evidence of structures. It appears to have been a camp intermittently occupied from a few hundred years ago to historic times. Site 24BH212 was a complex of occupations at the mouth of Bull Elk Canyon 18 miles above the dam. It contained six stone circles, two circles of shallow postholes, midden deposits, fireplaces, a profusion of scrapers and other small stone tools but very few projectile points and no evidence of pottery. Five of the stone circles contained semicompacted floors, floor debris, and a central fireplace, and one had a midden deposit just outside the stone circle all emphasizing the fact that they served the function of actual tipi rings. The circular arrangements of shallow postholes with a suggestion of floors indicate structures of temporary pole construction. Occupation was shallow with only one level apparent except in one small section of the site where three levels were apparent. Artifacts are not very diagnostic but probably represent a period of three or four centuries before White contact. The third major site excavated by Brown's crew was located on the opposite (left) bank of the Big Horn River at the mouth of Dry Head Creek some 25 miles above the dam. There, four levels of occupation produced large quantities of bison, deer, and elk bone, numerous small stone artifacts, an elk bone flesher, numerous fire pits, and basin-shaped pits but neither pottery nor structures. Several rock shelters between Black Canyon and Dry Head were investigated and tested but none proved to contain worthwhile occupational materials. This party returned to the Lincoln headquarters August 31 after 11 weeks in the field.

Wilfred M. Husted was in charge of the second Yellowtail field party excavating a series of sites in the upper reaches of the reservoir. Working from various campsites between the village of Kane at the extreme southern end of the reservoir to Barry's Landing, some 20 miles to the north, this crew used boat, Jeep, carryall, and foot transportation to resurvey this portion of the Big Horn Canyon and excavate five sites. A rock shelter (48BH206) was sampled but not completed owing to difficulty of access. A large tipi ring site (48BH10) with 20 stone circles, on the left bank of Crooked Creek, was excavated. Five of the circles were dug and three of them contained central fireplaces as well as exterior fireplaces. One open campsite (48BH211) and several rock shelters were examined and tested but provided no useful archeological data. On the Wyoming side of the reservoir, a site at Barry's Landing (24CB201) was excavated. It had superimposed hearths and roasting pits and numerous projectile points and scrapers. The artifacts represent the latter part of the Middle Prehistoric Period overlain by an occupation of the Late Prehistoric Period. A nearby rock shelter (24CB223) was excavated and furnished similar material. The Sorenson site (24CB202), half a mile below Barry's Landing, was completely excavated with excellent results. Five levels of occupation extending from historic times back to the pre-Middle Prehistoric Period were delineated. Lanceolate projectile points in the lowest level (dated at 7,500–7,800 years ago) were overlain by materials of the Middle and Late Prehistoric Period and capped by a historic occupation. Materials included cordage, basketry, hide, bone tools, stone tools, roasting pits, and hearths. In the resurvey of this section of the canyon, 21 new sites were located, of which 18 will be flooded. Husted's party completed the season's work August 30 after 11 weeks in the field.

A survey party directed by Oscar L. Mallory, consisting of a crew of three, made a detailed reconnaissance of the Missouri Breaks along the Missouri River from Fort Benton to the upper reaches of the Fort Peck Reservoir. Beginning at the Fort Benton end of the Breaks, this party utilized boats, horses, vehicles, and foot transportation to locate 55 archeological sites within this 180-mile stretch of extremely rugged river country. Of these sites, 20 were campsites, 21 were campsites with tipi rings, 2 were burials, 3 were bison-kill sites, and 9 were historic sites. Surface collections were made from most of these and two were tested. Artifact yield was minimal but enough to suggest a fairly long period of occupation and significant excavation potential in the area.

The final Missouri Basin Project field party at work at the beginning of the year was directed by Carl F. Miller who, with a crew of nine, was at work in the Tuttle Creek Reservoir of northeastern Kansas. With headquarters in the town of Blue Rapids, Kans., this party investigated seven sites in the upper reaches of the reservoir and excavated one. This was the last chance to examine any of the threatened sites in this reservoir, as the water was already rising, and by the summer of 1963 any sites that were to be flooded would have been submerged. The Pishney site (39MH2) received the attention of Miller's party most of the season and provided a single house structure, a portion of a second house, several cache pits, and a substantial yield of artifacts. The houses at this site were square with rounded corners and the artifacts suggest a cultural position within the Central Plains Phase but with definite indications of influences from the south. Miller's party left the field on August 16 after working for a period of 9 weeks.

Cooperating institutions active in the Missouri Basin at the beginning of the fiscal year included six field parties representing five State agencies in Nebraska, Kansas, Missouri, and Montana. Dr. Dee C. Taylor with a crew from Montana State University conducted a survey of portions of the shoreline of the Fort Peck Reservoir in east-central Montana, locating archeological sites that have been exposed by bank erosion along the shores of the reservoir. Marvin F. Kivett, assisted by Dr. Roger T. Grange with a crew from the Nebraska State Historical Society, completed salvage excavations in the area of the Red Willow Reservoir in southwestern Nebraska. Dr. Preston Holder, assisted by Dr. Emily Blasingham and a crew of University of Nebraska students, completed excavation and testing of sites to be flooded in the Norton Reservoir area of northwestern Kansas. Dr. Carlyle S. Smith, assisted by Walter Birkby and a crew of students from the University of Kansas, excavated two sites, sampled several others, and completed salvage work in the Melvern Reservoir area of east-central Kansas. Dr. Carl Chapman and a crew from the University of Missouri continued the surveying and testing of sites in the Kaysinger Bluff Reservoir area in west-central Missouri. A second crew tested a large series of sites in the Stockton Reservoir area of central Missouri. All these parties operated under agreements with the National Park Service and in cooperation with the Smithsonian Institution in the Inter-Agency Archeological Salvage Program.

The 1963 field season began with an archeological survey team under Lionel A. Brown, assisted by Lee G. Madison and Stephen H. Schwartz. This team began operations on May 6 and completed its work on May 29. It investigated the proposed area of the Almena Reservoir on Prairie Dog Creek, in northwestern Kansas, finding no archeological sites but recording one paleontological locality. The members of the party next went to the proposed area of the Herndon Reservoir on Beaver Creek in Rawlins County, Kans., where they recorded one archeological site. In Ellis County, Kans., on Big Creek, the proposed Ellis Reservoir was surveyed and two sites were recorded. The proposed area of the Fort Scott Reservoir in Bourbon County, Kans., was next surveyed and six sites were located. The next survey, made in Anderson County, Kans., found seven sites at the location of the proposed Garnett Reservoir. The final reservoir of the six surveyed was the Angus Reservoir in Nuckols County, Nebr., where two archeological sites were recorded. A total of 18 archeological sites and 1 paleontological locality were recorded in 6 reservoir areas.

On May 13 and 14, G. Hubert Smith and Oscar L. Mallory conducted a brief investigation of the site of the Fort Randall Military Post, near the Fort Randall dam in southeastern South Dakota. As an aid to the U.S. Corps of Engineers in developing this for public use, Smith and Mallory pinpointed the significant cultural features and made recommendations for their development.

On June 7 the Pony Creek field party began work in that part of Mills County, southwestern Iowa, where the Soil Conservation Service is constructing several very small reservoirs and terracing most of the adjacent valley area. Headquartered in the town of Glenwood, this party of eight, directed by Lionel A. Brown, had by the end of the year visited and tested six sites (three of which had not previously been recorded) and begun excavations in sites 13ML4 and 13ML18, both of which appear to be villages of rectangular (or square) houses of the Nebraska Aspect.

On June 6 Dr. Elden Johnson of the University of Minnesota joined the staff of the Missouri Basin Project and spent 4 days in a brief investigation of the area of the James Diversion Project for detailed survey and excavation early in the next fiscal year.

The single field party in the Yellowtail Reservoir area of Montana and Wyoming, directed by Wilfred M. Husted, consisted of a crew of seven which left Lincoln on June 11. This crew started in the upper reaches of the reservoir where Husted's party left off the previous season. By the end of the year they had completed excavation of a small rock shelter and were continuing investigations on downstream.

In the Oahe Reservoir area of central South Dakota, three field parties were operating at the end of the year. Robert W. Neuman, in charge of a crew of eight, began work on June 11 at the Grover Hand site (39DW240), a group of Woodland burial mounds on the right bank of the Missouri River some 9 miles below Mobridge. By the end of the year, Mound 1 at this site had been excavated. This mound contained a burial pit covered with timbers. Bison skeletons were found on the mound floor.

The second Oahe party was directed by Oscar L. Mallory. With a crew of eight he began work on June 11 at site 39DW231, a presumed village or camp occupation site of the Plains Woodland Period that may be related to some of the burial mounds being dug by the Neuman party. The site is situated some 11 miles below Mobridge on the right bank of the Missouri River. Both the Neuman and Mallory crews camped at the Molstad ranch about a mile above the Grover Hand site, and both crews utilized 16-foot motorboats with 10-horsepower motors as their main means of transportation. This was necessitated by the high water of the Oahe Reservoir and the lack of roads in the area south of the Molstad ranch.

The third Oahe party also began work on June 11 under the direction of Dr. Alfred W. Bowers, who again joined the Missouri Basin Project staff for the summer, taking leave from his regular position at the University of Idaho. Dr. Bowers' crew of 10 camped at the east edge of Mobridge and started digging on the Davis site (39CO14) at the west end of the Mobridge bridge. They had begun there the previous season and by the end of the year were well along with the excavations. They had also dug the last unexcavated lodge at the adjacent Red Horse site (39CO34) that Bowers's crew excavated in the 1962 season.

One historic-sites party was in the field at the end of the year, having begun work on June 14. This party, directed by G. Hubert Smith, was searching for some of the more obscure historic sites in the Big Bend Reservoir area, such as Loisel's Trading Post, Fort Defiance-Bouis, and the Red Cloud Agency. If they find any of these sites they will begin a program of excavations. By the end of the year Smith had devoted considerable time to searching records in various historical files both in Pierre and at Fort Pierre.

Three crews excavating prehistoric sites in the Big Bend area also began work on June 14. John J. Hoffman and a crew of 11 were at work at the end of the year on the series of sites, in the southeast corner of Lyman County on the right bank of the Missouri some 20 miles below Pierre, known as the "La Roche Sites." There, each of several sites has been called "La Roche" and much interpretation has been based on a concept of "La Roche." Hoffman's party was to excavate each of the sites and endeavor to identify some one element as La Roche and correlate the others with it. By the end of the year excavations were well under way in 39ST9, the site which W. H. Over many years ago designated as La Roche.

The second Big Bend field party was directed by William J. Folan, who joined the Smithsonian Institution staff, for the summer season, from Southern Illinois University. This crew of eight camped with the Hoffman crew and was directing its attention to the same problem. The two crews started together on the same site so that they would begin with the same orientation. By the end of the year Folan's crew was ready to move its operations to one of the other related sites in the area. All the sites appear to represent villages of late circular houses, or at least have one component of this "La Roche" trait.

The third Big Bend field party was directed by Richard E. Jensen. It consisted of a crew of 11 and was camped on the left bank of the Missouri in the "pocket" of the Big Bend, some 40 miles by road below Pierre. It was to conduct excavations in a series of circular-house villages nearby. By the end of the year progress had been made in work on the remains of an extensive, diffuse village, 39HU213. Widespread test trenching and the excavation of cache pits, middens, and a multiple burial had been completed.

Dr. William M. Bass of the University of Kansas, and an assistant, Walter Birkby of the same institution, joined the Missouri Basin

Project staff for the summer as temporary employees, in order to conduct laboratory research. Dr. Bass and his assistant analyzed a large quantity of skeletal material, excavated over the past several years by Dr. Bass, from several Missouri Basin sites in the Oahe Reservoir. Principal of these was the Sully site (39SL4) where 557 burials have been recovered. Bass and Birkby were working in the new laboratory facilities at the University of Kansas in Lawrence.

Cooperating institutions in the Missouri Basin at the end of the year included eight parties operating in five States. Dr. Dee C. Taylor and a Montana State University crew were continuing the shoreline survey of the Fort Peck Reservoir in east-central Montana, searching for and testing sites that had been exposed by bank erosion. Robert Gant and a University of South Dakota party were continuing a shoreline survey of the Gavins Point Reservoir in southeastern South Dakota, searching for and testing sites that had been exposed by bank erosion. Particular emphasis was being placed on the search for Plains Woodland and earlier sites. Both of these parties were continuing work begun the previous season. Dr. Preston Holder, assisted by James Marshall and a crew of University of Nebraska students, was excavating the Glen Elder site in the Glen Elder Reservoir in Mitchell County, north-central Kansas, and was searching for and testing additional sites within that reservoir. Dr. Carlyle S. Smith, assisted by Jon Muller and a party of Kansas University students, began the survey and testing of sites in the area to be flooded by the Milford Reservoir in Clay County, north-central Kansas. Dr. Carl Chapman had three University of Missouri parties at work at the end of the year. One was a survey group locating and testing sites in the area to be flooded by the Hackleman Corners Reservoir in southwestern Missouri. A second party was excavating sites in the Kaysinger Bluff Reservoir in west-central Missouri. The third party was digging sites in the Stockton Reservoir of west-central Missouri. Both of the latter were continuing work begun the previous season. Marvin F. Kivett, assisted by Dr. Roger T. Grange, Jr., and a Nebraska State Historical Society crew, surveyed two small reservoirs, Calamus and Davis Creek, in central Nebraska. Both surveys located only a few sites of doubtful archeological potential and it was recommended that no further work be done there unless material is uncovered during earth-moving operations for the construction of the two dams.

The Missouri Basin Chronology Program had been in operation for 5½ years by the end of the year. Cooperation of nearly all the archeologists and archeological institutions in the Plains area continued as in previous years, and leadership and direction of the program continued to be by the staff archeologists of the Missouri Basin Project.

In October a Missouri Basin Project team composed of J. J. Hoffman and Lee G. Madison joined Dr. Paul Sears of Yale University, Dr. J. G. Ogden of Ohio Wesleyan University, and Dr. Harry A. Tourtelot of the U.S. Geological Survey in a trip to collect fossil pollen cores in the sandhills of northwestern Nebraska. The field trip was a part of the chronology program and a part of a continuing program of palynology designed to reconstruct prehistoric floral conditions for a portion of the Missouri Basin. Cores were collected at several of the fossil lakes in the area and will be analyzed by Dr. Ogden.

Other chronology studies included a continuation of the dendrochronology section under the direction of Dr. Warren W. Caldwell, with the volunteer assistance of Harry E. Weakly. The carbon-14 section continued to progress with the addition of 16 new dated samples of vegetal material, tested by the laboratory of Isotopes, Inc., of Westwood, N.J. Robert W. Neuman continued to be in charge of this section of the program and submitted several samples for dating to the new carbon-14 laboratory at the Smithsonian Institution in Washington, D.C. In addition, two samples were sent to the University of Texas for analysis in its carbon-14 laboratory.

The laboratory and office staff of the Missouri Basin Project devoted most of its full effort during the year to processing specimen materials for study, photographing and illustrating specimens, preparing specimen records, and typing, filing, and illustrating record and manuscript materials. The accomplishments of the laboratory and office staff are listed in tables 1 and 2.

Dr. Robert L. Stephenson, chief, devoted a large part of his time during the year to management of the overall Missouri Basin Project, including the office and laboratory in Lincoln, the several field activities, and the preparation of plans and budgets. His individual archeological research and report writing was minimal during the year, but some further progress was made on the monograph "The Whitney Reservoir, Texas" and on analyses of specimens from his excavations at the Sully site (39SL4) in the Oahe Reservoir. He made final revisions on his manuscript "The Accokeek Creek Site: A Middle Atlantic Seaboard Culture Sequence" and submitted it to the University of Michigan for publication. He also revised a paper he read at the 1962 meeting of the Society for American Archeology, entitled "Administrative Problems of the River Basin Surveys," for publication in *American Antiquity.* He continued to serve as chairman of the Missouri Basin Chronology Program; as assistant editor of "Current Research" in the Plains Area for *American Antiquity;* and, until December 1, as associate editor of the *Plains Anthropologist.* On December 1 he became editor of that journal. He also participated in the Visiting Scientist Program of the Nebraska Academy of Sciences and lectured to student groups at Sutton and Sidney, Nebr.

Dr. Stephenson attended the 19½ Plains Conference in Pierre, S. Dak., in July and served as a panel member in a symposium on "The Salvage Program So Far." At the 20th Plains Conference in Lincoln on Thanksgiving weekend he served as local arrangements chairman and as chairman of a symposium on "Plains Chronology." During the period of December 12–21 he attended the "Management Development Program for Field Managers" of the U.S. Department of Agriculture Graduate School, held on the Voorhis Campus of California State Polytechnic College in San Dimas, Calif. He attended the 73d annual meeting of the Nebraska Academy of Sciences in Lincoln on April 27 and the annual meeting of the Society for American Archeology in Boulder, Colo., on May 1–3. While at Boulder he participated in the meeting of the Committee for the Recovery of Archeological Remains and reported on the year's activities of the Missouri Basin Project and on the prospects for the coming year. He wrote several book reviews for scientific journals, gave talks to various local civic organizations on the work of the River Basin Surveys, and represented the Smithsonian Institution at special occasions at the invitation of local civic organizations. He served throughout the second half of the year on the organizing committee for the INQUA meetings to be held in Boulder, Colo., in September 1965, and was named as one of the field conference organizers for a preconference field trip through the Plains area.

Lionel A. Brown, archeologist, when not in charge of field parties, devoted most of his time to analyzing specimen materials he had recovered during the past year and to materials recovered by others in the Missouri Basin in previous years. He completed a major draft of a manuscript entitled "Archeology of the Lower Yellowtail Reservoir, Montana," which describes the work and material recovered from the several sites that he excavated and tested in that area during the summer of 1963. He completed a major draft of a preliminary manuscript entitled "Archeological Investigations in the Pony Creek Watershed, Iowa," which describes the work and reports the analyses of materials he recovered from that area of southwestern Iowa in the spring of 1962. This manuscript will be combined with the report of the work currently being done in that area to form an overall publication on the Pony Creek researches. In the early spring he studied the specimens and field records from the Gillette site (39ST23) in the Oahe Reservoir, excavated by Donald D. Hartle of the Missouri Basin Project in 1957, and nearly completed the major draft of a manuscript covering those investigations.

In July Mr. Brown addressed the Billings Archeological Society in Billings, Mont., on the subject "The Amateur Archeologist in the Salvage Program." During Thanksgiving weekend he attended the 20th Plains Conference in Lincoln and presented two papers, "A Survey of the Pony Creek Watershed" and "Archeology of the Lower Yellowtail Reservoir." Both were published in abstract in the *Proceedings of the 73d Meeting of the Nebraska Academy of Sciences.* He attended the meetings of the Society for American Archeology in Boulder, Colo., on May 1–3. At the end of the year he was again excavating archeological sites in the Pony Creek area of Iowa.

Dr. Warren W. Caldwell, archeologist, was in the field from the beginning of the year until the end of August. He devoted the remainder of his time to specimen and field-record studies concerning sites that he had excavated in previous years. Primary attention was devoted to the analyses (with Richard E. Jensen) of sites 39LM208, 39LM209, and 39LM232, excavated last year in the Big Bend Reservoir of South Dakota by Caldwell and Jensen. He completed the analytical studies and began a manuscript reporting the results. He also completed analyzing materials from, and prepared a major draft of a monograph on, "Investigations at the McKensey Village (39AR-201), South Dakota," a site that he excavated in 1960. In collaboration with G. Hubert Smith, he prepared and submitted for publication a handbook for the U.S. Corps of Engineers' Reservoir Series, entitled "Oahe Reservoir: Archeology, History and Geology." This was the fourth handbook in this series, prepared by the same authors. He also prepared a popular article on "Fortified Villages of the Dakotas," published in *Missouri Basin Progress.* He published two book reviews in the *Plains Anthropologist* and prepared several administrative and progress reports concerning the work of the Missouri Basin Project.

Dr. Caldwell participated in the 19½ Plains Conference in Pierre in July and discussed his current fieldwork. He participated in the 20th Plains Conference in Lincoln at the end of November, presenting a paper on "Investigations in the Lower Big Bend Reservoir, South Dakota" and also serving as a panel member on "Plains Chronology," presenting a discussion of "Dendrochronology in the Plains—Past and Present." He attended the 73d annual meeting of the Nebraska Academy of Sciences and presented a paper, "Primus in Orbe Deos Fecit Timor or Ceramics ad Nauseam," that was published in abstract in the *Proceedings* of the meeting. His paper "Fortified Villages of the Northern Plains" was read in absentia at the annual meeting of the Society for American Archeology in Boulder, Colo., on May 3. Throughout the year he continued to serve as chairman of the dendrochronology section of the Missouri Basin Chronology Program, as contributing editor for book reviews for the *Plains Anthropologist*, and as collaborator for the Plains area for "Abstracts of New World Archeology." He participated in the visiting scientist program of the Nebraska Academy of Sciences, lecturing to student groups at Gretna, Nebr., on January 8. During the period from September to June, on annual-leave time, he served as part-time assistant professor in the Department of Anthropology at the University of Nebraska and taught a course on "The American Indian." At the end of the year he was in the Lincoln laboratory analyzing specimens from past fieldwork.

John J. Hoffman, archeologist, when not in the field conducting excavations, devoted most of his time to laboratory analyses and preparation of reports resulting from his work of the past season. He completed the analyses of specimen materials and records of his 1962 excavations at the Molstad Village site (39DW234) in the Oahe Reservoir area and prepared a major draft of a manuscript on this work. He completed a short article on the "Molstad Village and the La Roche Sites" and submitted it to the *Plains Anthropologist* for publication. By the time he returned to the field in June he was well along on a manuscript entitled "The Swift Bird Lodge (39DW233)." In July, Hoffman attended the 19½ Plains Conference in Pierre and reported on his fieldwork during the season. At Thanksgiving, he presented a paper at the 73d annual meeting of the Nebraska Academy of Sciences in Lincoln entitled "Temporal Ordering of the Chouteau Aspect." The end of the year found him again in the field engaged in archeological excavations.

Wilfred M. Husted, archeologist, while not in the field conducting archeological excavations, was at work in the laboratory analyzing materials and preparing reports on his activities in the field during the 1962 season and also on materials that others had collected in previous seasons. He wrote a "Preliminary Report of the 1962 Archeological Investigation in the Upper Yellowtail Reservoir," which will be combined with a study of his 1963 season's work in the same area so that there will be a comprehensive monograph on the archeology of that region. He also completed the laboratory analyses of, and prepared a major draft of a monograph on "The Brice (39LM31) and Clarkstown (39LM47) Sites, Fort Randall Reservoir." These two sites were excavated in 1954 by the late Paul L. Cooper. At the 20th Plains Conference, November 22–24 in Lincoln, he presented a paper entitled "Investigations in Upper Yellowtail Reservoir, Montana-Wyoming."

Richard E. Jensen, archeologist, spent July, August, and June in the field conducting archeological excavations and the remainder of the year in the laboratory in Lincoln analyzing materials and writing reports. He prepared descriptions of the artifacts and features recovered from the Langdeau site (39LM209), the Jiggs Thompson site (39LM202), and the Pretty Head site (39LM232), which he excavated in conjunction with Dr. Caldwell. They include various statistical analyses relative to sequential alinements and relationships to other sites. In July he gave a report of his current fieldwork at the 19½ Plains Conference in Pierre. During Thanksgiving he attended the 20th Plains Conference in Lincoln. On May 18, accompanied by J. J. Hoffman and Dr. Stephenson, he attended an informal conference on Dakota pottery typology in Vermillion, S. Dak. He and Hoffman proceeded from Vermillion to the Big Bend Reservoir area to select campsites for the summer. At the end of the year he was again in the field excavating archeological sites in the Big Bend Reservoir area.

Oscar L. Mallory, archeologist, when not in the field was at work in the laboratory examining materials previously collected. He studied the background data and analyzed the specimens obtained from the "Missouri Breaks" area of Montana and prepared a report on the work entitled "An Archeological Appraisal of the Missouri Breaks Region, Montana." He then began a detailed analysis of the unusual collection of perishable goods from the Mouat Cliff Burial site (24TE401) excavated last year by the Billings Archeological Society, in central Montana, near Hardin. He spent much of his evening and weekend time working on "A Comparative Cultural Analysis of Textiles from McGregor Cave, Washington," his thesis for a master of arts degree at Washington State College. In April he served, with Robert W. Neuman, as adviser to the U.S. Army Corps of Engineers in conference with the local community developers of Mobridge, S. Dak., on a project to reconstruct an earth-lodge village in that area He presented a paper, "Survey of the Missouri Breaks Area," at the 20th Plains Conference in Lincoln on Thanksgiving weekend. At the close of the year he was conducting archeological excavations in the Oahe Reservoir area.

Robert W. Neuman, archeologist, when not in the field was mainly at work in the laboratory doing research on materials excavated by him in past years in the Oahe and Big Bend Reservoir areas. From October 6 to 13 he was on loan to the University of South Dakota to assist in salvage excavations at the Wolfe Creek Mound site (39HT-201) in Hutchinson County, S. Dak. In the laboratory, he corrected galley proof on his monograph "The Good Soldier Site (39LM238), Lyman County, South Dakota," being published by the Bureau of American Ethnology as a River Basin Surveys Paper. He did research on materials from his Big Bend excavations and brought to near completion a manuscript on "Preceramic Occupations in the Big Bend Reservoir Area, South Dakota." He also served as chairman of the radiocarbon section of the Missouri Basin Chronology Program. He reported on his current fieldwork at the 19½ Plains Conference in Pierre in July. He attended the 20th Plains Conference in Lincoln, November 22–24, where he served as a panel member in the symposium on "Plains Chronology," presenting a discussion of "Carbon-14 on the Plains—Past, Present and Future." In mid-April he and Oscar L. Mallory served as advisers to the U.S. Army Corps of Engineers in discussions with local community supporters of a project to reconstruct an earth-lodge village near Mobridge, S. Dak. On April 27 he served as chairman of the Anthropology Section of the 73d annual meeting of the Nebraska Academy of Sciences in Lincoln and presented a paper entitled "A Brief Review of Anthropology in the Nebraska Academy of Sciences," that was published in abstract in the *Proceedings* of the meeting. This was the best attended and had the largest selection of outstanding papers of any of the meetings of this section of the Academy since its inception. He also attended the annual meetings of the Society for American Archeology in Boulder, Colo., May 1–3, where he presented a paper entitled "Check Stamping on the Northern Plains," that has been accepted for publication in *American Antiquity*. At the end of the year Neuman was conducting excavations in the Oahe Reservoir area.

G. Hubert Smith, archeologist, spent July, August, and the last half of June conducting archeological excavations, and during the remainder of the year was in the Lincoln office analyzing and doing research on materials from historic sites in the Missouri Basin that he had excavated in previous years. He completed a report on the fieldwork done at the site of Fort George (39ST202) in the summer of 1962, and had a major draft of that manuscript ready for final typing at the end of the year. He continued with the preparation of the comprehensive report on the site of "Like-a-Fishhook Village and Fort Berthold I and II (32ML2), North Dakota." With Dr. Caldwell he prepared a popular booklet on "The Oahe Reservoir: Archeology, History and Geology," that was published by the U.S. Army Corps of Engineers in their Reservoir Series, of which this is the fifth. He also prepared a book review published in *American Antiquity* in April.

Smith attended the 19½ Plains Conference in Pierre in July and reported on his current fieldwork. During the Thanksgiving weekend he attended the Plains Conference in Lincoln, where he reported on "Excavations at Fort George, South Dakota." On January 10, he was the featured speaker at the meeting of the Yankton County Historical Society in Yankton, S. Dak., where he gave an illustrated talk on "Salvage Archeology." On April 27 he attended the 73d annual meeting of the Nebraska Academy of Sciences in Lincoln and presented a paper entitled "Ethnographic Contributions of Ferdinand

V. Hayden." He attended the 17th annual meeting of the Mississippi Valley Historical Association and took part in the historic sites committee meeting of that group. He addressed the Kansas City Archeological Society on "Historical Archeology in the Missouri Basin" on May 7, and on May 19 he gave an illustrated talk on "Historic Buildings of Nebraska" at the Nebraska State Historical Society in Lincoln. At the end of the year he was again in the field conducting investigations of historic sites in the Big Bend Reservoir.

TABLE 1.—*Specimens processed, July 1, 1962–June 30,1963*

Reservoir	Number of sites	Catalog numbers assigned	Number of specimens processed
Big Bend	13	4, 354	24, 196
Missouri Breaks	24	178	390
Oahe	10	2, 978	22, 400
Pony Creek	13	408	1, 775
Yellowtail	22	1, 749	3, 038
Site totals	82	9, 667	51, 799
Collections not assigned site numbers	2	11	24
Overall collection totals	84	9, 678	51, 823

As of June 30, 1963, the Missouri Basin Project had cataloged 1,391,219 specimens from 2,410 numbered sites and 60 collections not assigned site numbers.

Specimens restored: Five pottery vessels and six vessel sections.

Specimens donated to the Missouri Basin Project for comparative use: By the W. H. Over Museum, University of South Dakota, courtesy of Dr. Wesley R. Hurt—75 pot rim sherds collected from 39GR1 (Scalp Creek site), 39WW7 (Swan Creek site), and 39WW303. These sherds respresent eight pottery wares, namely: Akaska, Le Beau, Randall, Rygh, Scalp, Steamboat, Swan Creek, and Talking Crow.

TABLE 2.—*Record material processed, July 1, 1962–June 30, 1963*

MISSOURI BASIN PROJECT	
Reflex copies of records	8, 967
Photographic negatives made	3, 128
Photographic prints made	13, 712
Photographic prints mounted and filed	7, 660
Transparencies mounted in glass	66
Kodachrome pictures taken in lab	72
Cartographic tracings and drawings	38
Illustrations	27
Lettering of plates	12
Profiles drawn	92
Plate layouts made for manuscripts	18

Virginia.—During the period September 10–November 18, 1962, Carl F. Miller conducted excavations in four sites in the Smith Mountain and Leesville Reservoir areas. Data obtained indicate that the cultural range represented extended from the terminal phase of Late Archaic around 4000 B.C. to the Middle Woodland Period at about A.D. 500. One of the characteristic artifacts normally associated with such remains, namely, stone projectile points, was scarce, while ceramics and bone tools were rather plentiful. There were numerous portions and fragments from clay tobacco pipes. As a matter of fact, those particular objects were much more numerous than has been indicated by evidence from that general area.

Mr. Miller returned to the Smith Mountain Project area on May 15, 1963, and from that date until the end of the fiscal year was occupied in the excavation of the Hales Ford site (44FR15). In the work there thirty-seven 10-foot squares were dug to a depth of 5 feet; 136 features and 1 partial burial were recovered. The burial, representing an early Middle Woodland Phase, was that of a male who was about 60 years of age at the time of death. Mortuary offerings consisted of two turtle-shell dishes. The use of turtle shells for dishes apparently was a well-established trait at that location. At least two new pottery types were found at the Hales Ford site, and they were apparently correlated to a similar textile-impressed type found in the John H. Kerr Reservoir area farther south on the Roanoke River. The latter, however, produced much less of this type than the Smith Mountain Reservoir. The significance of this will need to be determined by further studies in the laboratory. The projectile points recovered are sufficient in number to illustrate a developmental series. This also is true of clay pipes. The bone material was particularly well preserved, and several new types of artifacts were recovered. Potsherds number into the thousands, and it will be possible to restore a number of vessels from them. No European material was found at the site, which apparently was abandoned well before the White man's influence reached that part of Virginia. No evidence was obtained relative to habitations and consequently nothing is known of the type of dwelling used at that locality.

The material from the combined work in the fall of 1962 and the spring of 1963 will give an excellent source of information about a fairly long period of occupation in the upper reaches of the Roanoke River.

ARCHIVES

The Bureau archives continued under the custody of Mrs. Margaret C. Blaker, archivist. She was assisted throughout the year by Miss

Regina M. Solzbacher, and on a part-time basis by Miss Margaret V. Lee.

During the week of September 30–October 6, Mrs. Blaker attended the annual meeting of the Society of American Archivists in Rochester, N.Y., and searched for early photographs of American Indians in the collections of George Eastman House, the Rochester Historical Society, and the Rochester Museum of Arts and Sciences. A considerable number of fine stereoscopic views of the 1870's and 1880's were located at Eastman House, and copies of them are currently being made for the Bureau collections. At the University of Rochester Library Mrs. Blaker examined the notebooks of Louis Henry Morgan that deal with his visits to the Seneca Indians, and the circulars containing the original information collected and used by Morgan in preparing his *Systems of Consanguinity*, published by the Smithsonian in 1870. Microfilm duplicates of the circulars will be made available to the Bureau through the library's special collections division.

On October 12–15 Mrs. Blaker attended the joint annual meeting of the American Indian Ethnohistoric Conference and the Iroquois Conference at Albany, N.Y., and examined photographic and other pictorial resources on the American Indian in the New York State Museum. On November 14–19 she attended the annual meeting of the American Anthropological Association in Chicago and examined pictorial resources in the Newberry Library and the Chicago Natural History Museum. On May 20–21 she visited Carlisle, Pa., to see photographs in the collections of the Army War College and the Hamilton Library. Both of these institutions have albums of excellent photographs of the students who attended Carlisle Indian school and of their parents, many of them distinguished chiefs, who visited the school. Arrangements for borrowing the albums for copying are in progress.

Ethnographic notes of the late Lyda Averill Taylor, on the Alabama, Choctaw, and Koasati, collected in Polk County, Tex., in 1936–40, and a partial draft of a manuscript on comparative southeastern ethnology, were received from John M. Goggin, to whom they had been given in 1960 by Walter W. Taylor.

A ledger containing drawings of war scenes, apparently all drawn by the same Indian artist, was acquired. The book is undated and the artist unidentified, but he was probably a Cheyenne, since the short written titles indicate that the winners of the contests depicted were Cheyennes. Cheyenne warfare with a number of different tribes is portrayed—Osage, Snake (Shoshoni), Pawnee, Ute, Crow, Shawnee, Sac and Fox, Navaho, and Pueblo. There are also a number of pictures of combat with the U.S. Army. Two pictures depict the

Cheyenne Indian "Horse Road in fight with General Miles near Red River," and another, the historic fight of the Cheyenne with Forsyth's scouts at Beecher's Island on September 17, 1868, in which Chief Roman Nose was killed. Another drawing depicts a Cheyenne battle with soldiers under Lieutenant Henley, 6th Cavalry, on Smoky Hill River, and one shows Indians running off cavalry horses at Fort Dodge, 1865.

A sketchbook containing crayon and pencil drawings of Indian life on the Plains, made by a Cheyenne Indian named Buffalo Meat, while he was a prisoner at Fort Marion, Fla., about 1875 was received as a gift from Miss Julia Whiting of Middleburg, Va.

A photograph of an oil painting of the Comanche chief Yellow Wolf, made in 1859 by Col. Arthur T. Lee, and a photograph of a drawing made by Yellow Wolf were received through the courtesy of Charles F. Hayes III, of the Rochester Museum of Arts and Sciences, Rochester, N.Y., which owns the originals.

Negatives of four sketches of Missisauga Indians, three of Hurons and two of Creek Indians, all drawn by Basil Hall in 1827–28, were obtained from the Lilly Library, Indiana University, which owns the original drawings.

An important collection of photographic negatives and prints, taken by Jesse Hastings Bratley in the period 1893–ca. 1903, while he was teaching at Indian schools in the West, was lent by Francis V. Crane, director of the Southeast Museum, Marathon, Fla. A total of 280 copy negatives were made and added to the Bureau files. Most of the negatives relate to the Dakota Indians of Rosebud Reservation, S. Dak.; the Havasupai of Cataract Canyon, Ariz.; and the Hopi of Polacca, Ariz. There are also a few photographs of Salish Indians of Puget Sound, and of Cheyenne and Arapaho from Contonment, Okla.

A series of 36 negatives taken at the mouth of Windy River, northwestern extremity of Neultin Lake, southwestern Keewatin, Canada, in 1947 shows Caribou Eskimo and a few Cree Indians. The negatives include portraits; camp scenes showing food and hide preparation; and views of transport by canoe and on foot with pack and dog travois. They were made and donated by Dr. Francis Harper, Chapel Hill, N.C. Dr. Harper also donated five negatives showing Poosepatuck men and native fishing equipment, taken by him at the Poosepatuck Reservation, Mastic, Long Island, in 1909 and 1910.

A series of 11 photographs taken at the Poosepatuck Reservation, Mastic, Long Island, showing members of the Poosepatuck tribe, and views taken at the June meeting at Poosepatuck in 1912, were copied from an album of snapshots owned by Walter B. Raynor, Patchogue, N.Y. Two photographs of White men's hunting camps having palmetto-thatch structures built in the Seminole style were from the same album.

Nineteen portraits of Jicarilla Apaches and views taken on the Jicarilla Reservation near Dulce, N. Mex., ca. 1915–62, were copied from photographs lent by Dr. D. Harper Sims, Arlington, Va.

Negatives of four views of the monument on the grave of the Choctaw chief Pushmataha, in the Congressional Cemetery, Washington, D.C., were deposited by Dr. William C. Sturtevant.

A photograph of a Shoshoni chief, Jack Edmo, and his family, taken about 1917, was donated by Mrs. Arthur White, Middleburg, Va.

A collection of 90 Indian portraits from the studios of a number of late 19th-century commercial photographers was obtained through Carl Russell, Orinda, Calif. Over 50 of the portraits are of members of various Dakota tribes; other tribes represented are Apache, Crow, Diegueño, Maricopa, Papago, and Yuma.

A collection of approximately 675 photographic negatives made in the approximate period 1900–1920 has been acquired but is not yet cataloged in detail. The collection consists of studio and outdoor portraits, camp scenes, views of dances, and other subjects. Of the more than 25 tribes represented, the principal ones are: Apache, Arapaho, Assiniboin, and Gros Ventres; Blackfoot, Cheyenne, Crow, Dakota, Eskimo, Hopi, Osage, Pawnee, Seminole, and Wichita.

LIBRARY

During the year 1962–63, work continued on the organization of the collection and its records under the supervision of Mrs. Carol Jopling in the Bureau of American Ethnology Library.

When the library's maps were evaluated, several very old and rare ones were discovered. Among them were a Nicholas Visscher map of the Western Hemisphere, *Novissima et Accuratissima Totius Americae*, and *Nova Belgica et Anglia Nova* by W. J. Blaeu (Amsterdam, 1635). Of particular interest to the Bureau, however, was the *Census of the State of California* (1852) map and a quantity of other North American maps with linguistic and archeological annotations.

Some fine books were given to the library, including a set by Sir Richard Phillips, *A Collection of Modern and Contemporary Voyages and Travels* (London, 1805–) presented by Dr. Frank H. H. Roberts, Jr.

The librarian attended the Special Libraries Convention in Denver, June 9–14, 1963, and visited a number of libraries and museums having special collections on the North American Indian and Western history.

The following statistics will serve to indicate some of the work conducted in the library:

Reference questions answered	1,820
Library users	1,301
Publications circulated	1,071
Loans to other libraries	151
Volumes sent for binding	1,103

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau continued during the year under the immediate direction of Mrs. Eloise B. Edelen. The following publications were issued:

Seventy-ninth Annual Report of the Bureau of American Ethnology, 1961–62. ii+29 pp., 2 pls. 1963.

Bulletin 181. Isleta paintings, with introduction and commentary by Elsie Clews Parsons. Edited by Esther S. Goldfrank. xvi+299 pp., 142 pls. 1962.

Bulletin 182. River Basin Surveys Papers, No. 25. Frank H. H. Roberts, Jr., editor. xvi+447 pp., 110 pls., 65 figs., 20 maps. 1962.

Archeology of the John H. Kerr Reservoir Basin, Roanoke River, Virginia-North Carolina, by Carl F. Miller. With appendix: Human skeletal remains from the Tollifero (Ha6) and Clarksville (Mc14) sites, John H. Kerr Reservoir Basin, Virginia, by Lucile E. Hoyme and William M. Bass.

Bulletin 184. The Pueblo of Sia, New Mexico, by Leslie A. White. xii+358 pp., 12 pls., 55 figs. 1962.

Bulletin 185. River Basin Surveys Papers, Nos. 26–32, Frank H. H. Roberts, Jr. editor. xii+344 pp., 57 pls., 43 figs., 5 maps. 1963.

No. 26. Small sites on and about Fort Berthold Reservation, Garrison Reservoir, North Dakota, by George Metcalf.

No. 27. Star Village: A fortified historic Arikara site in Mercer County, North Dakota, by George Metcalf.

No. 28. The dance hall of the Santee Bottoms on the Fort Berthold Reservation, Garrison Reservoir, North Dakota, by Donald D. Hartle.

No. 29. Crow-Flies-High (32MZ1), a historic Hidatsa village in the Garrison Reservoir area, North Dakota, by Carling Malouf.

No. 30. The Stutsman Focus: An aboriginal culture complex in the Jamestown Reservoir Area, North Dakota, by R. P. Wheeler.

No. 31. Archeological manifestations in the Toole County section of the Tiber Reservoir Basin, Montana, by Carl F. Miller.

No. 32. Archeological salvage investigations in the Lovewell Reservoir Area, Kansas, by Robert W. Neuman.

Bulletin 188. Shonto: A study of the role of the trader in a modern Navaho Community, by William Y. Adams. xi+329 pp., 10 pls., 3 figs., 3 maps, 12 charts. 1963.

Publications distributed totaled 17,722 as compared with 19,326 for the fiscal year 1962.

ILLUSTRATIONS

The staff artist for the Bureau of American Ethnology, E. G. Schumacher, prepared the illustrations to accompany 16 manuscripts to be published by the Bureau, some as entire bulletins and others composing bulletins in the Anthropological Papers and the River Basin Surveys Papers series. The work included the drawing or redrawing of maps, diagrams, charts, and other text figures, and effectively combining and mounting photographs, all covering the fields of anthropology, archeology, and ethnology. Approximately 500 illustrations were prepared.

MISCELLANEOUS

Dr. M. W. Stirling, Dr. A. J. Waring, and Sister Inez Hilger continued as research associates. Dr. Wallace L. Chafe, linguist on the staff of the Bureau from April 4, 1959, resigned on August 20, 1962, to accept an associate professorship in the department of linguistics at the University of California in Berkeley.

In addition to the usual extensive correspondence answering specific questions, many of which were of a technical nature, the Bureau prepared several bibliographies to provide reference material for which there has been recurring demand. Among those recently compiled, the following were printed by the multilith process:

SIL–2, 3d rev., 6/63: Selected bibliography on arrowheads. 5 pp.

SIL–105, rev., 7/62: Selected bibliography on Cherokee customs and history. 6 pp.

SIL–174, rev., 6/63: Selected references on the Indians of Southeastern North America. Compiled by William C. Sturtevant. 17 pp.

SIL–363, 4/63: Bibliography of wild food plants of Canadian Indians. Compiled by F. R. Irvine. 13 pp.

Other bibliographies prepared are in typescript.

More than 100 specimens, both ethnological and archeological, were received by mail or brought to the office for identification and such information as could be provided by Bureau specialists.

Respectfully submitted.

Frank H. H. Roberts, Jr., *Director.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

Report on the National Zoological Park

Sir: I have the honor to submit the following report on the condition and operations of the National Zoological Park for the fiscal year ended June 30, 1963:

GIFTS

A number of accessions to the animal collection were due to the generosity of friends of the National Zoological Park. On January 6, 1963, a fine Bengal tiger arrived from the zoo in Ahmedabad, India, as a gift from Ralph Scott of Washington and Miami Beach. Although Samson is a normally colored tiger, he carries the white genes, being both half-brother and uncle to Mohini, the Zoo's white tigress. Samson was bred under the direction of the Maharajah of Rewa. The two animals are now living together, and it is hoped that they will produce white cubs.

Edward D. Sweeney and Ralph E. Becker, both of Washington, presented a pair of husky young polar bears which they acquired on a voyage to the Arctic last summer.

The U.S. Air Force retired Ham, the chimpanzee astronaut, which on January 31, 1961, soared through space in a capsule boosted by an 83-foot Redstone rocket. Ham's 16-minute ride took him to a height of 155 miles and a distance of 420 miles down the coast from Cape Canaveral. He seems to have adjusted nicely to his comparatively quiet routine in the Zoo's ape quarters, which he entered on April 5, 1963.

The U.S. Forest Service captured a young adult female (cinnamon phase) American black bear, which was flown to Washington from New Mexico and installed in a cage adjoining that of the famous Smokey Bear. The formal presentation was made on September 8 by New Mexico Forester Ray L. Bell on behalf of the Department of Game and Fish and the New Mexico State Land Office, the Ghost Ranch Museum, and the Governor and Senators of New Mexico. "Goldie," soon to be "Mrs. Smokey," was accepted on behalf of the Smithsonian Institution by Dr. Carmichael.

The State of Hawaii sent a pair of nene, or Hawaiian geese. A few years ago these birds were threatened with extinction by hunters and predators. The State Fish and Game Division undertook a program of propagating the birds in captivity and then releasing them to join wild birds in sanctuary areas on Hawaiian volcanoes, and the numbers have now increased. The nene, the State bird of Hawaii, is an attractive bird and an interesting addition to the national collection; it had not been exhibited here since 1936. The pair was presented by the Honorable Daniel K. Inouye, Senator from Hawaii, on June 19, 1963, and formally accepted by the Secretary of the Smithsonian Institution. The Zoo is grateful to Paul Breese, Director of the Honolulu Zoo, for his efforts in obtaining for it these rare specimens.

Through Alton W. Hemba, American Consul General at Guayaquil, Ecuador, a large Galápagos tortoise (from Albemarle Island) was received as a gift from Dr. Jorge E. Proano P.

Volkmar Wentzel, of the National Geographic Society, presented to the Zoo a young specimen of the giant forest rat which he obtained during his travels in Africa. This animal is now more than 2 feet long (including the tail) and is still growing.

Dr. Doris M. Cochran, curator of reptiles and amphibians at the U.S. National Museum, presented a number of reptiles collected on a trip to Central and South America.

A gift of two hummingbirds, *Heliomaster squamosus* and *Colibri delphinae greenewaltii*, was received from Dr. Augusto Ruschi, Santa Teresa, Brazil. Dr. Ruschi is an authority on the Colibridae and is noted for his splendid collection of live birds. His visit to the National Zoological Park last September established the standards and methods of care for a large group of hummingbirds to be applied when the renovation of the birdhouse is completed.

Kenneth Sather, Round Lake, Minn., sent four giant Canada geese (*Branta canadensis major*), a form previously thought to be extinct: a welcome addition to the waterfowl collection.

The National Zoological Park's animal collection has also been generously enriched by the Eistophos Science Club of Washington, D.C., and Mrs. Joseph Campbell, also of Washington.

Space does not permit listing all gifts received in the course of the year, but the following are of special interest:

Bogley, Samuel W., III, Hyattsville, Md., woolly monkey.

Cochran, Dr. Doris, Washington, D.C., bronze vine snake, 2 Central American toads, Brazilian striped frog, Raddi's frog, Brazilian light-spotted frog, 14 diamondback terrapins, South American water turtle.

Dembin, Edward and Eugene, Washington, D.C., Western indigo snake, red-tailed boa, boa constrictor, bull snake.

DePrato, Mario, Washington, D.C., river frog, Hermann's tortoise.

Florida Nurserymen and Growers Association, Key Biscayne, Fla., through Jim Griffin, 2 mandarin ducks, chestnut-breasted teal, 2 fulvous tree ducks.

Fulton, Mrs. Robert, Washington, D.C., keel-billed toucan.

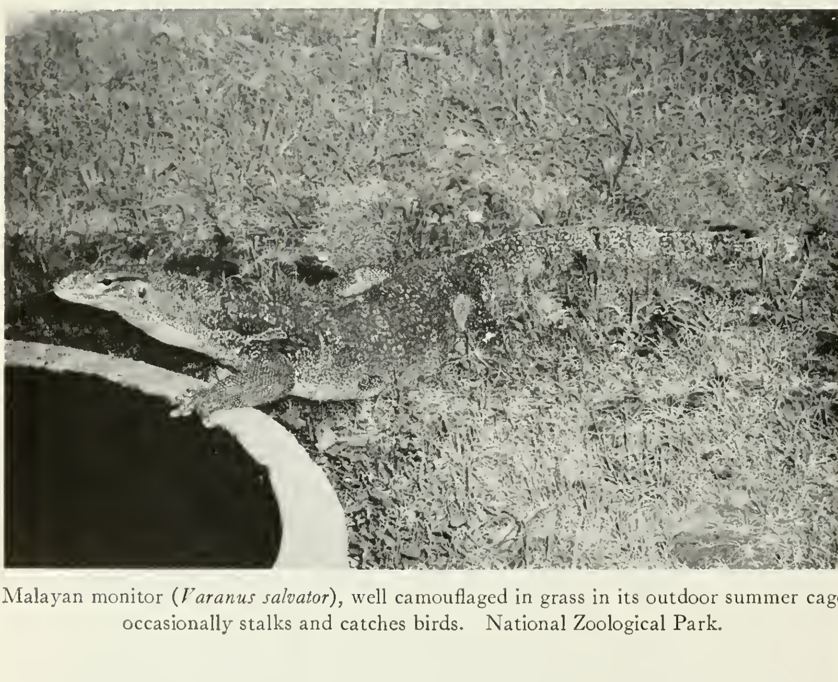
George's Pet Shop, Bladensburg, Md., speckled agouti, black agouti, 2 jaguarondis, anaconda, 2 matamata turtles, 2 boa constrictors.

Hadley, Mrs. Harry E., Annandale, Va., ocelot.

Still thriving, the Siberian crane (*Grus leucogeranus*) that came to the National Zoological Park on June 26, 1906.

Nene, or Hawaiian geese (*Branta sandvicensis*), in their pool at the National Zoological Park.

An unusually long-lived many-banded krait (*Bungarus multicinctus*). This specimen arrived at the National Zoological Park as an adult on April 3, 1958.



Malayan monitor (*Varanus salvator*), well camouflaged in grass in its outdoor summer cage occasionally stalks and catches birds. National Zoological Park.

Male lowland gorilla born at the National Zoological Park on September 9, 1961. Tomoka at 1 year 7 months with a basketball.

Baby gibbon born in this outdoor enclosure on December 8, 1962. National Zoological Park.

One of the brindled gnus (*Connochaetes taurinus*) born at the National Zoological Park. Photograph by Walter Oates, Washington Evening Star.

Hecht Co., Washington, D.C., blue peacock.
Henderson, Paul, Silver Spring, Md., drill.
LaDu, Dr. Bert N., Bethesda, Md., habu snake.
Locke, Otto Martin, New Braunfels, Tex., 5 coachwhip snakes, 4 racers, 2 yellow bullsnakes, 2 indigo snakes.
Olafson, Joseph M., Falls Church, Va., jaguarondi.
Purkis, Mrs. Dorothy, Washington, D.C., woolly monkey.
Safeway Warehouse, Landover, Md., South American opossum.
Silva, James R., Washington, D.C., red-shouldered hawk.
Smith, Mrs. Hiram, Richmond, Va., ocelot.
Smith, Mrs. Leland F., Washington, D.C., cockatiel.
U.S. Department of Agriculture, Beltsville, Md., mink.
U.S. Fish and Wildlife Service: Mason, Mich., bald eagle; Seattle, Wash., 4 bald eagles; Washington, N.C., bald eagle.
U.S. National Museum, through Dr. Philip Humphrey, 6 red-tailed tropicbirds.

BIRTHS AND HATCHINGS

Following the procedure of previous years, all births and hatchings are listed below, whether or not the young were successfully reared. In many instances the record of animals having bred in captivity is of interest.

MAMMALS

Common name	Number	Common name	Number
Squirrel glider	1	Neumann's genet	5
Rat kangaroo	1	Formosan spotted civet	2
European hedgehog	1	Water civet	1
Ring-tailed lemur	1	Bobcat	1
Squirrel monkey	*1	Serval	1
Black spider monkey	2	Black leopard	2
Rhesus monkey	1	African lion	4
Barbary ape	4	Sea-lion	1
Sooty mangabey	*1	Grant's zebra	*1
DeBrazza's guenon	*1	Collared peccary	3
Hybrid gibbon	2	Hippopotamus	1
Chimpanzee	1	Pygmy hippopotamus	2
Two-toed sloth	2	Llama	4
Woodchuck	5	White fallow deer	2
Prairie-dog	2	Axis deer	2
Beaver	1	Red deer	2
Crested rat	1	Sika deer	4
Egyptian spiny mouse	9	Virginia deer	3
Patagonian cavy	9	Reindeer	7
Speckled agouti	*1	Caribou × reindeer	1
Jackal	3	Brindled gnu	2
Timber wolf	5	Yak	1
Korean bear	2	Cape buffalo	1
European brown bear	3	Dorcas gazelle	2
Grizzly bear	2	African pygmy goat	2
Hybrid bear	2	Barbary sheep	*2
Raccoon	2		

*Stillborn.

BIRDS

Common name	Number	Common name	Number
Crested screamer	4	Mallard duck	33
Whooper swan	1	Peafowl	4
Canada goose	4	Kookaburra	8
Wood duck	28	Formosan red-billed pie	3

REPTILES

Box turtle	1	Crevice spiny lizard	31
Painted turtle	10	Ribbon snake	8
Red-lined turtle	31	Queen snake	6
Yellow-bellied turtle	13	Garter snake	8
Northern yellow-bellied turtle	10		

DEPOSITS

During the process of the National Zoological Park's capital improvement program, animals which are rare in the United States and would be crowded or poorly housed during the construction period are being sent to municipal zoos and other facilities. During the past year rare or valuable specimens have been dispersed to locations thought to have good breeding conditions as well as better living accommodations. Other animals have been dispersed with the understanding that they or similar specimens will be returned when suitable portions of the new exhibit areas are available here in the park. These deposits are:

Brookfield Zoo, Brookfield, Ill., female Dall sheep.

Busch Gardens, Tampa, Fla., male concave-casqued hornbill, female Solomon Islands cockatoo.

Defense General Supply Center Preserve, Richmond, Va., male American elk.

Round Lake Waterfowl Station, Round Lake, Minn., 31 cotton teals.

St. Louis Zoo, St. Louis, Mo., male guar, 4 king penguins, Adélie penguin, female chimpanzee.

EXCHANGES

The National Zoological Park continues a program of exchanging surplus animals with zoos of other countries. Notable exchange arrangements were negotiated with several foreign zoos. The West Berlin Zoo in Germany received 4 wood ducks, 2 turkey vultures, 2 whistling swans, 2 great horned owls, a red-tailed hawk, a red-shouldered hawk, and 2 barred owls. El Pinar Zoo in Caracas, Venezuela, received 2 American alligators, a pair of wood ducks, and a female Nile hippopotamus. The Calgary Zoo, Alberta, Canada, received 2 scarlet ibises, 2 roseate spoonbills, 2 cattle egrets, 2 eastern glossy ibises, 2 little blue herons, a Louisiana heron, a red-shouldered hawk, an osprey, 2 chimachimas, 2 crested curassows, an Ariel toucan, 2 barred owls, and 2 kookaburras. The Edinburgh Zoo in Scotland received 6 raccoons, 1 jaguarondi, 2 squirrel monkeys, 2 kinkajous, 4 opossums, and 3 king snakes.

The exchange of specimens with zoos and institutions in the United States is also continuing. With the decrease in wild animal populations in various parts of the world, it becomes important to replace animal losses from stock propagated in other zoos. An actual surplus of any one kind of animal is best dissipated by distributing to other American zoos so that new displays and further propagation may be achieved.

Animals obtained through exchange were:

Baltimore Zoo, Baltimore, Md., Grant's zebra.
Bronx Zoo, New York, N.Y., cusimanse, European dormouse, 2 otters.
Buffalo Zoo, Buffalo, N.Y., 5 timber rattlesnakes, 2 black garter snakes, 2 Blanding's turtles.
Calgary Zoological Society, Alberta, Canada, 2 bald eagles.
Cheyenne Mountain Zoo, Colorado Springs, Colo., 8 golden-mantled ground squirrels.
Cincinnati Zoo, Cincinnati, Ohio, clouded leopard.
Columbus Zoo, Columbus, Ohio, 2 golden eagles, king vulture.
Franklin Park Zoo, Boston, Mass., 2 giant salamanders, puma.
Hanson, Charles, Oak Harbor, Ohio, Arizona king snake, ground snake, 2 shovel-nosed snakes, California mountain king snake, hooded merganser, 3 sidewinder rattlesnakes, alligator lizard, Texas long-nosed snake, eastern massasauga.
Houston Zoological Gardens, Houston, Tex., 6 blotched water snakes, 2 yellow-bellied water snakes, diamondback water snake, 2 coral snakes, 6 water moccasins, 5 rat snakes, 7 western rattlesnakes, 2 speckled king snakes, 3 Lindheimer's rat snakes.
Hoxie Bardex Circus, Sarasota, Fla., wild hog.
Kenefick, James H., Danielson, Conn., pygmy rattlesnake, 2 gopher tortoises.
Lincoln Park Zoo, Chicago, Ill., brown lemur, ruffed lemur.
Mortimer, Bill, Anaheim, Calif., rosy boa, chuckwalla.
Norfolk Zoo, Norfolk, Va., 4 cottonmouth water moccasins, 2 common king snakes, brown water snake, rainbow snake, 2 canebrake rattlesnakes.
San Diego Zoo, San Diego, Calif., Allen's swamp monkey (male).
Tote-Em-In Zoo, Wilmington, N.C., 2 star tortoises, leopard, African scorpion, 4 African red-tail squirrels, puff adder, unidentified tortoise, tree shrew, 2 moustached marmosets, African python, Indian python, titi monkey.
Zinner, Hermann, Vienna, Austria, 12 European vipers, 3 sand vipers, 3 Aesculapian snakes, 3 European water snakes, 14 European lizards, 5 European turtles, 2 sand boas.

The following animals were sent to other zoos and to private collectors in exchange:

Air Force Institute of Pathology, Washington, D.C., water moccasin, Asiatic rat snake, many-banded krait, green palm viper, lesser Indian rat snake.
Baltimore Zoo, Baltimore, Md., Nile hippopotamous, Grant's zebra.
British Guiana Zoo, Georgetown, British Guiana, lion cub (female).
Buck, Warren, Marlton, N.J., 4 Gelada baboons.
Buffalo Zoo, Buffalo, N.Y., lesser panda, 2 Taiwan cobras.
Busch Gardens, Tampa, Fla., 2 whistling swans.

Cincinnati Zoo, Cincinnati, Ohio, 4 mallards, 4 wood ducks, 4 lesser scaups, 4 canvasbacks, ringneck duck, redhead duck, emu, 2 glossy ibises, 2 scarlet ibises, 3 snowy egrets, Bengal tiger, 2 European brown bear cubs.

Emperor Valley Zoo, Port of Spain, Trinidad, genet, cacomistle, 2 California ground squirrels, kinkajou.

Franklin Park Zoo, Boston, Mass., 2 black swans, 2 whistling swans, cavy.

Fresno Zoo, Fresno, Calif., 3 cattle egrets.

Hanson, Charles, Oak Harbor, Ohio, lesser Indian rat snake, Aesculapian snake, Taiwan habu, palm viper, krait, western cottonmouth moccasin.

Hoxie Bardex Circus, Sarasota, Fla., 2 squirrel monkeys.

Jimmy Morgan Zoo, Birmingham, Ala., 2 magpies.

John Ball Zoological Park, Grand Rapids, Mich., 2 scarlet ibises, 2 curassows, 2 roseate spoonbills.

Johns Hopkins University, Baltimore, Md., 4 canvasback ducks.

Lincoln Park Zoo, Chicago, Ill., lemur catta, pair Barbary apes.

Lincoln Park Zoo, Oklahoma City, Olka., 2 scarlet ibises.

Mortimer, Bill, Anaheim, Calif., 2 baby Cook's tree boas, Aesculapian snake.

National Institutes of Health, Bethesda, Md., 4 fat-tailed gerbils, alligator, Neumann's genet.

Palmer, Harold C., Douglasville, Ga., squirrel monkey, kookaburra.

Patuxent Wildlife Refuge, Laurel, Md., red-tailed hawk, 2 sparrow hawks, barn owl, 3 great horned owls, 4 barred owls, 12 wood thrushes, 9 buntings, warblers.

San Diego Zoo, San Diego, Calif., Allen's swamp monkey (female).

Southwick Game Farm, Blackstone, Mass., 2 axis deer.

Zinner, Hermann, Vienna, Austria, Lindheimer's snake, 2 pilot black snakes, 3 bull snakes, timber rattler, 2 western diamondback rattlesnakes, 2 southern copperheads, 3 water moccasins, 25 anoles, spiny-tailed iguana, common iguana, speckled king snake, common king snake, 2 common water snakes, diamond-backed water snake, 3 broad-banded water snakes, yellow-bellied water snake, 3 blotched water snakes, 3 indigo snakes.

PURCHASES

The National Zoological Park has been fortunate in purchasing a wild Grevy zebra stallion from Africa. This animal is particularly valuable in that wild blood has been assured in the continued breeding program of the Grevy herd here in the zoo.

The same is true of a male Masai giraffe import. The reception of this animal completes a trio of these unusual animals, and it is hoped that they will produce fine offspring—important items in the program of the interchange of animals among zoos of the United States.

A monkey or baboon island is a great attraction to visitors to any zoo. With the hope of a new island exhibit to be built, 16 Gelada baboons from Ethiopia were purchased and are being acclimated as eventual inhabitants of an island exhibit. Geladas are among the most hardy of the primate family, and it is expected that these specimens will condition to year-round outdoor environment with minimum heat requirements for their well-being.

Other purchases of interest were:

6 lungfishes
3 cantils
2 Mexican beaded lizards
2 olive baboons
2 South American wood rails
1 wattled guan

STATUS OF THE COLLECTION, JUNE 30, 1963

Class	Orders	Families	Species or subspecies	Individuals
Mammals	12	47	238	646
Birds	20	67	343	1, 068
Reptiles	4	25	192	699
Amphibians	2	10	25	107
Fishes	4	10	23	66
Arthropods	3	4	4	77
Mollusks	1	1	1	30
Total	46	164	826	2, 693

In the following list of mammals, sex is given where known; 1.0 indicates one male, 0.1 indicates one female, 1.1 indicates one male and one female, etc.:

ANIMALS IN THE COLLECTION ON JUNE 30, 1963

MAMMALS

MONOTREMATA

Family and common name	*Scientific name*	*Number*
Tachyglossidae:		
Echidna, or spiny anteater	*Tachyglossus aculeatus*	0. 1
MARSUPIALIA		
Didelphidae:		
Opossum	*Didelphis marsupialis virginiana*	0. 1
Murine opossum	*Marmosa* sp	0. 1
Central American opossum	*Didelphis marsupialis*	2. 0
Dasyuridae:		
Tasmanian devil	*Sarcophilus harrisii*	1. 0
Phalangeridae:		
Sugar glider	*Petaurus breviceps*	1. 1
Squirrel glider	*Petaurus norfolcensis*	2. 4
Phascolomidae:		
Hairy-nosed wombat	*Lasiorhinus latifrons*	2. 0
Mainland wombat	*Wombatus hirsutus*	0. 1
Macropodidae:		
Tree kangaroo	*Dendrolagus matschiei*	1. 0
Rat kangaroo	*Potorous* sp	1. 2
INSECTIVORA		
Erinaceidae:		
European hedgehog	*Erinaceus europaeus*	2. 1
African desert hedgehog	*Paraechinus* sp	0. 1

PRIMATES

Family and common name	*Scientific name*	*Number*
Lemuridae:		
Ring-tailed lemur	*Lemur catta*	2.1
Brown lemur	*Lemur fulvus*	1.1
Lorisidae:		
Great galago	*Galago crassicaudatus*	1.1
Bushbaby	*Galago senegalensis zanzibaricus*	2.0
Common potto	*Perodicticus potto*	0.1
Cebidae:		
Douroucouli	*Aotus trivirgatus*	2.0
Titi monkey	*Callicebus cupreus*	1.0
Capuchin	*Cebus capucinus*	3.5
Weeping capuchin	*Cebus griseus*	1.0
White-faced saki	*Pithecia pithecia*	0.1
Squirrel monkey	*Saimiri sciureus*	2.3
Spider monkey	*Ateles geoffroyi*	1.5
Black spider monkey	*Ateles fusciceps*	1.5
Woolly monkey	*Lagothrix* sp	1.1
Callithricidae:		
Pygmy marmoset	*Cebuella pygmaea*	1.0
Cottontop marmoset	*Saguinus oedipus*	1.0
Red-handed marmoset	*Saguinus midas*	0.1
Moustached tamarin	*Saguinus mystax*	1.1
Cercopithecidae:		
Toque, or bonnet macaque	*Macaca sinica*	1.2
Philippine macaque	*Macaca philippinensis*	1.0
Crab-eating macaque	*Macaca irus*	0.1
Rhesus monkey	*Macaca mulatta*	3.1
Javan macaque	*Macaca irus mordax*	2.1
Formosan macaque	*Macaca cyclopis*	1.1
Red-faced macaque	*Macaca speciosa*	0.1
Barbary ape	*Macaca sylvanus*	5.1
Moor macaque	*Macaca maurus*	0.1
Gray-cheeked mangabey	*Cercocebus albigena*	0.1
Agile mangabey	*Cercocebus agilis*	1.0
Golden-bellied mangabey	*Cercocebus chrysogaster*	1.0
Red-crowned mangabey	*Cercocebus torquatus*	1.1
Sooty mangabey	*Cercocebus fuliginosus*	3.1
Crested mangabey	*Cercocebus aterrimus*	1.0
Black-crested mangabey	*Cercocebus aterrimus*	1.1
Drill	*Mandrillus leucophaeus*	1.0
Olive baboon	*Papio anubis*	3.2
Gelada baboon	*Theropithecus gelada*	7.6
Chacma baboon	*Papio comatus*	1.0
Vervet guenon	*Cercopithecus aethiops*	1.0
Green guenon	*Cercopithecus aethiops*	3.2
Grivet guenon (color variant)	*Cercopithecus aethiops*	0.1
Moustached monkey	*Cercopithecus cephus*	1.2
Diana monkey	*Cercopithecus diana*	1.0
Roloway monkey	*Cercopithecus diana roloway*	0.1
DeBrazza's guenon	*Cercopithecus neglectus*	1.0
White-nosed guenon	*Cercopithecus nictitans*	0.1

Family and common name	*Scientific name*	*Number*
Cercopithecidae—Continued		
Lesser white-nosed guenon	*Cercopithecus petaurista*	1.0
Allen's swamp monkey	*Allenopithecus nigroviridis*	1.1
Spectacled, or Phayre's, langur	*Presbytis phayrei*	1.0
Hanuman, or entellus monkey	*Presbytis entellus*	0.1
Crested langur	*Presbytis cristatus*	1.0
Pongidae:		
White-handed gibbon	*Hylobates lar*	1.1
Wau-wau gibbon	*Hylobates moloch*	0.1
Hybrid gibbon	*Hylobates lar* × *H.* sp	0.5
Siamang gibbon	*Symphalangus syndactylus*	1.0
Sumatran orangutan	*Pongo pygmaeus*	1.1
Bornean orangutan	*Pongo pygmaeus*	0.1
Chimpanzee	*Pan satyrus*	3.2
Lowland gorilla	*Gorilla gorilla*	2.1
EDENTATA		
Myrmecophagidae:		
Giant anteater	*Myrmecophaga tridactyla*	0.1
Bradypodidae:		
Two-toed sloth	*Choloepus didactylus*	3.4
Dasypodidae:		
Nine-banded armadillo	*Dasypus novemcinctus*	0.1
RODENTIA		
Sciuridae:		
European red squirrel	*Sciurus vulgaris*	2.2
Gray squirrel, albino	*Sciurus carolinensis*	2.0
Tassel-eared, or Abert's squirrel	*Sciurus aberti*	1.0
Western fox squirrel	*Sciurus niger*	1.0
Indian palm squirrel	*Funambulus palmarum*	0.1
South African red squirrel	*Paraxerus palliatus*	1.2
Tri-colored squirrel	*Callosciurus prevosti*	0.1
Formosan tree squirrel	*Callosciurus erythraeus*	1.1
Woodchuck, or groundhog	*Marmota monax*	4.2
Prairie-dog	*Cynomys ludovicianus*	15
California ground squirrel	*Citellus beecheyi*	2.2
Washington ground squirrel	*Citellus washingtoni*	1.1
Golden-mantled ground squirrel	*Citellus lateralis*	2.4
Eastern chipmunk	*Tamias striatus*	1.1
Eastern chipmunk, albino	*Tamias striatus*	1.0
Yellow pine chipmunk	*Eutamias amoenus*	0.1
Townsend's chipmunk	*Eutamias townsendii*	1.0
Eastern flying squirrel	*Glaucomys volans*	2.3
Heteromyidae:		
Kangaroo rat	*Dipodomys* sp	2.0
Castoridae:		
Beaver	*Castor canadensis*	3
Pedetidae:		
Cape jumping hare	*Pedetes capensis*	2.1
Cricetidae:		
White-footed mouse	*Peromyscus* sp	1.3
East African maned rat	*Lophiomys ibeanus*	2.0

Family and common name	*Scientific name*	*Number*
Cricetidae—Continued		
Pine vole	*Microtus pinetorum*	1.0
Gerbil	*Gerbillus pyramidum*	0.1
Fat-tailed gerbil	*Pachyuromys duprasi*	3.3
Egyptian gerbil	*Gerbillus dasyurus*	0.1
Hairy-tailed jird	*Sekeetamys calurus*	0.1
Muridae:		
Egyptian spiny mouse	*Acomys cahirinus*	10.14
Egyptian spiny mouse	*Acomys dimidiatus*	6.10
Giant forest rat	*Cricetomys gambianus* ssp	1.0
Slender-tailed cloud rat	*Phloeomys cumingii*	1.0
Gliridae:		
Garden dormouse	*Eliomys quercinus*	0.1
Hystricidae:		
Malay porcupine	*Acanthion brachyura*	1.0
African porcupine	*Hystrix cristata*	2.4
Palawan porcupine	*Thecurus pumilus*	1.1
Caviidae:		
Patagonian cavy	*Dolichotis patagonum*	3.6
Dasyproctidae:		
Hairy-rumped agouti	*Dasyprocta prymnolopha*	2.1
Agouti, black phase	*Dasyprocta prymnolopha*	1.1
Acouchy	*Myoprocta acouchy*	1.0
Chinchillidae:		
Mountain viscacha	*Lagidium* sp	0.1

CARNIVORA

Canidae:		
Dingo	*Canis familiaris dingo*	1.2
Coyote	*Canis latrans*	0.1
Common jackal	*Canis aureus*	1.1
Timber wolf	*Canis lupus nubilus*	1.3
Texas red wolf	*Canis niger rufus*	0.1
Arctic fox	*Alopex lagopus*	1.0
Fennec	*Fennecus zerda*	1.1
Gray fox	*Urocyon cinereoargenteus*	1.2
Red fox	*Vulpes fulva*	1.0
Raccoon dog	*Nyctereutes procyonoides*	1.1
Cape hunting dog	*Lycaon pictus*	1.1
Ursidae:		
Spectacled bear	*Tremarctos ornatus*	1.0
Himalayan bear	*Selenarctos thibetanus*	0.1
Japanese black bear	*Selenarctos thibetanus japonicus*	1.0
Korean bear	*Selenarctos thibetanus ussuricus*	1.1
European brown bear	*Ursus arctos*	1.2
Iranian brown bear	*Ursus arctos syriacus*	1.1
Grizzly bear	*Ursus horribilis*	1.1
Black bear	*Euarctos americanus*	1.1
Polar bear	*Thalarctos maritimus*	1.2
Hybrid bear	*Thalarctos maritimus* × *Ursus middendorffi*	2.2

Family and common name	Scientific name	Number
Ursidae—Continued		
Malayan sun bear	*Helarctos malayanus*	0.2
Sloth bear	*Melursus ursinus*	1.1
Procyonidae:		
Cacomistle	*Bassariscus astutus*	2.2
Raccoon	*Procyon lotor*	1.4
Raccoon, albino	*Procyon lotor*	0.1
Raccoon, black phase	*Procyon lotor*	1.0
Coatimundi	*Nasua nasua*	1.3
Red coatimundi	*Nasua nasua*	1.0
Peruvian coatimundi	*Nasua nasua dorsalis*	1.1
Kinkajou	*Potos flavus*	2.1
Olingo	*Bassaricyon gabbi*	1.0
Mustelidae:		
Marten	*Martes americana*	0.1
Fisher	*Martes pennanti*	0.1
British Guiana tayra	*Eira barbara poliocephala*	1.1
Grison	*Galictis allamandi*	1.0
Zorilla	*Ictonyx striatus*	1.0
Wolverine	*Gulo gulo luscus*	0.1
Ratel	*Mellivora capensis*	1.0
American badger	*Taxidea taxus*	1.0
Golden-bellied ferret-badger	*Melogale moschata subaurantiaca*	1.2
Common skunk	*Mephitis mephitis*	2.0
California spotted skunk	*Spilogale putorius phenax*	1.0
River otter	*Lutra canadensis*	2.0
Viverridae:		
Genet	*Genetta genetta neumanni*	2.5
Genet, black phase	*Genetta genetta*	1.0
Formosan spotted civet	*Viverricula indica*	1.1
Linsang	*Prionodon linsang*	0.1
African palm civet	*Nandinia binotata*	1.1
Formosan masked civet	*Paguma larvata taivana*	1.0
Binturong	*Arctictis binturong*	1.0
African gray mongoose	*Herpestes ichneumon*	0.1
African water civet	*Atilax paludinosus*	1.4
African striped mongoose	*Crossarchus fasciatus*	1.1
Cusimanse	*Crossarchus* sp	0.1
White-tailed mongoose	*Ichneumia albicauda*	1.0
Black-footed mongoose	*Bdeogale* sp	1.1
Hyaenidae:		
Striped hyena	*Hyaena hyaena*	1.1
Felidae:		
Bobcat	*Lynx rufus*	1.1
Canadian lynx	*Lynx canadensis*	1.0
Caracal	*Lynx caracal caracal*	1.0
Jungle cat	*Felis chaus*	1.1
Pallas's cat	*Felis manul*	1.1
Serval	*Felis serval*	0.2
Leopard cat	*Felis bengalensis*	1.0
Golden cat	*Felis aurata*	1.0
Ocelot	*Felis pardalis*	1.2

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Family and common name	*Scientific name*	*Number*
Felidae—Continued		
Jaguarondi	*Felis yagouaroundi*	1.1
Puma	*Felis concolor*	1.1
Leopard	*Panthera pardus*	3.1
Black leopard	*Panthera pardus*	1.2
Lion	*Panthera leo*	4.4
Bengal tiger	*Panthera tigris*	2.1
White Bengal tiger	*Panthera tigris*	0.1
Jaguar	*Panthera onca*	1.0
Clouded leopard	*Neofelis nebulosa*	2.0
Snow leopard	*Uncia uncia*	1.1
Cheetah	*Acinonyx jubata*	1.1
PINNIPEDIA		
Otariidae:		
California sea-lion	*Zalophus californianus*	3.3
Patagonian sea-lion	*Otaria flavescens*	0.1
Phocidae:		
Harbor seal	*Phoca vitulina*	1.1
TUBULIDENTATA		
Orycteropodidae:		
Aardvark	*Orycteropus afer*	1.0
PROBOSCIDEA		
Elephantidae:		
African elephant	*Loxodonta africana*	0.1
Forest elephant	*Loxodonta cyclotis*	1.0
Indian elephant	*Elephas maximus*	0.2
PERISSODACTYLA		
Equidae:		
Mongolian wild horse	*Equus przewalskii*	1.0
Grevy's zebra	*Equus grevyi*	1.2
Grant's zebra	*Equus burchelli*	1.3
Burro, or donkey	*Equus asinus*	1.0
Tapiridae:		
Brazilian tapir	*Tapirus terrestris*	1.1
Rhinocerotidae:		
Indian one-horned rhinoceros	*Rhinoceros unicornis*	1.0
African black rhinoceros	*Diceros bicornis*	1.1
White, or square-lipped, rhinoceros	*Ceratotherium simum*	1.1
ARTIODACTYLA		
Tayassuidae:		
Collared peccary	*Tayassu tajacu*	4.3
Hippopotamidae:		
Hippopotamus	*Hippopotamus amphibius*	1.1
Pygmy hippopotamus	*Choeropsis liberiensis*	1.4
Camelidae:		
Bactrian camel	*Camelus bactrianus*	0.1
Llama	*Lama glama*	2.4
Guanaco	*Lama glama guanicoe*	1.1
Alpaca	*Lama pacos*	1.1

Family and common name	*Scientific name*	*Number*
Cervidae:		
White fallow deer	*Dama dama*	3.3
Axis deer	*Axis axis*	3.2
Red deer	*Cervus elaphus*	4.3
Sika deer	*Cervus nippon*	3.11
Père David's deer	*Elaphurus davidianus*	1.0
White-tailed, or Virginia, deer	*Odocoileus virginianus*	2.6
American elk	*Cervus canadensis*	*1.0
Forest caribou	*Rangifer caribou*	0.1
Reindeer	*Rangifer tarandus*	3.11
Giraffidae:		
Nubian giraffe	*Giraffa camelopardalis*	0.1
Masai giraffe	*Giraffa c. tippelskirchi*	1.2
Bovidae:		
Sitatunga	*Tragelaphus spekii*	1.0
Anoa	*Anoa depressicornis*	1.1
Yak	*Poephagus grunniens*	1.3
Gaur	*Bibos gaurus*	2.0
Cape buffalo	*Syncerus caffer*	1.4
American bison	*Bison bison*	1.0
Brindled gnu	*Connochaetes taurinus*	1.4
Dorcas gazelle	*Gazella dorcas*	3.4
Saiga antelope	*Saiga tatarica*	0.1
Rocky Mountain goat	*Oreamnos americanus*	0.1
Himalayan tahr	*Hemitragus jemlahicus*	0.1
African pygmy goat	*Capra hircus*	3.2
Ibex	*Capra ibex*	1.0
Aoudad, or Barbary sheep	*Ammotragus lervia*	1.1
Dall sheep	*Ovis dalli*	*0.1
Big-horn sheep	*Ovis canadensis*	1.1

BIRDS

SPHENISCIFORMES

Spheniscidae:		
King penguin	*Aptenodytes patagonica*	*4
Adelie penguin	*Pygoscelis adeliae*	*1

STRUTHIONIFORMES

Struthionidae:		
Ostrich	*Struthio camelus*	1

RHEIFORMES

Rheidae:		
Rhea	*Rhea americana*	1

CASUARIIFORMES

Casuariidae:		
Double-wattled cassowary	*Casuarius bicarunculatus*	2
Dromiceidae:		
Emu	*Dromiceius novaehollandiae*	2

*On deposit at another zoo or sanctuary

TINAMIFORMES

Family and common name	*Scientific name*	*Number*
Tinamidae:		
Pileated tinamou	*Crypturellus soui panamensis*	1

PROCELLARIIFORMES

Family and common name	*Scientific name*	*Number*
Diomedeidae:		
Black-footed albatross	*Diomedea nigripes*	2
Phaethontidae:		
Red-tailed tropicbird	*Phaethon rubicauda*	3

PELECANIFORMES

Family and common name	*Scientific name*	*Number*
Pelecanidae:		
White pelican	*Pelecanus erythrorhynchos*	3
Brown pelican	*Pelecanus occidentalis*	1
Dalmatian pelican	*Pelecanus crispus*	2
Sulidae:		
Gannet	*Sula bassana*	1
Phalacrocoracidae:		
Double-crested cormorant	*Phalacrocorax auritus auritus*	3
Farallon cormorant	*Phalacrocorax auritus albociliatus*	1
European cormorant	*Phalacrocorax carbo*	6

CICONIIFORMES

Family and common name	*Scientific name*	*Number*
Ardeidae:		
Reddish egret	*Dichromanassa rufescens rufescens*	8
Snowy egret	*Egretta thula*	3
Eastern green heron	*Butorides virescens*	2
Louisiana heron	*Hydranassa tricolor*	2
Black-crowned night heron	*Nycticorax nycticorax*	12
American bittern	*Botaurus lentiginosus*	1
Tiger bittern	*Tigrisoma lineatum*	1
Balaenicipitidae:		
Shoebill	*Balaeniceps rex*	1
Ciconiidae:		
American wood ibis	*Mycteria americana*	2
European white stork	*Ciconia ciconia*	4
White-bellied stork	*Sphenorhynchos abdimia*	2
Open-billed stork	*Anastomus oscitans*	1
Threskiornithidae:		
White ibis	*Guara alba*	2
Scarlet ibis	*Guara ruber*	2
Black-faced ibis	*Theristicus melanopis*	1
Black-headed ibis	*Threskiornis melanocephala*	1
White-faced glossy ibis	*Plegadis falcinellus mexicana*	1
Eastern glossy ibis	*Plegadis falcinellus falcinellus*	1
Phoenicopteridae:		
Chilean flamingo	*Phoenicopterus chilensis*	1
Cuban flamingo	*Phoenicopterus ruber*	1
Old World flamingo	*Phoenicopterus antiquorum*	1

ANSERIFORMES

Family and common name	*Scientific name*	*Number*
Anhimidae:		
Crested screamer	*Chauna torquata*	6
Anatidae:		
Coscoroba swan	*Coscoroba coscoroba*	4
Mute swan	*Cygnus olor*	3
Black-necked swan	*Cygnus melanocoriphus*	2
Whooper swan	*Olor cygnus*	4
Whistling swan	*Olor columbianus*	11
Trumpeter swan	*Olor buccinator*	2
Black swan	*Chenopis atrata*	7
Egyptian goose	*Alopochen aegyptiacus*	4
White-fronted goose	*Anser albifrons*	3
Indian bar-headed goose	*Anser indicus*	5
Emperor goose	*Anser canagicus*	2
Blue goose	*Anser caerulescens*	6
Lesser snow goose	*Anser caerulescens caerulescens*	2
Greater snow goose	*Anser caerulescens atlanticus*	5
Ross's goose	*Anser rossii*	4
Nene, or Hawaiian goose	*Branta sandvicensis*	2
Red-breasted goose	*Branta ruficollis*	4
Canada goose	*Branta canadensis*	26
Lesser Canada goose	*Branta canadensis*	5
Giant Canada goose	*Branta canadensis major*	4
Cackling goose	*Branta canadensis*	4
White-cheeked goose	*Branta canadensis*	3
Canada goose × Lesser snow goose (blue phase), hybrid	*Branta canadensis* × *Anser caerulescens*	1
Fulvous tree duck	*Dendrocygna bicolor*	1
Ruddy shelduck	*Casarca ferruginae*	2
Wood duck	*Aix sponsa*	104
Mandarin duck	*Aix galericulata*	12
Indian cotton teal	*Nettapus coromadelianus*	*3
Pintail duck	*Anas acuta*	4
Green-winged teal	*Anas crecca*	1
Chestnut-breasted teal	*Anas castanea*	1
Gadwall	*Anas strepera*	4
European widgeon	*Anas penelope*	2
Mallard duck	*Anas platyrhynchos*	60
Mallard duck × American pintail duck, hybrid	*Anas platyrhynchos* × *Anas acuta*	1
Black duck	*Anas rubripes*	8
Greater scaup duck	*Aythya marila*	11
Lesser scaup duck	*Aythya affinis*	55
Redhead	*Aythya americana*	17
Ring-necked duck	*Aythya collaris*	18
Canvasback duck	*Aythya valisineria*	40
Rosy-billed pochard	*Metopiana peposaca*	1

*On deposit at another zoo or sanctuary.

Family and common name	*Scientific name*	*Number*
Anatidae—Continued		
Red-crested pochard	*Netta rufina*	1
Bufflehead	*Bucephala albeola*	1
American goldeneye	*Bucephala clangula*	1
Baldpate	*Mareca americana*	8
Hooded merganser	*Lophodytes cucullatus*	1
FALCONIFORMES		
Cathartidae:		
Andean condor	*Vultur gryphus*	1
King vulture	*Sarcoramphus papa*	1
Sagittariidae:		
Secretarybird	*Sagittarius serpentarius*	2
Accipitridae:		
Hooded vulture	*Necrosyrtes monachus*	1
Griffon vulture	*Gyps fulvus*	1
Rüppell's vulture	*Gyps ruppellii*	2
African yellow-billed kite	*Milvus migrans*	2
Brahminy kite	*Haliastur indus*	1
Black-faced hawk	*Leucopternis melanops*	1
Red-winged hawk	*Heterospizias meridionalis*	1
Red-tailed hawk	*Buteo jamaicensis*	1
Swainson's hawk	*Buteo swainsoni*	1
Mauduyt's hawk eagle	*Spizaetus ornatus*	1
Black-crested eagle	*Lophaetus occipitalis*	1
Great black hawk	*Ictinaetus malayensis*	1
Golden eagle	*Aquila chrysaetos*	5
Imperial eagle	*Aquila heliaca*	2
White-breasted sea eagle	*Haliaee tus leucogaster*	1
Pallas's eagle	*Haliaeetus leucoryphus*	1
Bald eagle	*Haliaeetus leucocephalus*	9
Harpy eagle	*Harpia harpyja*	1
Guianan crested eagle	*Morphnus guianensis*	1
Martial eagle	*Polemaetus bellicosus*	1
Bateleur eagle	*Terathopius ecaudatus*	1
Lammergeier	*Gypaetus barbatus*	1
Falconidae:		
Sparrow hawk	*Falco sparverius*	4
Duck hawk	*Falco peregrinus anatum*	1
Feilden's falconet	*Neohierax cinereiceps*	1
Red-footed falcon	*Falco vespertinus*	1
Forest falcon	*Micrastur semitorquatus*	2
Chimango	*Milvago chimango*	1
Audubon's caracara	*Polyborus cheriway*	2
White-throated caracara	*Phalcoboenus albogularis*	1
GALLIFORMES		
Megapodiidae:		
Brush turkey	*Alectura lathami*	1
Cracidae:		
Wattled curassow	*Crax globulosa*	2
White-headed piping guan	*Pipile cumanensis*	1
Wattled guan	*Pipile* sp	1

Family and common name	*Scientific name*	*Number*
Phasianidae:		
Gambel's quail	*Lophortyx gambeli*	2
Valley quail	*Lophortyx californica vallicola*	3
Argus pheasant	*Argusianus argus*	1
Golden pheasant	*Chrysolophus pictus*	3
Red junglefowl	*Gallus gallus*	3
Black-backed kaleege pheasant	*Gennaeus melanonotus*	2
Silver pheasant	*Gennaeus nycthemerus*	1
Peafowl	*Pavo cristatus*	6
Ring-necked pheasant	*Phasianus colchicus*	1
Ring-necked pheasant, albino	*Phasianus colchicus*	2
Ring-necked pheasant × Green pheasant, hybrid.	*Phasianus colchicus* × *Phasianus versicolor.*	1
Bhutan, or grey peacock pheasant	*Polyplectron bicalcaratum*	1
Numididae:		
Vulturine guineafowl	*Acryllium vulturinum*	1
GRUIFORMES		
Gruidae:		
Siberian crane	*Grus leucogeranus*	1
European crane	*Grus grus*	2
Demoiselle crane	*Anthropoides virgo*	4
Sarus crane	*Grus antigone*	1
African crowned crane	*Balearica pavonina*	5
Psophiidae:		
Trumpeter	*Psophia crepitans*	1
Rallidae:		
Cayenne wood rail	*Aramides cajanea*	1
Virginia rail	*Rallus limicola*	1
Purple gallinule	*Porphyrula martinica*	2
Eurypygidae:		
Sun bittern	*Eurypyga helias*	1
Cariamidae:		
Cariama, or seriama	*Cariama cristata*	1
Otididae:		
Kori bustard	*Eupodotis kori*	2
Senegal bustard	*Eupodotis senegalensis*	1
CHARADRIIFORMES		
Jacanidae:		
Common jaçana	*Jacana spinosa*	2
Haematopodidae:		
Oystercatcher	*Haematopus ostralegus*	1
Charadriidae:		
Australian banded plover	*Zonifer trivolor*	2
European lapwing	*Vanellus vanellus*	3
South American lapwing	*Belonopterus cayennensis*	4
Crocodile bird	*Pluvianus aegyptius*	7
Recurvirostridae:		
Black-necked stilt	*Himantopus mexicanus*	1
Laridae:		
Ring-billed gull	*Larus delawarensis*	3
Kelp gull	*Larus dominicanus*	2

Family and common name	Scientific name	Number
Laridae—Continued		
Laughing gull	*Larus atricilla*	3
Herring gull	*Larus argentatus*	1
Great black-backed gull	*Larus marinus*	1
Silver gull	*Larus novaehollandiae*	6
COLUMBIFORMES		
Columbidae:		
Band-tailed pigeon	*Columba fasciata*	1
High-flying Budapest pigeon	*Columba livia*	1
Black-billed pigeon	*Columba nigrirostris*	1
Triangular spotted pigeon	*Columba guinea*	2
Crowned pigeon	*Goura victoria*	1
Blue ground dove	*Claravis pretiosa*	4
Ruddy ground dove	*Chaemepelia rufipennis*	1
Indian emerald-winged tree dove	*Chaleophaps indica*	5
Diamond dove	*Geopelia cuneata*	1
Plain-breasted ground dove	*Columbigallina minuta*	2
Ground dove	*Columbigallina passerina*	1
Ring-necked dove	*Streptopelia decaocto*	5
Blue-headed ring dove	*Streptopelia tranquebarica*	2
White-winged dove	*Zenaida asiatica*	1
Mourning dove	*Zenaidura macroura*	1
PSITTACIFORMES		
Psittacidae:		
Kea parrot	*Nestor notabilis*	2
Banksian cockatoo	*Calyptorhynchus magnificus*	1
White cockatoo	*Kakatoe alba*	1
Solomon Islands cockatoo	*Kakatoe ducrops*	*1
Sulphur-crested cockatoo	*Kakatoe galerita*	2
Bare-eyed cockatoo	*Kakatoe sanguinea*	3
Great red-crested cockatoo	*Kakatoe moluccensis*	1
Leadbeater's cockatoo	*Kakatoe leadbeateri*	6
Cockatiel	*Nymphicus hollandicus*	5
Yellow-and-blue macaw	*Ara ararauna*	4
Red-and-blue macaw	*Ara chloroptera*	2
Red-blue-and-yellow macaw	*Ara macao*	2
Illiger's macaw	*Ara maracana*	2
Brown-throated conure	*Conurus aeruginosus*	8
Petz's parakeet	*Aratinga canicularis*	2
Rusty-cheeked parrot	*Aratinga pertinax*	2
Yellow-naped parrot	*Amazona auropalliata*	2
Finsch's parrot	*Amazona finschi*	1
Blue-fronted parrot	*Amazona aestiva*	1
Red-fronted parrot	*Amazona bodini*	1
Double yellow-headed parrot	*Amazona oratrix*	4
African gray parrot	*Psittacus erithacus*	4
Black-headed, or Nanday, parrot	*Nandayus nanday*	7
Lineolated parakeet	*Bolborhynchus lineolatus*	5
White-winged parakeet	*Brotogeris versicolorus*	1
Tovi parakeet	*Brotogeris jugularis*	1

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Family and common name	*Scientific name*	*Number*
Psittacidae—Continued		
Greater ring-necked parakeet	*Psittacula eupatria*	2
Rose-breasted parakeet	*Psittacula alexandri*	1
Moustached parakeet	*Psittacula fasciata*	1
Lesser ring-necked parakeet	*Psittacula krameri*	2
Barraband's parakeet	*Polytelis swainsoni*	1
Quaker parakeet	*Myiopsitta monacha*	7
Grass parakeet	*Melopsittacus undulatus*	1
Red-faced lovebird	*Agapornis pullaria* ssp	2
Rosy-faced lovebird	*Agapornis roseicollis*	1
Black-headed caique, or seven-color parrot	*Pionites melanocephala*	2
Yellow-thighed caique	*Pionites leucogaster*	1
CUCULIFORMES		
Musophagidae:		
White-bellied go-away bird	*Crinifer leucogaster*	1
Plantain-eater	*Crinifer africanus*	1
Cuculidae:		
Koel	*Eudynamys scolopacea*	1
Roadrunner	*Geococcyx californianus*	2
Coucal, or crow-pheasant	*Centropus sinensis*	1
STRIGIFORMES		
Tytonidae:		
Barn owl	*Tyto alba*	1
Strigidae:		
Screech owl	*Otus asio*	3
Spectacled owl	*Pulsatrix perspicillata*	1
Malay fishing owl	*Ketupa ketupu*	1
Snowy owl	*Nyctea nyctea*	4
Barred owl	*Strix varia*	1
Burrowing owl	*Speotyto cunicularia hypugaea*	2
Nepal brown wood owl	*Strix leptogrammica newarensis*	1
CORACIIFORMES		
Alcedinidae:		
Kookaburra	*Dacelo gigas*	16
Coraciidae:		
Lilac-breasted roller	*Coracias caudata*	2
Indian roller	*Coracias benghalensis*	2
Bucerotidae:		
Concave-casqued hornbill	*Buceros bicornis*	*1
Pied hornbill	*Anthracoceros malabaricus*	1
Abyssinian ground hornbill	*Bucorvus abyssinicus*	2
Leadbeater's ground hornbill	*Bucorvus leadbeateri*	1
Grey hornbill	*Tockus birostris*	1
Great black-casqued hornbill	*Certaogymna atrata*	1
Crowned hornbill	*Tockus alboterminatus*	1
Yellow-billed hornbill	*Tockus flavirostris*	1

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PICIFORMES

Family and common name	*Scientific name*	*Number*
Capitonidae:		
Asiatic great barbet	*Megalaima virens*	1
Toucan barbet	*Semnornis ramphastinus*	1
Ramphastidae:		
Keel-billed toucan	*Ramphastos culminatus*	2
Sulphur-and-white-breasted toucan	*Ramphastos vitellinus*	1
Razor-billed toucanet	*Pteroglossus castanotis*	2

PASSERIFORMES

Family and common name	*Scientific name*	*Number*
Tyrannidae:		
Kiskadee flycatcher	*Pitangus sulphuratus*	4
Eastern kingbird	*Tyrannus tyrannus*	1
Alaudidae:		
Horned lark	*Eremophila alpestris*	1
Corvidae:		
Magpie	*Pica pica*	1
Yellow-billed magpie	*Pica nuttalli*	1
Asiatic tree pie	*Crypsirina formosae*	1
Magpie jay	*Calocitta formosa*	1
European jay	*Garrulus glandarius*	2
African white-necked crow	*Corvus albus*	2
American crow	*Corvus brachyrhynchos*	1
Raven	*Corvus corax principalis*	2
Indian crow	*Corvus splendens*	1
Formosan red-billed pie	*Cissa caerulea*	9
Occipital blue pie	*Cissa occipitalis*	1
Hunting crow	*Cissa chinensis*	1
Inca jay	*Xanthoura yncas*	1
Paridae:		
Great tit	*Parus major*	1
Timaliidae:		
White-capped redstart	*Chaimarrhornis leucocephalus*	1
Red-eyed babbler	*Chrysomma sinense*	1
Scimitar babbler	*Pomatorhinus schisticeps*	1
White-crested laughing thrush	*Garrulax bicolor*	4
Black-headed sibia	*Heterophasia capistrata*	2
Silver-eared mesia	*Mesia argentauris*	3
Pekin robin	*Leiothrix luteus*	5
Pycnonotidae:		
Red-eared bulbul	*Pycnonotus jocosus*	1
Black-headed bulbul	*Pycnonotus atriceps*	2
Red-vented bulbul	*Pycnonotus cafer*	4
White-cheeked bulbul	*Pycnonotus leucogenys*	3
White-eared bulbul	*Pycnonotus leucotis*	1
Turdidae:		
Robin, albino	*Turdus migratorius*	1
European song thrush	*Turdus ericetorum*	2
Blackbird	*Turdus merula*	1
Cliff chat	*Thamnolaea cinnamomeiventris*	1
Bombycillidae:		
Cedar waxwing	*Bombycilla cedrorum*	1

Family and common name	*Scientific name*	*Number*
Sturnidae:		
Rose-colored pastor	*Pastor roseus*	1
Purple starling	*Lamprocolius purpureus*	3
Burchell's long-tailed starling	*Lamprotornis caudatus*	1
Amethyst starling	*Cinnyricinclus leucogaster*	1
Tri-colored starling	*Spreo superbus*	1
Jungle mynah	*Acridotheres tristis*	1
Lesser hill mynah	*Gracula religiosa indica*	3
Greater Indian hill mynah	*Gracula religiosa intermedia*	2
Nectariniidae:		
Variable sunbird	*Cinnyris venustus raceis*	1
Scarlet-tufted malachite sunbird	*Nectarinia johnstoni*	1
Beautiful sunbird	*Nectarinia pulchella*	1
Purple sunbird	*Nectarinia asiatica*	1
Zosteropidae:		
White-eye	*Zosterops palpebrosa*	2
Chloropseidae:		
Blue-winged fruit-sucker	*Chloropsis hardwickei*	2
Coerebidae:		
Black-headed sugarbird	*Chlorophanes spiza*	2
Bananaquit	*Coereba flaveola*	1
Parulidae:		
Kentucky warbler	*Oporornis formosus*	1
Redstart	*Setophaga ruticilla*	1
Ovenbird	*Seiurus aurocapillus*	1
Ploceidae:		
Red-naped widowbird	*Coliuspasser laticauda*	4
Giant whydah	*Diatropura procne*	1
Baya weaver	*Ploceus baya*	3
Vitelline masked weaver	*Ploceus vitellinus*	1
Red bishop weaver	*Euplectes orix*	1
White-headed nun	*Lonchura maja*	2
Indian silverbill	*Lonchura malabarica*	1
Bengalese finch	*Lonchura* sp	3
Cut-throat weaver finch	*Amadina fasciata*	1
Lavender finch	*Estrilda coerulescens*	1
Strawberry finch	*Estrilda amandava*	1
Common waxbill	*Estrilda troglodytes*	1
Zebra finch	*Poephila castanotis*	7
Gouldian finch	*Poephila gouldiae*	1
Icteridae:		
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	1
Rice grackle	*Psomocolax oryzivora*	2
Swainson's grackle	*Holoquiscalus lugubris*	1
Glossy cowbird	*Molothrus bonariensis*	2
Brown-headed cowbird	*Molothrus ater*	1
Bay cowbird	*Molothrus badius*	1
Colombian red-eyed cowbird	*Tangavius armenti*	1
Red-winged blackbird	*Agelaius phoeniceus*	2
Red-breasted marshbird	*Leistes militaris*	4

Family and common name	*Scientific name*	*Number*
Thraupidae:		
Palm tanager	*Tanagra palmarum*	1
Blue tanager	*Thraupis cana*	1
White-edged tanager	*Thraupis leucoptera*	1
Yellow-rumped tanager	*Ramphocelus icteronotus*	1
Passerini's tanager	*Ramphocelus passerinii*	1
Maroon, or silver-beaked, tanager	*Ramphocelus jacapa*	2
Fringillidae:		
Tropical seed finch	*Oryzoborus torridus*	2
Rice grosbeak	*Oryzoborus crassirostris*	1
Evening grosbeak	*Hesperiphona vespertina*	1
Black-throated cardinal	*Paroaria gularis*	3
Cardinal	*Richmondena cardinalis*	1
European linnet	*Acanthis cannabina*	1
European goldfinch	*Carduelis carduelis*	1
Green finch	*Chloris chloris*	1
Lesser yellow finch	*Sicalis luteola*	1
Saffron finch	*Sicalis flaveola*	3
White-lined finch	*Spermophila lineola*	4
Slate-colored junco	*Junco hyemalis*	1
Buff-throated saltator	*Saltator maximus*	1
Tawny-bellied seedeater	*Sporophila minuta*	5
Song sparrow	*Melospiza melodia*	1
Dickcissel	*Spiza americana*	3
White-crowned sparrow	*Zonotrichia leucophrys*	2
Yellowhammer	*Emberiza citrinella*	1
European bunting	*Emberiza calandra*	1
Jacarini finch	*Volatinia jacarini*	4

REPTILES

LORICATA

Alligatoridae:		
Caiman	*Caiman sclerops*	4
Black caiman	*Melanosuchus niger*	7
American alligator	*Alligator mississipiensis*	17
Chinese alligator	*Alligator sinensis*	2
Crocodilidae:		
Broad-nosed crocodile	*Osteolaemus tetraspis*	2
African crocodile	*Crocodylus niloticus*	3
Narrow-nosed crocodile	*Crocodylus cataphractus*	1
Salt-water crocodile	*Crocodylus porosus*	1
American crocodile	*Crocodylus acutus*	1
Gavialidae:		
Indian gavial	*Gavialis gangeticus*	1

CHELONIA

Chelydridae:		
Snapping turtle	*Chelydra serpentina*	13
Alligator snapping turtle	*Macrochelys temminckii*	1
Kinosternidae:		
Musk turtle	*Sternotherus odoratus*	4
Mud turtle	*Kinosternon subrubrum*	5
South American mud turtle	*Kinosternon cruentatum*	1

Family and common name	*Scientific name*	*Number*
Emydidae:		
Box turtle	*Terrapene carolina*	63
Three-toed box turtle	*Terrapene carolina triunguis*	2
Ornate box turtle	*Terrapene ornata ornata*	1
Florida box turtle	*Terrapene bauri*	5
Kura kura box turtle	*Cuora amboinensis*	2
Diamondback turtle	*Malaclemys terrapin*	6
Map turtle	*Graptemys geographica*	1
Mississippi map turtle	*Graptemys kohni*	3
Barbour's map turtle	*Graptemys barbouri*	4
Painted turtle	*Chrysemys picta*	10
Western painted turtle	*Chrysemys picta belli*	12
Southern painted turtle	*Chrysemys dorsalis*	1
Cumberland turtle	*Pseudemys troostii*	7
South American red-lined turtle	*Pseudemys scripta callirostris*	2
Yellow-bellied turtle	*Pseudemys scripta scripta*	18
Red-bellied turtle	*Pseudemys rebriventris*	8
Red-eared turtle	*Pseudemys scripta elegans*	33
Southern water turtle	*Pseudemys floridana*	7
Florida red-bellied turtle	*Pseudemys nelsoni*	2
Central American turtle	*Pseudemys ornata*	2
Cuban water turtle	*Pseudemys decussata*	1
Chicken turtle	*Deirochelys reticularia*	2
Spotted turtle	*Clemmys guttata*	2
Wood turtle	*Clemmys insculpta*	5
Iberian pond turtle	*Clemmys leprosa*	2
European water terrapin	*Clemmys caspica rivulata*	13
European pond turtle	*Emys orbicularis*	3
Blanding's, or semi-box, turtle	*Emys blandingii*	3
Reeves's turtle	*Chinemys reevesii*	4
Testudinidae:		
Duncan Island tortoise	*Testudo ephippium*	2
Galapagos tortoise	*Testudo vicina*	2
Galapagos tortoise	*Testudo elephantopus*	1
Giant Aldabra tortoise	*Testudo elephantina*	2
South American tortoise	*Testudo denticulata*	5
Star tortoise	*Testudo elegans*	2
Mountain tortoise	*Testudo emys*	2
Hermann's tortoise	*Testudo hermanni*	1
Gopher tortoise	*Gopherus polyphemus*	2
Texas gopher tortoise	*Gopherus berlandieri*	1
Pelomedusidae:		
African water turtle	*Pelusios sinuatus*	2
African black mud turtle	*Pelusios subniger*	1
Amazon spotted turtle	*Podocnemis unifilis*	4
Chelydidae:		
Southern American side-necked turtle	*Batrachemys nasuta*	2
Australian side-necked turtle	*Chelodina longicollis*	3
Matamata turtle	*Chelys fimbriata*	2
Small side-necked turtle	*Hydromedusa tectifera*	2
Large side-necked turtle	*Phrynops hilarii*	7

Family and common name	Scientific name	Number
Chelydidae—Continued		
Krefft's turtle	*Emydura krefftii*	3
Murray turtle	*Emydura macquarrii*	3
South American gibba turtle	*Mesoclemmys gibba*	2
Flat-headed turtle	*Platemys platycephala*	2
Trionychidae:		
Southern soft-shelled turtle	*Trionyx ferox*	4
Texas soft-shelled turtle	*Trionyx emoryi*	1
African soft-shelled turtle	*Trionyx triunguis*	2
	SAURIA	
Gekkonidae:		
Tokay gecko	*Gekko gecko*	21
Day gecko	*Phelsuma cepedianum*	2
Day gecko	*Phelsuma* sp	2
Iguanidae:		
Common iguana	*Iguana iguana*	2
Carolina anole	*Anolis carolinensis*	75
Texas horned lizard	*Phrynosoma cornutum*	1
Crevice spiny lizard	*Sceloporus poinsetti*	2
Spiny-tailed iguana	*Ctenosaura acanthura*	2
Agamidae:		
Agamid lizard	*Hoplurus saxicola*	1
Scincidae:		
Mourning skink	*Egernia luctuosa*	2
White's skink	*Egernia whitei*	3
Greater five-lined skink	*Eumeces fasciatus*	1
Great Plains skink	*Eumeces obsoletus*	2
Stump-tailed skink	*Tiliqua rugosa*	1
Malayan skink	*Mabuya multifasciata*	2
Gerrhosauridae:		
African plated lizard	*Zonosaurus* sp	2
Madagascar plated lizard	*Zonosaurus madagascariensis*	2
Plated lizard	*Gerrhosaurus major*	1
Lacertidae:		
European lizard	*Lacerta strigata trilineata*	1
European green lizard	*Lacerta viridis*	3
European lizard	*Lacerta erhardtii*	1
European wall lizard	*Lacerta muralis*	1
Teiidae:		
Ameiva lizard	*Ameiva ameiva praesignis*	1
Yellow tegu	*Tupinambis teguixin*	2
Whip-tailed lizard	*Cnemidophorus tigris*	1
Teiid lizard	*Cnemidophorus* sp	1
Cordylidae:		
South African spiny lizard	*Cordylus vandami perkoensis*	2
Varanidae:		
Duméril's monitor	*Varanus dumerili*	2
Malayan monitor	*Varanus salvator*	1
Philippine monitor	*Varanus nuchalis*	2
Helodermatidae:		
Mexican beaded lizard	*Heloderma horridum*	3
Beaded lizard, black phase	*Heloderma horridum alvernensis*	1

Family and common name	Scientific name	Number
Anguidae:		
Glass lizard	*Ophisaurus ventralis*	3
European glass lizard	*Ophisaurus apodus*	2

SERPENTES

Family and common name	Scientific name	Number
Boidae:		
Anaconda	*Eunectes murinus*	1
Cook's tree boa	*Corallus enydris cooki*	4
Emerald tree boa	*Corallus caninus*	1
Boa constrictor	*Constrictor constrictor*	4
Emperor boa	*Constrictor imperator*	1
Cuban ground boa	*Tropidophis melanura*	1
Rainbow boa	*Epicrates cenchria*	3
Cuban tree boa	*Epicrates angulifer*	3
Sand boa	*Eryx conica*	3
Ball python	*Python regius*	2
Indian rock python	*Python molurus*	3
Regal python	*Python reticulatus*	4
African python	*Python sebae*	1
Acrochordidae:		
Elephant trunk snake	*Acrochordus javanicus*	1
Colubridae:		
King snake	*Lampropeltis getulus getulus*	2
Speckled king snake	*Lampropeltis getulus holbrooki*	2
California king snake	*Lampropeltis getulus californiae*	1
Florida king snake	*Lampropeltis getulus floridana*	2
Sonoran king snake	*Lampropeltis getulus splendida*	1
Scarlet king snake	*Lampropeltis triangulum doliata*	1
Milk snake	*Lampropeltis triangulum*	1
Tropical king snake	*Lampropeltis polyzonus*	1
Garter snake	*Thamnophis sirtalis sirtalis*	2
Garter snake, melanistic phase	*Thamnophis sirtalis*	4
Ribbon snake	*Thamnophis sauritus*	1
Eastern hognosed snake	*Heterodon platyrhinos*	1
Common water snake	*Natrix sipedon*	2
Red-bellied water snake	*Natrix erythrogaster*	1
European grass snake	*Natrix natrix natrix*	5
Brazos water snake	*Natrix harteri*	1
Water snake	*Natrix harteri paucimaculata*	2
Diamondback water snake	*Natrix rhombifera*	4
Queen snake	*Natrix septemvittata*	1
Brown water snake	*Natrix taxispilota*	1
Broad-banded water snake	*Natrix confluens*	6
Blotched water snake	*Natrix transversa*	12
Yellow-bellied water snake	*Natrix flavigaster*	5
Indigo snake	*Drymarchon couperi*	1
Western indigo snake	*Drymarchon erebennus*	1
Pilot black snake	*Elaphe obsoleta obsoleta*	2
Pilot black snake, albino	*Elaphe obsoleta obsoleta*	1
Corn snake	*Elaphe obsoleta guttata*	1
Corn snake, albino	*Elaphe obsoleta guttata*	1
Fox snake	*Elaphe vulpina*	1

Family and common name	*Scientific name*	*Number*
Colubridae—Continued		
Formosan striped rat snake	*Elaphe taeniura*	5
Lindheimer's snake	*Elaphe lindheimeri*	2
Great Plains rat snake	*Elaphe emoryi*	1
Chicken snake	*Elaphe quadrivittata*	1
Aesculapian snake	*Elaphe longissima*	4
Aesculapian snake	*Elaphe longissima subgrisea*	1
Rainbow snake	*Abastor erythrogrammus*	1
Formosan cat-eyed snake	*Dinodon rufozonatum*	4
Cat-eyed snake	*Leptodeira annulata*	1
Black racer	*Coluber constrictor constrictor*	1
European racer	*Coluber jugularis caspius*	2
Red racer	*Masticophis flagellum frenatum*	1
Eastern coachwhip	*Masticophis flagellum*	1
Western coachwhip	*Masticophis flagellum testaceus*	2
Ring-necked snake	*Diadophis punctatus edwardsii*	1
Eastern worm snake	*Carphophis amoenus*	1
DeKay's snake	*Storeria dekayi*	1
Green whip snake	*Dryophis prasinus*	1
Bull snake	*Pituophis sayi*	2
Florida pine snake	*Pituophis mugitus*	1
Great Basin gopher snake	*Pituophis catenifer deserticola*	1
File snake	*Simocephalus capensis*	1
Wolf snake	*Lycodon flavomaculatus*	1
Cat-eyed snake	*Eteirodipsas* sp	1
Green-headed tree snake	*Leptophis mexicanus*	1
Bronze vine snake	*Oxybelis aeneus*	1
Elapidae:		
Coral snake	*Micrurus tenere*	1
Indian cobra	*Naja naja*	1
Taiwan cobra	*Naja naja atra*	11
King cobra	*Ophiophagus hannah*	2
Many-banded krait	*Bungarus multicinctus*	4
Crotalidae:		
Southern copperhead	*Ancistrodon contortrix contortrix*	5
Northern copperhead	*Ancistrodon contortrix mokeson*	2
Broad-banded copperhead	*Ancistrodon contortrix laticinctus*	1
Cottonmouth water moccasin	*Ancistrodon piscivorus*	3
Western water moccasin	*Ancistrodon leucostoma*	9
Cantil	*Ancistrodon bilineatus*	3
Eastern massasauga	*Sistrurus catenatus catenatus*	1
Pygmy rattlesnake	*Sistrurus miliarius*	1
Green palm viper	*Trimeresurus gramineus*	1
Green palm viper	*Trimeresurus stejnegeri*	1
Mamushi	*Trimeresurus elegans*	1
Habu	*Trimeresurus flavoviridis*	2
Taiwan habu	*Trimeresurus okinavensis*	1
Western diamondback rattlesnake	*Crotalus atrox*	8
Timber rattlesnake	*Crotalus horridus*	4
Viperidae:		
Puff adder	*Bitis arietans*	1

AMPHIBIANS

CAUDATA

Family and common name	*Scientific name*	*Number*
Cryptobranchidae:		
Giant salamander	*Megalobatrachus japonicus*	2
Amphiumidae:		
Congo eel	*Amphiuma means*	1
Ambystomatidae:		
Spotted salamander	*Ambystoma maculatum*	1
Salamandridae:		
Japanese red-bellied newt	*Diemictylus pyrrhogaster*	8
Red-spotted newt	*Diemictylus viridescens*	14
Broken-striped newt	*Diemictylus viridescens dorsalis*	7

SALIENTIA

Bufonidae:		
American toad	*Bufo terrestris americanus*	1
Fowler's toad	*Bufo woodhousei fowleri*	3
Blomberg's toad	*Bufo blombergi*	2
Giant toad	*Bufo marinus*	6
Cuban toad	*Bufo peltocephalus*	6
Central American toad	*Bufo typhonius*	2
Pelobatidae:		
European spadefoot toad	*Pelobates fuscus*	3
Pipidae:		
Surinam toad	*Pipa pipa*	12
African clawed frog	*Xenopus laevis*	3
Leptodactylidae:		
Colombian horned frog	*Ceratophrys calcarata*	2
Hylidae:		
Raddi's frog	*Hyla raddiana*	1
Barking tree frog	*Hyla gratiosa*	1
European tree frog	*Hyla arborea*	1
Gray tree frog	*Hyla versicolor*	2
Microhylidae:		
Narrow-mouthed toad	*Microhyla carolinensis*	2
Ranidae:		
River frog	*Rana heckscheri*	1
African bull frog	*Rana adspersa*	1
American bull frog	*Rana catesbeiana*	1
Green frog	*Rana clamitans*	1
Leopard frog	*Rana pipiens*	25

FISHES

NEOCERATODONTOIDEI

Protopteridae:		
African lungfish	*Protopterus annectens*	2
Snake-headed fish	*Polypterus palmas*	1

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OSTARIOPHYSOIDEI

Family and common name	*Scientific name*	*Number*
Characidae:		
Piranha	*Serrasalmus niger*	1
Metynnis	*Metynnis maculatus*	1
Black tetra	*Gymnocorymbus ternetzi*	1
Cyprinidae:		
Zebra danio	*Brachydanio rerio*	4
Tiger barb	*Barbus partipentazona*	1
White cloud mountain fish	*Tanichthys albonubes*	1
Electrophoridae:		
Electric eel	*Electrophorus electricus*	8

CYPRINODONTOIDEI

Poeciliidae:		
Flag-tailed guppy	*Lebistes reticulatus*	10
Guppy	*Lebistes reticulatus*	15
Black mollie	*Mollienesia latipinna*	1
Platy, or moonfish	*Xiphophorus maculatus*	5

PERCOMORPHOIDEI

Anabantidae:		
Climbing perch	*Anabas testudineus*	3
Kissing gourami	*Helistoma temmincki*	1
Centrarchidae:		
Common bluegill	*Lepomis macrochirus*	1
Cichlidae:		
Peacock cichlid	*Astronotus ocellatus*	1
Egyptian mouthbreeder	*Haplochromis multicolor*	1
African mouthbreeder	*Pelmatochromis belladorsalis*	1
Angelfish	*Pterophyllum eimekei*	1
Jack Dempsey fish	*Cichlasoma biocellatum*	3
Gobiidae:		
Bumblebee fish	*Brachygobius doriae*	1
Locariidae:		
South American catfish	*Plecostomus plecostomus*	2

ARTHROPODS

DECAPODA

Cenobitidae:		
Land hermit crab	*Coenobita clypeatus*	23

ARANEIDA

Theridiidae:		
Black-widow spider	*Latrodectus mactans*	1
Aviculariidae:		
Tarantula	*Eurypelma* sp	3

ORTHOPTERA

Blattidae:		
Tropical giant cockroach	*Blaberus giganteus*	50

MOLLUSKS

PULMONATA

Planorbidae:		
Pond snail	*Helisoma trivolvis*	30

REPORT OF THE VETERINARIAN

The National Zoological Park was without a veterinarian from July 1, 1962, until May 6, 1963, when Dr. Clinton Gray was appointed. During the interim, the director and the general curator, assisted by Thomas Schneider as medical technologist, shared the responsibility for the health of the animals. They were fortunate in having the cooperation and assistance of men in various fields of clinical investigation and medicine. Among these were: Dr. Leonard Marcus and staff, of the Armed Forces Institute of Pathology; Dr. Clarence Hartman and staff, of George Washington University; Dr. M. B. Chitwood, Dr. A. McIntosh, and Dr. W. W. Becklund of the Beltsville Parasitological Laboratory, Department of Agriculture; Dr. A. G. Karlson, Mayo Clinic, Rochester, Minn.; Dr. F. R. Lucas, director of the Livestock Sanitary Laboratory, Centreville, Md.; and Dr. Anthony Morris of the National Institutes of Health, Bethesda, Md.

In October, Tomoka, the baby gorilla, became ill with an intestinal infection. Local pediatricians were called into consultation, but when the animal did not respond to treatment he was taken to Children's Hospital and put in an animal research laboratory under the care of Dr. Everett Lovrein, resident physician, and Dr. Robert E. Martin. Headkeeper Ralph Norris and senior keeper Bernard Gallagher stayed with the little ape 24 hours a day, and he made a speedy recovery. Despite a serious prognosis—Shigellosis complicated by dehydration and acidosis—Tomoka made a remarkable return to his normal weight gain after this hospitalization.

Nikumba, the adult male gorilla, showed signs of having a cold about the middle of June. Medication was given, and he appeared to be recovering, when he was stricken with bilateral paralysis. As of June 30, prognosis is impossible, but he is being treated by an orthopedic surgeon, Dr. Henry Feffer, and a neurosurgeon, Dr. Hugo V. Rizzoli, in consultation with Dr. Alf Nachemson, orthopedic surgeon of the University of Gothenburg, Sweden.

Specialists from George Washington University Medical School tried to establish a suspected pregnancy in Ambika, one of the Indian elephants, by means of electrocardiographic equipment. Electrocardiographs had been taken in the Portland (Oreg.) Zoo when their elephants were pregnant. In the case of Ambika, however, no fetal heartbeat could be detected, and she has now gone past the time for giving birth since the last possible conception date.

The bharal or blue sheep (*Pseudois nayaur*) was inadvertently omitted from the inventory printed in last year's annual report. On July 5, 1962, the last of the line, a female, died, and the post mortem showed liver abscesses. The original pair of these beautiful animals was brought to the Zoo in October 1937 by the National Geographic

Society-Smithsonian Institution Expedition to Netherlands East Indies, having been secured from an animal dealer in Shanghai. Seven young were born in the National Zoological Park between 1939 and 1945.

Following are the statistics for the mortality rates at the National Zoological Park for the past fiscal year and a table of comparison with the past 7 fiscal years:

Mortality, fiscal year 1963				Total mortality, past 7 years
Cause	Reptiles	Birds	Mammals	
No autopsy for sundry reasons [1]	149	35	10	1957----549
Attrition (within 7–14 days after arrival)	--------	21	5	1958----550
Internal diseases	67	37	29	1959----472
Infectious diseases	--------	5	4	1960----532
Parasites	27	2	1	1961----517
Injuries, accidents	5	96	21	1962----584
Euthanasia	--------	2	6	------------
Miscellaneous (stillborn, old age, shock)	8	3	7	------------
Undetermined	21	46	29	------------
Total	277	247	112	1963----636

[1] Reasons include preserving intact specimen for museum and research, progressed decomposition, insufficient remains in case of predators, etc.

VISITORS

Advanced planning for a National Zoological Park attendance survey began in August 1961 under the direction of Albert Mindlin, statistician of the Management Office, District of Columbia. The actual collection of data commenced on July 1, 1962, and was tabulated for the following 12 months.

The primary purposes of the survey are to obtain objective estimates of the total number of visitors during the fiscal year, the average number of visitors in the Park at any specific period during the year, and the average length of time a visitor's automobile remains within the Zoo.

The procedure involved hand-punching IBM porto-punchcards by specially trained and recruited employees on a statistically predetermined basis at all entrances and exits of the Zoo. Sample interviews of pedestrians and cars leaving at any gate were used as visitor determining factors.

The hand-punched-card data thus generated were mechanically converted into computer-adapted punchcards and fed into an especially programmed IBM 1401 B computer of the Science Information Exchange of the Smithsonian Institution.

Although the entire project had not been completed at the end of the year, projection of the data of the first 7 months forecasts a visitor population in excess of 3,200,000 from July 1, 1962, to June 30, 1963.

Number of bus groups visiting the Zoo in fiscal year 1963

Locality	Number of groups	Number in groups	Locality	Number of groups	Number in groups
Alabama	41	1, 284	Missouri	3	113
Arkansas	5	175	Nebraska	3	118
Colorado	3	90	New Hampshire	7	257
Connecticut	26	785	New Jersey	84	2, 851
Delaware	78	2, 197	New Mexico	11	279
District of Columbia	409	15, 185	New York	318	9, 539
Florida	105	3, 568	North Carolina	223	10, 047
Georgia	121	4, 025	Ohio	26	847
Illinois	15	501	Oklahoma	2	55
Indiana	4	186	Pennsylvania	552	19, 689
Iowa	3	130	Rhode Island	17	600
Kansas	3	94	South Carolina	60	2, 195
Kentucky	23	765	South Dakota	1	38
Louisiana	2	70	Tennessee	148	4, 752
Massachusetts	11	438	Texas	22	124
Maine	8	334	Virginia	1, 734	55, 429
Maryland	2, 260	64, 283	West Virginia	153	4, 693
Michigan	8	424	Wisconsin	2	115
Minnesota	1	41	Total	6, 496	206, 444
Mississippi	4	128			

About 2 p.m. each day the cars then parked in the Zoo are counted and listed according to the State or country from which they come. 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 fiscal year 1963 is as follows:

	Percentage		Percentage
Maryland	31.4	Massachusetts	0.8
Virginia	21.5	South Carolina	.7
District of Columbia	19.3	Illinois	.6
Pennsylvania	4.4	Connecticut	.6
New York	2.5	California	.6
North Carolina	1.9	Tennessee	.5
Ohio	1.4	Michigan	.5
New Jersey	1.4	Georgia	.5
West Virginia	1.3	Texas	.5
Florida	1.0	Indiana	.4

The remaining 8.2 percent came from other States, Canada, Canal Zone, France, Germany, Italy, Japan, Mexico, Newfoundland, Peru, Puerto Rico, and Saipan.

On the days of even small attendance there are cars parked in the Zoo from at least 15 States, the District of Columbia, and foreign countries. On average days there are cars from approximately 22 States, the District of Columbia, and foreign countries; and during the periods of greatest attendance the cars represent no less than 34 different States and countries.

PERSONNEL

Dr. Clinton W. Gray was appointed veterinarian on May 6, 1963. Prior to his appointment at the Zoo, Dr. Gray was employed as veterinarian by the Agency for International Development and spent considerable time overseas.

Henry P. (Harry) Leech, who for more than 20 years had been associated with his father, L. Gordon Leech, in the management of the Zoo restaurant, died on June 26 at the age of 41. He was well known to Zoo visitors, and particularly to the "Anteaters" who meet in the fall to eat wild game at the restaurant. He will be greatly missed by his many friends.

During the year eight employees retired. Pvt. Robert Ewell, appointed March 6, 1912, retired December 31, 1962. Most of his 50 years of service had been with the police force on night duty. Roy Jennier, appointed October 18, 1929, was for many years in charge of the reptile house. He was a member of the National Geographic-Smithsonian Expedition to the East Indies in 1937. At the time of his retirement, December 31, 1962, he was supervisory animal keeper in the monkey house. James Derrow, who also retired on December 31, was maintenance general foreman and responsible for all construction and repairs in the Zoo. He had been with the Park more than 30 years since his appointment on July 6, 1931. Michael Dubik, head supervisory gardener since July 31, 1956, retired May 24, 1963, because of ill health; Frank Mele, mason leader appointed July 24, 1947, retired August 18, 1962; Mirza Wilson, chief operating engineer appointed June 19, 1950, retired April 27, 1963; Lizzie McDaniel, custodial laborer since May 1, 1953, retired February 8, 1963; and Dave Rose, laborer, appointed March 2, 1949, retired April 30, 1963.

The director attended the annual meeting of the American Association of Zoological Parks and Aquariums in Kansas City, Mo., in September and was voted president-elect for 1962–63. He also attended the meeting of the International Union of Directors of Zoological Gardens in San Diego, Calif., later that same month. On

November 20 he attended the formal opening of the new zoo in Phoenix, Ariz. On March 1, he traveled to Fort Worth, Tex., for the board meeting of the American Association of Zoological Parks and Aquariums. On March 31, accompanied by Richard Dimon, project architect for the new construction at the National Zoological Park, he left for a short study tour of European zoos.

J. Lear Grimmer, associate director, attended the meeting of the American Association of Zoological Parks and Aquariums in Kansas City, and Travis E. Fauntleroy, assistant to the director, attended the midwinter conference of the same association at Fort Worth.

In 1963 there were 210 authorized positions, an increase of 5 positions over 1962: office of the director, 11; operations and maintenance department, which includes the mechanical division, police division, grounds division, and services division, 122, an increase of 4 (1 mechanic, 1 hydraulic equipment operator, 1 tree maintenance worker, and 1 laborer); animal department, 76, an increase of 1 (night keeper); and the scientific research department, 1.

ANIMAL DEPARTMENT

In preparation for reconstruction work planned for the National Zoological Park, several existing areas were made suitable to house evacuated animals. The entire stock of the birdhouse was moved to various outdoor enclosures and to the old antelope house, which had been closed to the public for several years. Converting the antelope house into a temporary birdhouse required the construction of one large flight cage and the rewiring of some of the old antelope stalls.

A number of animals that were heretofore housed singly were carefully introduced to one another, and by keeping several together in one cage, additional space was made available.

To utilize space further, the animal department continued the program begun last year of wintering tropical animals outdoors. A "flight cage" which had originally been built for indoor use by gibbons was rebuilt on the northeast side of the lion house. It was equipped with cinderblock and concrete shelters with one heat lamp and soil-cable floor heat in each shelter. A group of four young animals and a fully adult breeding pair were moved into this outdoor enclosure in August in order to give them sufficient time to become accustomed to the gradual drop of temperatures in autumn. The female of the adult pair gave birth to a baby in December, which she carefully nursed, bringing it outdoors for at least 2 hours a day except during bad weather.

Theoretically much less suited to withstand severe winter temperatures outdoors was a pair of South American tapirs, transferred to the so-called beaver pond late in summer. A shelter with tinfoil insulation between two layers of boards was constructed, but no artificial heat was installed. With the onset of cold weather, deep straw bedding was provided. Both tapirs were put on a diet of approximately eight fish a day in addition to their normal ration of fresh vegetables and A-1 ration. Despite the fact that the pond froze over completely for the better part of 4 months, both animals survived without any damage to the skin or feet. Neither animal appeared to object to the snow on the ground, and their customary summertime motion pattern was clearly indicated by footprints in the snow.

Patagonian cavies, another unusual species, were also successfully wintered. Although these animals were provided with a noninsulated but well-built shelter, they preferred to make their own excavations in frozen ground and seek shelter below the house provided. Six young have been born in this enclosure since February.

A number of tropical birds, primarily psittacines, wintered outdoors, provided only with minimal heated-perch shelters with infrared lamps.

Two female lion cubs born at the Zoo in March 1962 spent most of the winter in a large, exposed, open-air cage with no protection other than a continuously open indoor shelter which was rarely, if ever, used during the daytime.

The total number of accessions for the year was 986. This includes gifts, purchases, exchanges, deposits, births, and hatchings.

POLICE DIVISION

The most important activity of the police division was the creation of a law enforcement school. Appointed as training officer, Lt. D. B. Bell formulated plans for a comprehensive training program. Its value was readily recognized and received official approval for its implementation from the Secretary of the Smithsonian Institution. The course encompassed ten 8-hour days of sessions, at the conclusion of which an examination was given to participants. It was a highly successful venture, and it is now a basic requirement of the National Zoological Park police that all new officers must take and pass the course.

Three members of the division, Lieutenant Wolfe, Sergeant Grubbs, and Private Porter, were qualified as pistol instructors for the police force by special agent William Little, of the Security Branch, State Department, in September 1962. Fourteen visitors sent in written commendations on the courtesy, kindness, and consideration extended to the general public by the police. Through the efforts of Lt. J. R. Wolfe, 24 certificates were awarded by the American Red

Cross to employees of the National Zoological Park who have donated a gallon or more of blood to the blood-donor program.

Six walkie-talkie sets were acquired to facilitate direct communication between headquarters and the officers on outside duty in the Park. Two sets have been assigned to the animal department and have proved very useful.

The police, under the supervision of Private Adams, assisted Albert Mindlin of the Management Office of the District of Columbia in making the visitors' survey, as noted elsewhere in this report.

In January 1963 the Federal Bureau of Investigation requested from the division a monthly report on the number of arrests and complaints, to be used by the FBI in its compilation of data on the total crimes committed in the United States.

A total of 92 truant children were picked up in the Park, and appropriate action was taken by the division. The police found 311 lost children and returned them to their parents or chaperones. Eighteen pairs of eyeglasses and sunglasses, found and unclaimed, were sent to the Society for the Prevention of Blindness, and nine bags of clothing and miscellaneous articles, found and unclaimed, were turned over to Goodwill Industries. During the year 9,776 visitors stopped at the police station requesting various types of information. The first-aid station, at police headquarters, treated 69 severe cases and 705 minor cases.

The American Red Cross Blood Bank received 67 pints of blood from Zoo employees during the year. Total donations are now well over 700 pints.

MAINTENANCE, CONSTRUCTION, AND GROUNDS

The mechanical division has the responsibility for the maintenance and repair of the buildings and facilities of the National Zoological Park. This responsibility is met by the heating and ventilating section, and by the building section which, in addition to continuing maintenance, constructed numerous new shelters, paddocks, and cages for the animals exhibited.

The renovations of the puma house and the main bear line were completed. The interior dens at the puma house are now completely rebuilt. Five partition walls at the bear line were rebuilt, using the gunnite or sprayed concrete which proved so satisfactory during the previous year.

A new exhibit for gibbons was constructed in the area adjacent to the lion house. The cage, 12 by 40 feet, provides two separate enclosures, each large enough to allow space for the gymnastics of these animal aerialists.

Results of the maintenance program are most apparent in the reptile building. The new paint in the visitor area and the rebuilding and decorating of the cages, along with the contract work done as a safety measure, have resulted in an orderly, well-kept building. Among the improvements not readily apparent are the new electric panels which provide uninterrupted service for the electric lighting as well as power for the refrigeration and other commissary activities in the reptile-house basement.

The sign program, now well underway, required the coordination of the carpenter shop, paintshop, and metal shop to frame, paint, and erect the attractive and informative signs on the various exhibits throughout the Zoo.

The remodeling of the birdhouse and the construction of the new east-west access road put an additional burden on the mechanical division, as temporary shelters and enclosures had to be improvised for the birds and animals dislocated by the new construction. A flight cage was built in the old antelope house to provide a temporary home for birds evacuated from the birdhouse. A shelter and enclosure were provided for the dorcas gazelles, relocated because of the new road. In addition, a new yard with heavy fencing was prepared for the Cape buffalo.

The deep excavation required to maintain a suitable gradient for the new perimeter road unearthed a myriad of sewers and waterlines which had to be traced and relocated, thus adding to the already heavy workload of the plumbing crew.

Many of the improvements made during the year were in the interests of safety. In cooperation with the District of Columbia Department of Buildings and Grounds, practically all the glass cage fronts at the reptile house were replaced, as were also several large panes of glass separating the visitors from the animals in the small-mammal house.

The eagle cage, which is to remain in the remodeled birdhouse area, was painted under a contract with a local rigging company.

The walkway from the fox line through the hollow up to the owl and silver-gull cages was resurfaced, and road repairs were made.

The grounds department moved many plants from the birdhouse area to the center of the Zoo, sodded several areas where there previously had been no grass, and enhanced the appearance of the Park by the addition of flower beds around the buildings. A number of plants and shrubs were purchased, and donations of flowers and plants were received from the District of Columbia Waterworks, the Botanical Garden, Navy Hospital, Naval Ordnance, and the management of the annual flower show.

The building occupied by the grounds department was renovated to clear walkways and to store tools and equipment so as to eliminate trip hazards. Steel helmets, new ropes, and climbing equipment were placed in service, and an additional treeman was hired. Low limbs over bridle paths were cut, and dead limbs removed from 140 trees over walks and along the main road. Forty trees in bad condition were cut and removed. Large holes in lawns were filled in.

INFORMATION AND EDUCATION

After the planning, equipping, and staffing of a sign laboratory in the basement of the elephant house, which was completed October 12, 1962, the department's activities for the year were mainly concerned with the writing, designing, producing, and mounting of new modern animal identification labels for the Zoo. Durable outdoor labels are printed photographically on sensitized anodized aluminum. Other techniques of exhibits production successfully employed are silk-screen prints and film transparencies for indoor labeling.

To date, five units of the Zoo have been completely relabeled—the puma house, main bear line, short bear line, ring cages, and the elephant house. The reptile house is being labeled. A total of 397 animal identification labels and other supporting Zoo signs (such as large maps of the Zoo, explanation of the new construction, building and safety signs) were produced and mounted in the period from October 12, 1962, to June 30, 1963.

Additional department activities during the year included artwork, charts, graphs, mapwork, a number of special projects, dissemination of animal information by telephone and correspondence, library maintenance, and 18 special guided tours for groups of handicapped children, visiting schools, and foreign guests.

On July 10, 1962, a group of 2,300 foreign exchange students visited the Zoo; on May 12, 1963, 9,248 School Safety Patrol children, transported in 266 buses, came to the Zoo following their annual parade on Constitution Avenue. A group of the animal keepers, on their day off, entertained the underprivileged children from D.C. Junior Village, taking them on a tour of the Zoo and giving them lunch in the cafeteria. On May 24, 250 "Friends of the National Zoo" were given a guided night tour of the Park.

The director gave two radio talks and three talks to local organizations. He appeared on television, once in Sarasota, Fla., in connection with the proposed establishment of a zoo, and once on WTOP (Washington) with Dr. W. T. Roth, general curator. The associate director, J. Lear Grimmer, addressed the University Club, Wilmington, Del., in connection with the development of a zoo in that city.

The September 1962 issue of *Parks and Recreation* carried an article by Charles Thomas, senior keeper, on wintering tropical birds and animals outdoors. J. Lear Grimmer's account of his work with the hoatzin in British Guiana appeared in the September issue of *National Geographic Magazine.*

SAFETY SUBCOMMITTEE

The National Zoological Park safety subcommittee, consisting of Lt. John R. Wolfe, chairman; Capt. C. E. Brink, police division; F. M. Dellar, administration office; Bert J. Barker, animal department; Reily Straw, maintenance and construction; D. E. Schwartzbeck, grounds department; and Mrs. W. M. Holden, secretary, held monthly meetings to suggest, discuss, and make recommendations to the director on safety improvements.

A self-survival course, given by the American Medical Association and sponsored by the American Red Cross, was attended by Sergeants Canter and Grubbs. Sergeants Canter and Kadlubowski attended a traffic workshop, sponsored by the National Safety Council. Shotguns were installed in locked gun cabinets with glass fronts, located in principal buildings, and seven keepers were given instructions in the proper handling of these guns in case of emergency.

Steps of some buildings were painted with black and yellow stripes as a caution to the public. All buildings have been checked for fire hazards and have exit lights installed at main exits.

Members of the subcommittee periodically inspect all buildings, grounds, and equipment in the Park and remove or correct all minor hazards affecting visitor or employee safety.

COOPERATION

At all times special efforts are made to maintain friendly contacts with other Federal 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 animals, and in turn it furnishes information and, whenever possible, animals it does not need.

Through the cooperation of the U.S. Fish and Wildlife Service, and Charles A. Milton, chief game warden, Maryland Game and Inland Fish Commission, a number of waterfowl were obtained for the Zoo. Division headkeeper W. Widman and keepers Bruce Williams and Robert Williams were permitted to trap a number of wild ducks and geese on Chesapeake Bay.

Special acknowledgment is due William Taback and John Pulaski, in the office of the Dispatch Agent in New York City, and Stephen E. Lato, Dispatch Agent in San Francisco, who are frequently called upon to clear shipments of animals coming from abroad, often at great personal inconvenience—late at night, or on a weekend.

When it is necessary to quarantine animals coming into this country, they are taken to the U.S. Department of Agriculture's station in Clifton, N.J. During the past year, Dr. H. A. Waters and Andy Goodel, two of the officials stationed there, have been most cooperative in keeping the National Zoological Park informed as to the well-being of animals and birds being held there for quarantine.

Animals that die in the Zoo are offered to the U.S. National Museum. If the Museum does not need them, either as study specimens or as exhibits, they are sent on request to research workers in other institutions. Specialists at the Museum are always willing to be of help in identifying rare specimens that are acquired by the Zoo.

The National Zoological Park cooperated with the National Capital Parks and lent small animals to Park naturalists and to the Nature Center in Rock Creek Park for demonstrations.

FINANCES

Funds for the operation of the National Zoological Park are appropriated annually under the District of Columbia Appropriation Act. The operation and maintenance appropriation for the fiscal year 1963 totaled $1,470,200, which was $119,400 more than for the previous year. The increase consisted of $48,300 to cover salary increases for wage-board employees; $23,700 for within-grade salary advancements for both general-schedule and wage-board employees; $18,000 to cover costs of reallocations; $17,820 to establish five new positions for 75 percent of the year; $7,080 for the purchase of supplies and materials; and $4,500 for the purchase of new equipment.

Of the total appropriation, 84.7 percent ($1,245,809) was used for salaries and related personnel costs, and 15.3 percent ($224,391) for the maintenance and operation of the Zoo. Included in the latter figure were $74,000 for animal food; $19,000 for fuel for heating; $26,680 for materials for building construction and repairs; $12,826 for electricity; $13,725 for the purchase of animals; $6,255 for telephone, postal, and telegraph services; and $7,460 for veterinarian equipment and supplies. The balance of $64,445 in operational funds was expended for other items, including freight, sundry supplies, uniforms, gasoline, road repairs, equipment replacement, and new equipment.

CAPITAL IMPROVEMENTS

Money appropriated this year for new construction totaled $1,227,000.

During the first part of the fiscal year the preparation of detailed plans for the first phase of the capital improvement program was continued. These plans were submitted in final form in November. Two separate bids were advertised and awarded.

The Edrow Engineering Co. was awarded the contract for the renovation and modernization of the birdhouse and the construction of a new walk-through flight cage. Work started on April 29, 1963. As noted elsewhere, the birds had been evacuated prior to this date. It is anticipated that the work will be completed in April 1964.

The Cherry Hill Sand & Gravel Co. was awarded the contract for the relocation of the east-west access road. Work started on March 27, 1963. The excavation and grading are now well underway, and it is anticipated that the road will be ready for use in early fall.

National Capital Parks, Department of the Interior, is relocating Beech Drive, as mentioned in last year's report. This is being done for the National Park Service by the Bureau of Public Roads. After tunneling through more than 780 feet of solid rock under "Administration Hill," the top half of the tunnel was completed May 24, 1963.

Plans for the second phase of the capital improvement program, which will consist of enclosures for the hardy hoofed stock on the present site of the buffalo and zebra pens a new entrance on Connecticut Avenue, and deer paddocks on the hill behind the birdhouse, are being drawn up by the architectural firm of Daniel, Mann, Johnson & Mendenhall. Plans are also being made for the redevelopment of the office area.

All redevelopment work is being done under the direction of the District of Columbia Department of Buildings and Grounds. Special acknowledgment is due the director of that department and his able staff.

Respectfully submitted.

THEODORE H. REED, *Director.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Astrophysical Observatory

Sɪʀ: I have the honor to submit the following report on the operations of the Smithsonian Astrophysical Observatory for the fiscal year ended June 30, 1963:

The Astrophysical Observatory includes two divisions: the division of astrophysical research in Cambridge, Mass., for the study of solar and other types of energy impinging on the earth; and the division of radiation and organisms in Washington, for the investigation of radiation as it relates directly or indirectly to biological problems. Shops are maintained in Washington for work in metals, woods, and optical electronics, and to prepare special equipment for both divisions; and a shop conducted in cooperation with the Harvard College Observatory in Cambridge provides high-precision mechanical work. Twelve satellite-tracking stations are in operation, in Florida, Hawaii, and New Mexico in the United States and abroad in Argentina, Australia, Curaçao, India, Iran, Japan, Peru, South Africa, and Spain.

DIVISION OF ASTROPHYSICAL RESEARCH

Research at the Smithsonian Astrophysical Observatory continues to yield new knowledge and increased understanding of a broad range of astrophysical phenomena.*

Concerning members of the solar system—planets, satellites, meteoroids, comets, etc.—the scientific staff have pursued many investigations. The effects of solar phenomena on these other members of the system received particular attention, befitting the rapidly increasing scientific interest in these topics and the increasing national interest in space.

The sun itself deserves ever more intensive observation and analysis. Observatory scientists have applied their talents to these studies. Instruments carried on Orbiting Solar Observatories have become a major source of solar data.

Beyond the solar system, the stars, galaxies, nebulae, and interstellar matter present numerous research problems, many of which members of the Observatory staff have studied. Instrumentation now

* Unless otherwise noted, research is supported from Federal funds appropriated to the Smithsonian Institution. The Observatory, by support of the scientists, shares in the support of all research. Support from outside sources is noted numerically where appropriate and detailed in footnotes 1–20 on p. 164.

being prepared for the Orbiting Astronomical Observatories is expected to yield new data not obtainable from ground observatories. The use of electronic computers of great capacity and capability has allowed consideration of detailed aspects of stellar theories.

A strong feature of the broad scope of the Observatory's scientific program is the ease with which a scientist investigating some particular topic may draw on information and techniques generated by others pursuing different topics. Particularly gratifying were several cases in which instrumentation developed for a specific project was adapted to a quite different application. The many instances of cross-fertilization of scientific disciplines occurring within the Observatory's activities make subdivision of its program difficult. This, however, is a small price to pay for the program's increased scientific value.

Planetary sciences.—With the advent of intensive national and international space programs, interest in the planets has increased remarkably in both scientific and lay circles. Scientists, including those at the Observatory, have been attracted by the research opportunities offered by scientific spacecraft.

Studies of the earth were the first to benefit from artificial satellites as a research tool. Scientists at SAO have been leaders in the utilization of satellite data for many such investigations.

Three major areas of investigation are based on the precise satellite-tracking data obtained by the network of Baker-Nunn cameras.[1] The first is the determination of the density of the earth's atmosphere as a function of position and time. These dependencies, in turn, are used in detailed analyses of atmospheric phenomena and their correlations with other geophysical and solar phenomena. The second important area of investigation is directed initially toward the detailed specification of the earth's gravitational potential. This specification of the geopotential is of basic importance in studies of the interior of the earth. The third area is the determination of accurate geometrical positions of the Baker-Nunn stations relative to one another. Knowledge of these positions contributes strongly to an improved geometrical figure of the earth.

Although these three areas of investigation have quite different scientific objectives, they are nevertheless intimately related. Each depends on identification and isolation of factors that influence the accuracy with which a theoretical orbit may be made to fit the observational data. Basically, the analytical process consists of finding the values of such parameters as atmospheric density, geopotential coefficients, and station coordinates, which optimize the agreement between theoretical and observed satellite positions. The effects of these factors are interrelated in such a way that scientific progress

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in each of the three areas is best advanced by an iterative process in which refinements of the parameters are accomplished simultaneously or cyclically for a number of satellites. This diverse program is under the broad guidance of Dr. Fred L. Whipple, director of the Observatory.

From 5 years of investigation since the first artificial satellite, we now know much about the high atmosphere. The past year saw Dr. Luigi G. Jacchia's timely preparation of a survey, "Variations in the Earth's Upper Atmosphere as Revealed by Satellite Drag," for the *Reviews of Modern Physics*.[1] The comprehensive content of this review stands witness to the sensitivity and refinement of the techniques developed and employed at SAO.

Analyses by Dr. Jacchia and Jack W. Slowey have established that—

(1) Both electromagnetic (extreme ultraviolet) and corpuscular radiation from the sun contribute to the heating of the upper atmosphere.

(2) Most of the energy carried by these two forms of radiation is absorbed at heights lower than 200 km; the atmosphere above this level is heated by conduction from below.

(3) The greater heating in the sunlit hemisphere gives rise to a permanent atmospheric "bulge," at the center of which the temperature is 40 percent higher than it is at the opposite point in the dark hemisphere. Because of the earth's rotation, this bulge travels around the globe at a latitude equal to that of the subsolar point; its longitude is the one for which the local time is 2 p.m.

(4) The temperature of the upper atmosphere can be correlated with the decimetric (radio) solar flux, which exhibits variations with characteristic cycles of 27 days (caused by the rotation of the sun) and of 11 years (caused by the sunspot cycle). The temperature can be computed and instantaneous density profiles derived from atmospheric models when the decimetric solar flux is known.

(5) The atmosphere of the earth is heated and expanded during magnetic storms by a factor directly related to the geomagnetic planetary index a_p.

(6) The semiannual effect in upper atmospheric densities is real. This shows that the solar wind contributes substantially to atmospheric heating, even during quiet periods.

During the past year larger quantities of precisely reduced tracking data, particularly for satellites of quite different inclinations, have become available from the Baker-Nunn system. Imre Izsak, Dr. Yoshihide Kozai, and their associates have used these enlarged data in new determinations of the coefficients in an expansion of the gravitational field of the earth in spherical harmonics.[1]

Mr. Izsak has given particular attention to determination of coefficients of higher-order tesseral and sectorial harmonics. The perturbation theory of these effects being well developed, the problem actually consists of the construction of extensive computer programs that would analyze the large number of observations available. Sev-

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eral solutions have been obtained for the representation of the field of gravity. These solutions are in reasonable agreement with results obtained from the analysis of surface gravity data.

Other analyses of the geopotential are continuing. In Japan Dr. Kozai is at present seeking to establish whether the coefficients in the expansion of the earth's potential have seasonal variations.

Using the representation of the geoid derived by Izsak, Kozai, and their colleagues, Chi-Yuen Wang has found a strong correlation between the distribution of heat flow and the undulations of the geoid.[1] It is reasonable to say at this time that the ups and downs of the geoid may indicate cold and hot regions under the crust.

Two approaches to the determination of more accurate station coordinates are being pursued at the Observatory. One of these recognizes that the deviations between values observed from a station and values predicted from theoretical calculations depend on errors in the presumed station coordinates. Those coordinates that produce minimum deviations are adopted as improved coordinates. Mr. Izsak and Dr. George Veis are now effecting this procedure simultaneously with improvements in the geopotential coefficients.[1]

The second approach is purely geometrical. If two stations simultaneously observe a satellite, it is possible to calculate the direction cosines of the line joining the stations. During the past year a determined effort by the Baker-Nunn stations produced a number of simultaneous observations. Some of these were photographs of the light flashes from the ANNA geodetic satellite. Although we do not yet have so many simultaneous observations as we would desire, analysis by Dr. Veis, Jan Rolff, and Antanas Girnius have given reasonable values in satisfactory agreement with those of the other approach.

For computation of datum shifts of large (continental) geodetic systems,[1] Dr. Walter Köhnlein has developed special ellipsoidal transformations. These transformations are required to adjust the large system so that their relative configurations are in accord with the determined station locations.

For full exploitation of these geodetic capabilities, a more extensive network than the 12 Baker-Nunn stations is desirable. An inexpensive satellite-tracking camera able to photograph many of the brighter satellites has been designed and fabricated under the direction of Dr. Veis and Robert W. Martin. This prototype camera is in experimental operation in Athens, Greece.

Not only the orbit of an artificial satellite but also its motion about its center of mass is affected by its environment. A theory developed by Dr. Giuseppe Colombo has been confirmed with the observation

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of the changing in orientation of the spin axis of several satellites.[1] The variation of the angular velocity of the satellites has been successfully correlated with the variation of the component of the magnetic field normal to the spin axis.

Dr. Richard H. Giese used optical observations (Baker-Nunn and Moonwatch) to develop methods of attitude determination for cylindrical satellites with specular reflection.[1] For diffuse reflecting cylinders the formula for intensity as a function of arbitrary angles of illumination and observation was derived and applied to numerical computations for a tumbling cylinder.

Phenomena in the earth's high atmosphere are being investigated with several tools. As we have seen above, the atmospheric drag on satellites has provided a sensitive measurement of density variations above about 180 km. This altitude might be lowered if satellites of very high density were launched. Dr. Charles Lundquist is examining the value of launching an ensemble of spherical satellites, some with high densities, as a noninterference experiment on a development flight of a large rocket vehicle.

At altitudes between 80 and 100 km, the Doppler shifts in radar returns from meteor trails may be used to measure the velocity and direction of winds in the lower ionosphere. A project to make such measurements and to study wind relationships[2] to other ionospheric phenomena has been initiated by Dr. Mario Grossi in conjunction with the Harvard-SAO Radio Meteor Project.[3]

Laboratory studies of atomic collision processes[4] are being combined with a study of relevant problems in atmospheric physics in the work of Dr. Nathaniel P. Carleton and his associates, Dr. Charles H. Dugan, C. Papaliolios, and Miss Marion L. Shaw. The greatest effort has been applied to investigation of excitation of metastable states in O_2, N_2, and O by electron impact, and of the subsequent reactions of these metastable states with other gases, including excitation transfer and actual chemical reaction. Dr. Carleton, in collaboration with L. R. Megill of the National Bureau of Standards Boulder Laboratories, has used recent data on electron collisions to study the problem of electron heating by electric fields in the ionosphere. The group is investigating, in particular, which features of the airglow and aurora may be caused by electron-impact excitation by the heated electrons. They conclude that the red lines of atomic oxygen, 6300-6364 Å, are almost certainly excited by this means in low-latitude auroral forms, but that no other emission in the airglow or aurora is so excited.

The atmospheres and surfaces of other planets are being studied. Dr. Carl Sagan has made theoretical studies of the expected limb-

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darkening in planetary atmospheres, both at infrared and at microwave wavelengths, with particular reference to the atmosphere of Venus. Preliminary results predict only a moderate microwave limb-darkening from expected absorbers in the lower Cytherean atmosphere. The model of the Jovian red spot, which assumes it to be a floating object, was examined and shown to be unlikely.

Dr. Sagan was a coexperimenter on the infrared radiometer of the U.S. spacecraft *Mariner II*. The experimental results indicated distinct limb-darkening in the 10-micron region and no clear breaks in the Cytherean cloud layer. Dr. Sagan is also an experimenter for an infrared spectrometer designed for a forthcoming Mars fly-by mission.

Study of the rings of Saturn continues. Dr. Allan F. Cook and Dr. Fred Franklin are undertaking a more accurate scattering theory for the sunlight illuminating the rings and a more accurate solution of the Boltzmann equation for the ring particles.[5]

A theoretical investigation of the formation of absorption bands in a multiple scattering atmosphere was conducted by Dr. William M. Irvine. His investigation of strongly asymmetric multiple scattering is continuing, with emphasis on the variation in limb-darkening as a function of asymmetry factor and optical depth.

The existing theories of motion of the major planets are not satisfactory from the modern point of view, especially not for the requirements of space travel. Their improvement, however, is hardly conceivable without progress in computer technology. Mr. Izsak is therefore considering the possibility of using digital computers for the construction of analytical perturbation theories. As a first step, a very efficient program has been developed for the computation of Laplace coefficients and their derivatives. With cooperation from an MIT team, a program has been written for the construction of symbolic expressions, called the Newcomb operators. At present, a generalization of these results is being investigated, together with their application to the problem of close commensurabilities in celestial mechanics.

The orbits of the minor planets present problems which Dr. Don A. Lautman is considering. An analysis of the distribution of the perihelia of the minor planets has been completed.[1] Dr. Lautman and Dr. Colombo have examined the small-amplitude librations of a particle near the triangular point in the semirestricted three-body problem. They are extending this research to an analysis of orbits of minor planets whose periods are commensurate with that of Jupiter.

The origin of the solar system and the production of isotopes in protoplanets are the areas Dr. Henri Mitler is studying. A comparison of theoretical results with observations may allow a choice

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among several possible alternative primitive compositions for a proto-Earth.

Exobiology.—Ultraviolet irradiations of possible simulated primitive terrestrial environments, which Dr. Sagan performed in cooperation with Dr. C. Ponnamperuma, exobiology division, Ames Research Center, NASA, have produced nucleoside phosphates and other molecules intimately involved in contemporary terrestrial biological processes. Such synthetic reactions had been predicted by Dr. Sagan in 1957.

Dr. Sagan made other studies on methods for detection of extraterrestrial life and on the frequency of possible advanced extraterrestrial life forms. Using Mie theory and a computer program, he is continuing a critical study of the panspermia hypothesis.

In an experimental program performed by Dr. Sagan in cooperation with Dr. Stanley Scher at the University of California Space Sciences Laboratory,[6] simulated Martian environments have been inoculated with a variety of terrestrial soil types and assayed for the survival of the contained terrestrial microorganisms. The preliminary results indicate that all samples of terrestrial soil tested have a population of microorganisms that can probably survive on Mars. This conclusion emphasizes the necessity for rigorous sterilization of Mars-impacting space vehicles.

Lunar science.—The moon is now the object of intense investigation by many scientists from all parts of the world. This interest is stimulated, of course, by past and forthcoming lunar probes, orbiters, softly landed instrumentation packages, and eventual manned exploration.

The Astrophysical Observatory is pursuing several lunar investigations which are closely related to its other programs and for which, therefore, the Observatory is peculiarly well prepared. One such topic is the determination of the moon's gravitational potential from analyses of the motion of bodies orbiting it. Attempts by the United States to launch lunar orbiters have been unsuccessful to date, but will undoubtedly meet eventual success. Dr. Kozai has completed an approximate analytical study of the motion of an orbiter. He is proceeding with a program for numerically integrating the equations of motion.

Drs. Lautman and Colombo have shown that radiation pressure significantly changes the orbit of a "balloon" spacecraft and could effect a lunar capture of an initially geocentric orbit.

The impacts of meteorites on the moon produce craters of all sizes, depending upon the size and velocity of the incident body. The size distribution of lunar craters has been analyzed by Dr. Gerald S.

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Hawkins. The results of this study can be correlated with meteorite size and velocity distributions from other investigations.

Meteoritic science.—The solar system contains much meteoric matter. The Observatory applies a vast range of techniques and instrumentation in its broad meteoritic research program. Investigations include the nature of meteoritic matter in the solar system, the theory of meteors in the earth's atmosphere, observation of meteors by optical and radar instruments, mineralogical analyses of meteorites, metallurgical analyses of meteorites, and finally observations of artificial bodies simulating meteorites.

During the past year Dr. Whipple has made new calculations of the frequencies of small bodies near the earth and their penetrating powers on thin surfaces in space. The measurements made in a NASA satellite have confirmed the general order of magnitude of the new calculations, which have reduced the meteoritic hazard by some three orders of magnitude since early calculations. In these and other overall studies of meteoric matter in the solar system, Dr. Whipple draws on specific results from the diverse meteoritic investigations in which he cooperates as director of the Observatory.

Dr. Richard B. Southworth has formulated a convenient quantitative description for the steady-state space distribution of particles under the Poynting-Robertson effect. Using this description and results from analyses of Comet Arend-Roland, he is studying generation of the zodiacal cloud by cometary dust.

Robert E. Briggs is now extending previous work on the space distribution of interplanetary particles to include a study of velocity distributions.

Research into the concentration of micrometeorites in the vicinity of the earth continues. The many-pronged effort of Drs. Colombo and Lautman consists of: (a) Evaluation of the amount of dust placed into orbit around the earth as a result of meteors colliding with the moon and ejecting material; (b) gravitational focusing of interplanetary particles by the earth, the direct capture of interplanetary particles moving under the influence of the gravitational fields of the sun and earth, and the Poynting-Robertson effect; and (c) capture of particles by the combined effects of gravity, atmospheric drag, and radiation pressure.

When particles from space plunge into the earth's atmosphere, they generate a trail of luminosity and ionization. Several scientists of the Observatory continue to work on the physical theory of meteors. Theoretical studies are being made by Drs. Cook, Hawkins, Richard E. McCrosky, and Franco Verniani. Most of these studies are closely linked with analyses of observational data.[1, 5, 7]

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Dr. Carleton and his associates are conducting laboratory experiments on ion-molecule and molecule-molecule collisions in the range of 200–2,000 ev energy.[4] One application of this work is a calculation of the amount of excitation and ionization produced by micrometeorites too small to be observed individually on their entry into the atmosphere. In that connection they have considered what limits can be set on the rate of influx of such micrometeorites, concluding that such effects are negligible.

Statistical analyses of precisely reduced photographic meteor data from Super-Schmidt cameras are being made by Dr. Jacchia, Dr. Verniani, and Mr. Briggs. Their aim is to publish the wealth of information, obtained through several years of meteor photography and painstaking reductions, concerning the interaction between the meteor body and the atmosphere. In particular, they can determine the mass, luminous efficiency, and tensile strength of a meteor body more accurately than has been possible before.

In study of the spectra of meteors,[5] Dr. Cook is working with Dr. I. Halliday of the Dominion Observatory, Ottawa, and Dr. P. M. Millman of the National Research Council of Canada. Currently a quantitative spectral analysis of Perseid spectra is under way.

Work on daily motion of the radiant of the Quadrantid meteor stream was begun. Dr. Frances Wright will continue this project until all photographic film on hand has been measured, and the motion of the radiant is determined. This study will yield further knowledge of the nature of the Quadrantid meteor streams.

Dr. McCrosky has continued a cooperative research effort with Harvard College Observatory, U.S. Air Force,[5] MIT Lincoln Laboratory,[7] and NASA, in which various successful attempts have been made to inject into the upper atmosphere, at meteoric velocities, bodies of sufficient and known size to reproduce the meteor phenomena.

This research has led to improved values of the luminous efficiency of ablating hypervelocity bodies entering the atmosphere and of the masses and densities of meteoroids.

The Radio Meteor Project[3] is a joint enterprise of the Smithsonian Astrophysical Observatory and Harvard University. The project has operated a multistation radar system at Havana, Ill., at a peak transmitter power of 4 megawatts. Meteors have been detected down to a limiting magnitude of +12 on the visual scale. Dr. Hawkins is the scientist in charge of this project.

To determine the atmospheric trajectory of the meteoroid and its orbit in interplanetary space, Dr. Hawkins and Dr. Southworth have analyzed the radar echoes. Drs. Hawkins and Bertil-Anders Lindblad have found that there is a definite difference in the populations of large

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and small meteors.[3] Between magnitudes +6 and +9 the average velocity of meteors detected on the radar system has changed by 5 km sec $^{-1}$. This is attributed to the smaller orbits shown by the fainter meteors. The faint meteors show total fragmentation as they enter the upper atmosphere of the earth. In general, each meteor disintegrates into several hundred fragments, which together act as a cloud of independent particles.

The objective of the Photographic Meteorite Recovery Program,[8] under the direction of Dr. McCrosky, is to photograph the trails of extremely bright meteors so that the corresponding meteorite impacts may be determined and a search instigated for the meteorites. In the past year the project has completed the design of the station buildings, the cameras, and the photoelectric and control systems; selected and leased land at 16 sites in the Midwest; selected local station attendants and their alternates at each site; completed 16 buildings to the point where they are ready to receive cameras and begin operation; assembled, in Lincoln, Nebr., a team of four field personnel to operate the network and to recover freshly fallen meteorites; operated a prototype station at Havana, Ill., for 3 months; and initiated production on all major components of the stations.

The program for measuring radioactivities in material from outer space has continued on an expanded scale. In addition to tritium and argon radioactivities, Dr. Edward L. Fireman and his associates are now measuring carbon-14 and gamma-ray radioactivities from such isotopes as aluminum-26, manganese-54, sodium-22, and cobalt.

During the past year Dr. Fireman and James C. DeFelice have measured tritium, argon-37, and argon-39 in several meteorites, including the recently fallen Peace River. The resultant data provide comparative information on the production, intensity, and constancy of cosmic rays in space during a period of minimal solar activity. The absence of argon-39 in the Potter and Estacado meteorites indicates that they fell more than 1,500 years ago. The Estacado meteorite has been erroneously associated with an 1882 fireball. The argon-39 and tritium contents of Farmington are similar to those of other chondrites, but the aluminum-26 content of Farmington is a factor of more than 50 lower than in other chondrites. The content of these radioactivities permits the determination of the exposure age from radioactive isotopes alone. The cosmic-ray exposure age of the Farmington meteorite is between 7,000 and 25,000 years.

Studies of tritium concentrations in the metal phases of stony meteorites and in iron meteorites have continued during the past year. Dr. Fireman, Dr. David Tilles, and Mr. DeFelice plan further measurements to test the tentative hypothesis that tritium is lost from

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kamacite and retained in taenite. Measurements of tritium in the Sputnik IV fragment and studies by Dr. Tilles of tritium retention in a proton-irradiated target have provided additional data on the retention and loss of tritium in iron and steel.

Dr. Tilles has nearly completed assembling the parts of the high-sensitivity mass spectrometer [9] for studies of noble gases in meteorites. Anticipated research studies with the spectrometer will include measurements of noble gas abundance and isotopic composition in separated phases of meteorites.

Problems in the mineralogy and petrology of meteorites, with special reference to their temperature-pressure history and age, are being considered. In the course of these studies,[10] Mrs. Ursula B. Marvin discovered zircon, heretofore unknown in meteorites, in the Vaca Muerta mesosiderite. The zircon, which is radioactive, is of special significance in age determinations of any meteorite where it occurs. As part of a long-term project in collaboration with Dr. Fireman, Mrs. Marvin has separated mineral concentrates of high purity from Indarch, a stony meteorite abnormally rich in xenon and containing the rare minerals CaS and MgS. She will study the mineralogy and petrology of this meteorite in detail. The radioisotope group will make age determinations on the separated fractions and a bulk sample.

Initiating a program of study of the chemical compositions of microstructures in chondrites, Dr. John A. Wood used the electron microprobe in the University of Chicago Division of Geological Sciences as an analytical tool.[11] At present, the focus of the study is the grains and particles of nickel-iron metal present in chondrites. The compositions and compositional gradients in these are determined by the thermal history of the chondrite containing them. This study should hence yield information about the nature and thermal history of the planet from which the chondrites were derived.

Dr. Wood has also made a detailed theoretical study of the properties of the most common class of meteorite, the chondrites, in an attempt to understand the processes that operated to produce them.[12] He also studied the thermal history of nickel-iron phases and their compositional gradients in iron meteorites. This involved the use of a digital computer to solve the diffusion equation of nickel in nickel-iron alloys for various postulated cooling rates and thermal histories.[11] He found a thermal history that yielded the same nickel diffusion profiles observed in iron meteorites. Preliminary results indicate that the medium octahedrite iron meteorites originated in a small planet, about 200 km in radius; that this object originally accreted at a rate of $\sim$0.5 cm per year; and that it originally contained a short-lived radionuclide ($\sim$100 ppm of Al^{26} or the equivalent), which

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in decaying provided the planet with a pulse of high temperature followed by rapid cooling. Dr. Wood spent most of the past fiscal year at the Enrico Fermi Institute for Nuclear Studies, University of Chicago, working with Dr. Edward Anders on meteorite research.

Dr. F. Behn Riggs, Jr., completed his investigation [13] of the use of an electron probe specially designed to use with very large meteorite sections without enclosing the specimen in a vacuum chamber. Several meteorites were studied with this instrument.

To facilitate interpretation of metallurgical features of meteorites [14] Dr. Matthias F. Comerford (in cooperation with Prof. H. H. Uhlig of M.I.T.) and Joseph I. Goldstein (in cooperation with Prof. R. E. Ogilvie of M.I.T.) are pursuing separate investigations of diffusion processes at the interface of two different specimens of nickel-iron alloy. The dependence of the interdiffusion coefficients upon both temperature and pressure is being measured. Pressures up to 50,000 atmospheres are being used in these experiments.

Dr. Wright and Dr. Paul W. Hodge are pursuing a project to determine the amount and nature of extraterrestrial particles collected by the earth. This investigation has been furthered through collection, by diverse methods, of particles from a wide variety of geographical locations. The collected particles were microscopically examined and their chemical and physical properties determined. A total of 761 particles of possible extraterrestrial origin have been chemically analyzed with electron-probe techniques. The results are proving useful in establishing the chemical criteria for cosmic origin.

Cometary science.—Comets have frequently been investigated by Smithsonian Observatory scientists. A basic understanding of their composition, structure, and resultant phenomena promises to clarify important aspects of the origin of the solar system. The relationship of comets to meteor showers and the response of comets to solar activity are likewise important topics.

Currently, Dr. Whipple is directing his attention to the problem of the cometary nucleus as evidenced in the brightness and deterioration of the periodic comets. Starting from a combination of meteor and cometary studies he is performing calculations to ascertain more exactly the lifetime of a major comet such as Encke's, which has contributed a great complex of Taurid meteors. He is seeking to identify Comet Encke in ancient records in order to determine changes in period and brightness levels in the ancient past—perhaps 2,500 years ago. This research employs studies of photographic meteor orbits, theoretical calculations, and cooperation with historians.

Published photographs of Comet Arend-Roland, examined by Dr. Richard B. Southworth, combined with computed particle trajectories,

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showed that the comet had seven tails. Each consisted of dust ejected in accordance with Whipple's theory describing this process. The larger ejected particles collectively contain more mass than the small.

Using photographs made by the Baker-Nunn cameras, Daniel Malaise [15] is obtaining measurements of cometary tail activity. This inquiry bears on the interaction of the solar wind with the tails of comets.

During the summer of 1962 Dr. Pol Swings reviewed the possibilities for cometary research provided by the use of rocket vehicles and spacecraft. Observations of infrared and ultraviolet frequencies from orbiting observatories, measurements from a probe flight near a comet, and release of appropriate chemicals from rockets all offer significant opportunity for advancing cometary science.

Dr. Charles A. Whitney and Dr. Lundquist have initiated laboratory studies of the properties of ices in vacuum to provide several basic parameters for further theoretical descriptions of comets. Preliminary theoretical studies of the nature of comets have indicated the need for several modifications of existing theories.

Solar observations.—A historic advance in solar observation is the United States' Orbiting Solar Observatory program. To further its long-standing record of pioneering solar observations, SAO is playing an active role in this program.

Dr. Giovanni Fazio was a coexperimenter on the first Orbiting Solar Observatory, launched in March 1962. The experiment provided the first view of a solar flare in the high-energy gamma ray (>100 Mev) portion of the electromagnetic spectrum. Within the sensitivity of the detector, there was no evidence for gamma radiation. Data reduction [16] is continuing, and theoretical calculations on the sun's production of gamma rays have been made.

Dr. Leo Goldberg is directing a Harvard University project [17] to prepare instrumentation for the second Orbiting Solar Observatory, scheduled to be launched during the fall of 1963. The instrument is designed both to make scans of the solar spectrum and to obtain monochromatic solar images in the wavelength range 500–1500 Å. Both the prototype and the flight models of the satellite instrument have been delivered for integration into the spacecraft. A considerable number of the routine environmental tests have been passed.

Design work has already begun on an improved model of the scanning spectrometer-spectroheliograph, which has been allocated space on board the fourth Orbiting Solar Observatory. Design work is also proceeding on a spectrometer that will operate in the short wavelengths from 100–600 Å.[18]

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Observations of magnetic fields and velocity fields in the solar granulation were carried out by Dr. R. W. Noyes at the McMath Solar Telescope at Kitt Peak National Observatory in Tucson during June 1963. The data are now being analyzed.

Dr. Fireman, Dr. Tilles, and Mr. DeFelice have continued measurements of tritium concentrations in recovered satellites. Such measurements made during the past year have pertained to a period of relative solar quiescence. The apparent upper limit for trapped tritium abundance was much lower in 1962 than it was following the November 1960 solar flares. The measurements to date suggest that these large flares injected tritium into the trapped radiation belts with apparent lifetimes of months. This first evidence of direct solar injection of positive Van Allen particles is under continuing critical examination.

It is clear that particles and electromagnetic radiation from the sun produce many such diverse phenomena in the solar system. Their interaction with the earth's atmosphere results in large density variations which are manifest in variations of satellite orbits. These radiations also influence cometary activity. The interpretation of these far-reaching interrelated phenomena is particularly challenging because of its very scope. The present period of minimum solar activity has many advantages for research on these matters. The Observatory is vigorously pursuing these topics, which will be included in the U.S. program for the Year of the Quiet Sun.

Stellar observations.—The Observatory's astrophysical interests extend beyond the investigations of the solar system. Using various instruments, SAO acquires and analyzes observational data on stars, galaxies, and interstellar matter in all forms.

Like solar observations, stellar observations stand to benefit greatly from the advent of orbiting observatories. The Observatory is privileged to have responsibility for Project Celescope,[19] one of the two prime experiments on the first Orbiting Astronomical Observatory. Dr. Whipple is project director, and Dr. Robert J. Davis is project scientist. Dr. Grossi has supervised electronic aspects of the project.

The primary goal of Project Celescope is to obtain ultraviolet star catalogs in each of four colors between 1,000 and 3,000 Å. The wavelength range requires that this observing program be carried out above the earth's atmosphere. Four separate telescopes equipped with ultraviolet-sensitive television photometers will be used. The present phase of the program is concerned primarily with procurement of the necessary equipment. The experiment has required the development of the following pioneering instrumentation and techniques:

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ultraviolet-sensitive television camera tubes, Schwarzschild telescope systems, calibration lamps, a digital television photometric system, and automatic identification and cataloging of stars.

The ultraviolet-sensitive television camera tubes required much research and development. The Project has been working for 4 years with Westinghouse Research Laboratories to procure these devices. Problems solved during the past year include Westinghouse's development of a new target material that has increased the tube's sensitivity and its suitability as a stellar photometer. Laboratory measurements of the spectral response of this tube were made by Dr. Om P. Rustgi.

The telescope system to be used with Celescope requires the production of strongly aspheric optical surfaces mounted so as to survive the mechanical environment of satellite launching, and to be insensitive to large variations in temperature.

For calibration of Celescope equipment in orbit, it was necessary to obtain two types of ultraviolet point sources. One, utilizing a low-pressure mercury-vapor arc, radiates intensely at 2,537 Å. The other, utilizing a low-pressure xenon arc, radiates intensely at 1,470 A. The latter lamp required considerable developmental work in order to meet requirements for small size and power consumption, long life, and high efficiency. Dr. Rustgi and Clifford Miles have made laboratory tests of these sources.

The requirement to use a television system as a stellar photometer posed problems of accuracy, reliability, linearity, and dynamic range not encountered in the usual type of television data transmission. The system, as developed by Electro-Mechanical Research, Inc., has proved able to meet the performance requirements.

Finally, George Szabo, Mrs. Gail Wald, and Stephen Strom have prepared an ultraviolet identification catalog and are preparing techniques for automatic compilation and publication of the Celescope observational material.

The accurate measurement of the number and direction of high-energy gamma rays from the universe is a difficult instrumentation problem. The importance of the measurement, however, justifies great effort toward its accomplishment. Dr. Fazio has completed a theoretical study of the production of gamma rays by cosmic radiation in our galaxy. Using the results of these calculations, he is planning further gamma-ray astronomy instruments for future orbiting observatories. A new type of detector for high-energy gamma rays, a multiplate spark chamber, is now being developed at the Observatory.

A program of spectroscopic observations of bright stars, which Dr. Whitney initiated at the Agassiz Station of Harvard College Observatory, will provide data for the theoretical work on the spectra of normal stars. Drs. Wright and Hodge have located Population II

Cepheids in the Large Magellanic Cloud, in red globular clusters. A period-luminosity relation for these Cepheids has been established. This research is helpful in determining the extragalactic distance scale.

Six of the Baker-Nunn cameras have been used since 1960 to photograph flare stars in conjunction with radio-frequency measurements of their radio emissions.[1] The cooperating radio observatories are Jodrell Bank Experimental Station in England and the Commonwealth Scientific and Industrial Research Organization at Sydney, Australia. Leonard Solomon devised the photographic procedures used. The one major flare observed this year correlates in time with a major burst detected in the radio spectrum at Sydney. If these combined observations are significantly correlated, as they appear to be, they constitute the first observations of radio energy from "normal" stellar objects. Many minor flares (from previous years) correlate with small bursts observed at Jodrell Bank.

In collaboration with Prof. William Liller of Harvard, Dr. Goldberg has begun an observing program designed to search for evidence of cyclic stellar activity similar to that connected with the solar sunspot cycle. They will conduct the search by monitoring the intensities of the H and K emission lines of ionized calcium in the spectra of late-type stars. They will look for both short-term changes, such as may be produced by flares, and long-term cyclic variations.

A star catalog [1] of great value to many astronomical enterprises has been completed under the direction of Dr. Vies, Mr. Solomon, and Mrs. Katherine Haramundanis. Initiated in 1959 under the Satellite Tracking Program, the SAO Star Catalog was conceived as the compilation of a large number of fundamental and differential catalogs to cover the sky in a standard coordinate system. The project used about 40 catalogs, providing data on approximately a quarter of a million stars. Preparation of the Star Catalog involved investigations of the details of the coordinate system and derivation of proper motions of each catalog. Comparisons of several catalogs were also made in sky areas where the catalogs used did not provide adequate information, usually for proper motions. The complete catalog is stored on magnetic tape, while the publication of a book form is progressing. A set of star charts is to be produced from the Catalog in Lambert-conformal projection, probably at two different scales.

Stellar theory.—Theoretical studies of stellar atmospheres [20] continued in several directions under Dr. Whitney's supervision. Extensive calculations were performed concerning the structure of stellar convection zones and the nature of the perturbations they produce in stellar atmospheres. Investigations of the structure of shock fronts in

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atomic hydrogen have been extended; these represent a considerable refinement of the earlier work. Dr. Angelo J. Skalafuris and Dr. Wolfgang Kalkofen worked with Dr. Whitney on the latter studies. Dr. Owen Gingerich has examined some computational aspects of nongray stellar atmosphere models. In this connection, he has investigated several new opacity sources. Current work includes the addition of electron-scattering and absorption-line profiles to the computer program.

Dr. Max Krook has developed a perturbation-iterative procedure for solving the structure equations for nongray stellar atmospheres. He and Dr. Eugene H. Avrett have applied this method to a number of cases and have found it to converge very rapidly.

Dr. Noyes has made theoretical investigation of velocity fields in the solar atmosphere. The purpose of this work is to explain the recent observations of pronounced oscillatory motions in the solar atmosphere. Particular goals are to reproduce the well-determined period of 300 seconds for the oscillation. The relevant equations, including the effects of radiative damping, have been put in a form suitable for numerical analysis on an IBM–7090 computer. Preliminary results indicate that rapid change in radiative flux into the atmosphere induced by convection in the granulation, does indeed cause oscillatory motions of the solar atmosphere with the observed properties.

In collaboration with Dr. Y. Öhman of the Stockholm Observatory, Dr. Goldberg is carrying out a theoretical investigation of the scattering of the Lyman-α emission line by the high-speed electrons of the solar corona. Profiles of the scattering emission line are being calculated for various assumed models of the corona as a function of distance from the center of the solar disk.

The radiation pressure exerted on a nonstationary gaseous cloud by a neighboring exciting star of high temperature has been considered by Dr. Y. Hagihara.[1] He has employed quantum mechanical techniques and the assumptions that the atmosphere and the ions in the cloud are in systematic and random thermal motions.

Summary.—During the past year we have once more witnessed the ever-increasing recognition of astrophysical research as an essential component of the scientific needs of the nation. A previously unheard-of situation now exists in which major national programs—such as manned lunar exploration in this decade—depend on astrophysical information for their successful execution.

The Smithsonian Astrophysical Observatory is proud that for 73 years it has been generating and disseminating such knowledge. We also derive satisfaction from our realization that the research pro-

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grams of the Observatory have grown and continue to grow as the appropriate Smithsonian Institution response to these requirements.

OTHER ACTIVITIES

On June 11, in ceremonies at the White House, Dr. Whipple received the President's Award for Distinguished Federal Civil Service.

Dr. Whipple and Drs. Fireman, Wood, and Tilles attended the Gordon Research Conference at Tilton, N.H., in July 1962.

In August Dr. Avrett participated in the Third Colloquium on the Theory of Stellar Atmospheres, sponsored by Commission 36 of the International Astronomical Union, at Hailsham, England.

Dr. Colombo presented a paper at the Symposium on Gyrodynamics, sponsored by the IUTAM, at Celerina, Switzerland.

In September Dr. Lundquist presented a paper at the 13th International Astronautical Conference at Varna, Bulgaria.

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[1] Supported by grant NsG 87/60 from the National Aeronautics and Space Administration.

[2] Supported by contract 19(628)–3248 with the U.S. Air Force.

[3] Supported by grants G20135 and GP388 from the National Science Foundation to Harvard University and by grant NASr–158 from the National Aeronautics and Space Administration to Harvard University.

[4] Supported by contract 19(628)–2949 with the U.S. Air Force.

[5] Supported by contract AF19(604)5196 between the U.S. Air Force and Harvard University.

[6] Supported by grant number NsG 126/61 from the National Aeronautics and Space Administration to the University of California.

[7] Supported by contract AF19(604)7400 sub 234 between Harvard University and MIT Lincoln Laboratory.

[8] Supported by grant NsG 291–62 from the National Aeronautics and Space Administration.

[9] Supported by grant NsF 16067 from the National Science Foundation.

[10] Supported in part by grant NsG 282–63 from the National Aeronautics and Space Administration to Dr. Clifford Frondel of Harvard University.

[11] Supported by grant G 14298 from the National Science Foundation to the University of Chicago.

[12] Supported by contract AT(11–1) 382 between the Atomic Energy Commission and the Enrico Fermi Institute for Nuclear Studies, University of Chicago.

[13] Supported by contract AF18(600)–1596 with the U.S. Air Force.

[14] Research supported by grant G2777 from the National Science Foundation to the Massachusetts Institute of Technology.

[15] Research sponsored by fellowships from NASA, Fonds National de la Recherche Scientifique, Belgium, and European Preparatory Commission for Space Research.

[16] Supported by grant NAS5–3255 from the National Aeronautics and Space Administration.

[17] Supported by contract NASw184 between the National Aeronautics and Space Administration and Harvard University.

[18] Supported by grant NsG–438 from the National Aeronautics and Space Administration to Harvard University.

[19] Supported by contract NAS5–1535 with the National Aeronautics and Space Administration.

[20] Research supported by grants G–16339 and GP940 from the National Science Foundation.

Dr. Carleton presented a paper at the annual Gaseous Electronics Conference at Boulder, Colo., in October.

Dr. Fazio presented a paper at the 1962 International Symposium on Space Phenomena and Measurements in Detroit.

In November Dr. Fireman presented a paper at the Radioactive Dating Symposium in Athens, Greece. In December he attended the American Association for the Advancement of Science meeting in Philadelphia.

Dr. Tilles, Mrs. Marvin, and Mr. Slowey presented papers at the American Geophysical Union meeting at Stanford University, Palo Alto, Calif., in December.

In January Dr. Whipple delivered a lecture at the Ninth Annual Astronautical Society Meeting in Los Angeles. He also attended ceremonies at the Goddard Space Flight Center commemorating the fifth anniversary of international tracking of space vehicles.

Drs. Carleton, Lundquist, and Mitler attended the meeting of the American Physical Society in New York.

Drs. Lundquist, Fazio, and Jacchia attended the Goddard Scientific Symposium on Satellites in Washington, D.C. Dr. Fazio presented a paper at this meeting.

In April, Dr. Whipple took part in the Institute of Space Studies Symposium on the Origin and Evolution of Atmospheres and Oceans, held in New York City. He also presented a paper at the UGI meeting in Washington.

Drs. Carleton, Fazio, Fireman, Jacchia, Tilles, and Whipple attended the American Geophysical Union meeting in Washington.

Drs. Whipple, Jacchia, and Sagan presented papers at the COSPAR meeting in Warsaw, Poland, in June. Dr. Sagan also attended the 12th International Astrophysical Colloquium in Liége, Belgium.

BUILDINGS AND EQUIPMENT

In October 1962 and June 1963 several divisions of the Observatory, including those occupying space belonging to the IBM Corp. and to the Harvard University Press, moved to a building on Alewife Brook Parkway, about a mile from Observatory headquarters at the Harvard College Observatory. This move places all personnel in only two locations, between which mail- and passenger-shuttle operates on a regular schedule.

Also in October 1962 the IBM–7090 computer was taken over by, and moved to, the Harvard Computing Laboratory, from which the Observatory rents needed time.

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The Special Reports of the Astrophysical Observatory distribute catalogs of satellite observations, orbital data, and preliminary results of data analysis prior to journal publication. Numbers 99 through 126, issued during the year, contain the following material:

No. 99, July 16, 1962.
Chemical analysis of 643 particles collected by high-altitude aircraft and balloons, by F. B. Riggs, Jr., F. W. Wright, and P. W. Hodge.

No. 100, July 30, 1962.
Accurate drag determinations for eight artificial satellites; atmospheric densities and temperatures, by L. G. Jacchia and J. Slowey.

No. 101, July 31, 1962.
Numerical results from orbits, by Y. Kozai.

No. 102 (P-5), August 27, 1962.
Catalog of precisely reduced observations: Satellite 1959 α1 for the entire year 1960, prepared by J. MacDonald, K. Haramundanis, et al.

No. 103, August 28, 1962.
Satellite orbital data: Satellite 1959 Eta (Vanguard III), Sept. 1, 1960–Dec. 31, 1961, and Satellite 1960 ι1 (Echo I), Jan. 1–Dec. 31, 1961, by B. Miller, compiled by I. G. Izsak.

No. 104 (P-6), September 10, 1962.
Catalog of precisely reduced observations: Satellite 1961 δ1 from launch Feb. 16–June 30, 1961, prepared by J. MacDonald et al.

No. 105, September 28, 1962.
The trajectory of tektites, by G. S. Hawkins and S. K. Rosenthal.

No. 106 (P-7), November 1, 1962.
Catalog of precisely reduced observations: Satellite 1959 α1 from Jan. 1–June 30, 1961; Satellite 1959 η1 from Jan. 1–June 30, 1961, prepared by P. Stern.

No. 107, November 9, 1962.
On some singular orbits of an earth-moon satellite with a high area-mass ratio, by G. Colombo and D. A. Lautman.

No. 108, November 20, 1962.
On the libration orbits of a particle near the triangular point in the semi-restricted three-body problem, by G. Colombo, D. A. Lautman, and C. Munford.

No. 109, December 21, 1962.
Re-entry and recovery of fragments of satellite 1960 ϵ1, by C. A. Lundquist, R. C. Vanderburgh, W. A. Munn, D. Tilles, E. L. Fireman, and J. DeFelice.

No. 110, December 14, 1962.
Project Celescope, an astrophysical reconnaissance satellite, edited by R. J. Davis.

No. 111, December 15, 1962.
Possible contributions of space experiments to cometary physics, by P. Swings.

No. 112, January 21, 1963.
On the secular decrease in the inclination of artificial satellites, by R. C. Nigam.

No. 113, January 23, 1963.

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No. 114 (C-31), January 28, 1963.

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No. 115 (C-32), January 29, 1963.

Catalogue of satellite observations: Satellites 1960 ι1, 1960 ι2, and 1960 ξ1, for Jan. 1–June 30, 1962, prepared by B. Miller.

No. 116 (C-33), January 30, 1963.

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No. 117, February 11, 1963.

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No. 118 (P–8), February 14, 1963.

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No. 119 (E–2), March 15, 1963.

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No. 120, March 18, 1963.

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No. 121, April 1, 1963.

Smithsonian Astrophysical Observatory program writeup (SCROGE), by J. R. Cherniack and E. M. Gaposchkin.

No. 122, April 2, 1963.

Combinations of least-squares approximations in the case of correlated variables, by P. L. Kadakia.

No. 123, April 30, 1963.

Precise aspects of terrestrial and celestial reference frames, by G. Veis.

No. 124, May 27, 1963.

Notes on the design and operation of satellite tracking stations for geodetic purposes, by the staff of the Smithsonian Institution Astrophysical Observatory.

No. 125, May 28, 1963.

An analysis of the atmospheric drag of the Explorer IX satellite from precisely reduced photographic observations, by L. G. Jacchia and J. Slowey.

No. 126, June 24, 1963.

Satellite orbital data: Satellite 1958 α, Oct. 1–Dec. 31, 1962, by B. Miller; Satellites 1959 α1, 1959 η and 1959 ι1, Oct. 1–Dec. 31, 1962, by M. Gutierrez; Satellite 1960 γ2, Apr. 13–May 30, 1960; Sept. 29–Oct. 23, 1962, by R. C. Nigam; Satellites 1960 ι1, ξ1 and 1961 δ1, Oct. 1–Dec. 31, 1962, by J. Weingarten; Satellite 1962 αε1, July 10–Dec. 31, 1962, by M. Gutierrez; Satellites 1962 βλ1, Oct. 27–Dec. 20, 1962 and 1960 βμ1, Oct. 31–Dec. 31, 1962, by J. Weingarten; compiled by I. G. Izsak.

STAFF CHANGES

On July 22, 1962, Dr. Charles A. Lundquist joined the Observatory as assistant director for science. Other scientists who joined the staff during the year are physicists Dr. Eugene Avrett, Dr. Nathaniel P. Carleton, Dr. Charles Dugan, Dr. Giovanni G. Fazio, Dr. Owen Gingerich, Dr. William M. Irvine, Dr. Robert W. Noyes, Dr. Carl E. Sagan, Dr. Franco Verniani, and Chi-Yuen Wang; astronomer Dr. Gerald S. Hawkins; metallurgists Dr. Matthias Comerford and Joseph Goldstein; geodesist Dr. Walter Köhnlein; and Daniel Malaise, NASA–COPERS fellow. Jack Coffey was appointed personnel director, and Marc Malec was named contract specialist.

Resignations during the year included those of Thomas Noonan, Dr. F. Behn Riggs, and Dr. Om P. Rustgi, physicists; G. Nielson, administrative officer, Satellite Tracking Program; Dr. Pedro Zadunaisky and Rajendra C. Nigam, astronomers.

Consultants at the Observatory during the year were Dr. Gustav Bakos, Dr. Richard Giese, Dr. Yusuke Hagihara, Dr. Yoshihide Kozai, Dr. Otto Struve, Dr. Pol Swings, Dr. H. C. Van de Hulst, and Dr. George Veis.

On June 30, 1963, the Observatory employed 335 persons.

DIVISION OF RADIATION AND ORGANISMS

Prepared by W. H. Klein, Chief of the Division

The research program of the Division is concerned with the effects of solar and ionizing radiation on biological systems, with emphasis on developing systematic concepts of the metabolic mechanisms and responses of living organisms as influenced and regulated by radiation. Areas of concentrated effort include problems relating to the regulation of metabolism by radiation, the determination of structure and function of macromolecules involved in energy storage, the measurement of seasonal changes in spectral distribution of total sky radiation and the correlation of these changes with plant responses.

Plastids of flowering plants grown in the dark are converted to functional chloroplasts in the light. The antibiotic chloramphenicol partially inhibits light-dependent synthesis of whole leaf and chloroplast protein, and chloroplasts from chloramphenicol-treated leaves lack the ability to catalyze light-dependent formation of TPNH (reduced triphosphopyridine nucleotide) and ATP (adenosine triphosphate) which are needed for photosynthetic carbon dioxide fixation. Thus, nonfunctional plastids lack a number of structural proteins necessary for the generation of TPNH and ATP. Methods of isolating chloroplasts active in photoproduction of TPNH and ATP were examined. An unidentified inactivator was found in leaf homogenates. The presence of this inhibitor accounts for the previous difficulties encountered in obtaining chloroplasts active in photoproduction of TPNH and ATP.

The proteins of functional chloroplasts from treated and untreated leaves differ. Purified plastids from treated leaves contain a larger fraction of protein that can be made water soluble. Immunological analysis, however, shows that the soluble fraction from chloroplasts of control leaves contains more protein components. Differences are related to structural differences visualized with the electron microscope.

Unlike flowering plants, many algae form chloroplast pigments in the dark. However, differences in quantity and quality of light have been reported to affect pigmentation and photosynthetic capacity. A number of littoral diatom isolates were found to grow well in the dark. Similar pelagic isolates are being sought. Methods of quantitatively extracting chloroplast pigments are being developed to compare differences in pigmentation between organisms grown in light and dark.

Marine organisms are peculiarly suitable for fundamental investigation of radiation responses, and a section was organized within the division for marine biology research. The long-term aim of this study is toward establishing an adequate understanding of the physiology and biochemistry of the occurrence, behavior, and potential harvest of marine organisms.

In the sea, algae carry out the conversion of light energy to chemical energy. Phosphorus compounds are involved and play an important role in the determination of the bulk and growth rates of the algae. A number of types of phosphorus compounds in algae have been identified, quantitated, and used in structural studies. Metabolic activities of these compounds have been determined by the rate of incorporation of radioactive isotopes. Methylated ribose was demonstrated as a component of nucleotides of RNA (ribose nucleic acid) fraction. A number of sugars and neuraminic acids were demonstrated to be bound to the RNA.

The morphological development of plastids in the presence of a carbohydrate substrate has been demonstrated to be controlled by the phytochrome pigment system which is photosensitive to red and far-red radiant energy. Microscopic examinations of leaf preparations show a red light-induced disappearance of starch from within young etiolated plastids. This observation has been substantiated by biochemical analysis which also indicated that starch degradation was preceded by a similar loss in total soluble sugars. In addition, these changes, which are appreciable in 6 hours and maximal in 12 hours following a 3-minute exposure to light, correlate with the pronounced photomorphogenic leaf expansion. Studies of the kinetics of these changes, of temperature sensitivity and energy requirements for induction and reversal, have been completed as a necessary preliminary to an intensive study of the enzyme systems involved.

Attempts to correlate physiological responses in a number of tissues to reported in vivo measurements of phytochrome concentrations have led to the conclusion that a simple one-pigment system appears to be inadequate in explaining the observed results. A far-red dose response curve was determined immediately after, and 1½ hours after red induction. The data show a significant increase in sensitivity to far-red after 1½ hours in both lettuce seed germination and bean hypocotyl hook opening. It was also observed that complete reversal of the induced response can be obtained with sufficiently large amounts of far-red energy from 2½ hours to 4½ hours after induction for both lettuce and bean. Further, there is significant reversal of the red induction for at least a 10-hour period in both.

Experiments using *Avena* mesocotyl inhibition in which noninhibitory pretreatments of red irradiation were given 24 hours prior to inhibitory red treatments did not produce any change in sensitivity. The published in vivo measurements indicate that such pretreatments should have significantly reduced the level of phytochrome so that the sensitivity should have changed. Also, experiments in which red treatments were divided into two doses separated by 4-hour dark intervals, or given as one continuous dose, showed marked differences in the sensitivity to far-red reversal. These data do not fit reasonably with a single pigment system.

Many biological responses, such as flowering, pigment synthesis, seed germination, stem elongation, and leaf expansion are controlled by photochemical reactions initiated by various portions of the visible spectrum. In a program of study never previously undertaken anywhere, measurements of specific spectral regions of sun and sky radiation are being recorded and correlated with plant growth responses of living material produced in natural daylight and in controlled environment conditions. The greenhouse and controlled environment rooms, with such special features as automatically controlled changing light intensities and daylengths to reproduce natural conditions, have been developed and installed. The system for measuring sun and sky radiation has been developed and includes specially constructed thermopiles with filters which automatically measure solar radiation. A digital recording system has been adapted, with automatic data processing equipment for handling a larger amount of information, to register all data on punched tape. Measurements are being made at 3-minute intervals for six different wavebands simultaneously. Direct measurements with photomultipliers using interference filters at two specific wavelengths, 660 and 730 mμ, indicate that there is an appreciable shift of as much as two-fold in the ratio of red to far-red near sunrise and sunset. These shifts may be of significant import in determining the effective daylength for biological responses which utilize the phytochrome system.

The biological phase has been initiated, and at periodic intervals the plant material cultivated under precisely controlled conditions is observed and measured, and the data are recorded for purposes of comparison and correlation. It is expected that the degree and/or frequency of physiological responses initiated by photochemical stimuli will demonstrate a direct correlation with measured daily and seasonal fluctuations in the energy and quality of solar radiation as observed over relatively long periods of time.

It has been shown previously by Dr. W. M. Dugger, Jr., and Dr. O. C. Taylor at the Air Pollution Research Center, University of California at Riverside, that PAN (peroxyacetyl nitrate) is an oxidant, naturally present in smog, which produces necrotic lesions on young leaves in the presence of light. These previous observations also suggested that PAN might be affecting the photosynthetic system of the plant. Thus, an attempt was made to determine if the intracellular site of PAN action could be determined. The spectral sensitivity of the light requirement in producing damage in bean seedlings in the presence of the smog oxidant was determined cooperatively with Drs. Dugger and Taylor, and this action spectrum indicates an interaction with a carotenoid pigment having a strong absorption between 400 and 500 mμ. There is a residual small amount of damage for all wavelengths out to 700 mμ.

A concentration of 4 ppm PAN for 100 seconds with an intensity of 200 μw/cm^2 produces appreciable leaf damage. No leaf damage is observed if plants are kept in the dark immediately prior to or immediately following the fumigation with PAN with simultaneous light exposure. Thus the damage is indicated to be mediated not by chlorophyll directly, but through accessory carotenoid pigments in the photosynthetic system.

In the study of the photoresponses of *Phycomyces blakesleeanus*, detailed action spectra for the growth and tropic responses at high intensities have been completed. Within the visible range, the spectra are identical, indicating that no detectable bleaching of the photoreceptor occurs. It is concluded that direct spectrophotometric measurements for the detection of in vivo changes in the pigment photoreceptor system would be unprofitable.

Chromatographic and biochemical assays have been made of various compounds extracted from sporangiophores. These compounds include amino acids, reducing and nonreducing sugars, carotenoids, flavins, and various phosphorylated compounds. Dark-grown or light-adapted sporangiophores were exposed to saturating pulse-up light stimuli and assays made at 1-minute time intervals after the stimuli.

No detectable changes could be observed for carotenoids or amino acids. Significant changes both in quantity and quality of compounds present were observed between adapted and stimulated growing zones for flavins in stage I and IV sporangiophores. Quantitative changes were also observed for reducing sugars. The time course of these changes can be correlated with the observed time course of the light growth response.

One of the observed flavins, a blue fluorescing unknown, is present in large amounts in light-sensitive stages of sporangiophore development and is not found in the light-insensitive mycelia or during formation of the yellow sporangium in stage III sporangiophores. The total amount of this material is also a function of the adaptation level of the sporangiophore with the highest concentration occurring in dark-adapted sporangiophores.

The installation of a carbon-dating laboratory within the division was completed in September 1962, and the dating of a number of archeological samples has been completed. In addition to the service function, the carbon-dating program includes basic research in the techniques of dating by the use of the carbon-14 method and research employing this method as a tool.

The innovation of the use of mercury as the principal shielding material in the counting system has been most satisfactory and has resulted in low background levels and high precision. The absolute dates obtained with the mercury system are reliable when compared to those obtained by other laboratories.

A research project to determine the residence time of water in various systems was started in October 1962. Preliminary experiments indicate that the carbon-14 activity of ground or surface water can be readily determined and that this method can be used to determine several of the hydrologic characteristics of water-producing strata. Instrumentation for this research has been completed and includes: (1) apparatus for extracting the bicarbonate and dissolved carbon dioxide from the water samples and (2) a system to convert the carbon dioxide to pure methane gas.

PUBLICATIONS

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SISLER, EDWARD C., AND KLEIN, WILLIAM H. The effect of age and various chemicals on the lag phase of chlorophyll synthesis in dark grown bean seedlings. Physiol. Plantarum, vol. 16, pp. 321–328, 1963.

DUGGER, W. M., JR.; TAYLOR, O. C. KLEIN, W. H.; AND SHROPSHIRE, W., JR. Action spectrum of peroxyacetyl nitrate damage to bean plants. Nature, vol. 198, pp. 75–76, 1963.

OTHER ACTIVITIES

The division was represented during the year at a number of scientific meetings. At the American Institute of Biological Sciences meeting in August at Oregon State University, Corvallis, Oreg., were W. Shropshire, L. Price, M. M. Margulies, R. L. Latterell, and W. H. Klein. Papers presented at the meetings included "The Effect of Light and Chloramphenicol on Development of Photosynthetic Activities of Leaves," by M. M. Margulies; "Responses of *Phycomyces* to High Intensity Light," by W. Shropshire; and "Some Responses of the Bean Hypocotyl," by W. H. Klein. Dr. Klein attended the executive committee sessions of the American Society of Plant Physiologists.

Dr. D. L. Correll traveled to Woods Hole Oceanographic Institution, Yale University, and the Haskins Laboratories to confer on aspects of marine biology research. In August Dr. Klein with a representative of the U.S. Atomic Energy Commission visited the University of Washington at Seattle. J. H. Harrison attended the Intermediate Seminar for Scientific Glass Blowers held at the State University of New York in Alfred in September. In November, J. J. Sigalove and Dr. W. H. Klein went to Delaware, Ohio, to consult with Dr. J. G. Ogden of the carbon-dating laboratory at Ohio Wesleyan University. In January Dr. D. L. Correll and L. Lott made a collecting trip to the Florida Keys for specimens of marine algae.

Leonard Price and Dr. K. Mitrakos in February presented a symposium paper entitled "Photomorphogenesis and Carbohydrate Changes in Etiolated Leaf Tissue," at the 1963 meeting in Memphis, Tenn., of the Association of Southern Agricultural Workers. Also in February, Dr. W. Shropshire attended the 7th Annual Meeting of the Biophysical Society in New York City.

In April, the division was represented at three scientific meetings. Drs. P. J. A. L. deLint and D. L. Correll attended the annual meeting of the Federation of American Societies for Experimental Biology. J. H. Harrison attended the International Conference on Nonlinear Magnetics in Washington, D.C. Dr. Shropshire was an invited participant in the First American Meeting of the Royal Microscopical Society held at the National Institutes of Health.

J. J. Sigalove conferred in May with Dr. W. Broecker and the staff at Lamont Geological Observatory in Palisades, N.Y.

With the closing of the Table Mountain, Calif., Field Station, solar-radiation standards and some equipment were transferred to the division. The standards are being used in the calibration of instruments for measurement of solar radiation.

New members of the staff this year are Dr. David L. Correll, biochemist, and Joel J. Sigalove, geochemist. At the end of the year there were 29 members of the staff of the Division of Radiation and Organisms.

Respectfully submitted.

Fred L. Whipple, *Director*.

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution

Report on the National Collection of Fine Arts

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1963:

SMITHSONIAN ART COMMISSION

The 40th annual meeting of the Smithsonian Art Commission was held in Washington on Tuesday, December 4, 1962. Members present were Paul Manship, chairman; Leonard Carmichael, secretary; Gilmore D. Clarke, David E. Finley, Lloyd Goodrich, Bartlett H. Hayes, Jr., Ogden M. Pleissner, Charles H. Sawyer, and Stow Wengenroth. James C. Bradley, Assistant Secretary; Theodore W. Taylor, Assistant to the Secretary of the Smithsonian Institution; and Thomas M. Beggs, Director, National Collection of Fine Arts, were also present.

Resolutions on the deaths of Robert Woods Bliss and Archibald G. Wenley were submitted and adopted.

The Commission recommended appointment of Edgar P. Richardson to fill the vacancy caused by the death of Mr. Wenley, and of Paul Mellon, to fill that caused by the death of Mr. Bliss.

Recommendations were made for the reappointment of Gilmore D. Clarke, Stow Wengenroth, and Andrew Wyeth for the usual 4-year period.

The following officers were elected for the ensuing year: Paul Manship, chairman; Gilmore D. Clarke, vice chairman; and Leonard Carmichael, secretary.

The following were elected members of the executive committee for the ensuing year: David E. Finley, chairman; Gilmore D. Clarke, Ogden M. Pleissner, Edgar P. Richardson, with Paul Manship and Leonard Carmichael, ex officio.

Dr. Carmichael reported to the Commission on the progress in developing the old Patent Office Building to house the National Portrait Gallery and the National Collection of Fine Arts. He stated that plans had been submitted to the General Services Administration and that it was expected funds would be available to begin remodeling in the winter of 1963–64, with possible completion of the galleries in January 1966.

A resolution was unanimously passed that the Smithsonian Art Commission "approves acceptance by the National Collection of Fine Arts of those examples of the work of Paul Manship, sculptor, both unique and of duplicate or multiple casting as he may leave to the gallery by last will and testament. In acceptance of these works, it will be understood that they shall not be subject to use as part of a lending collection but shall be accorded treatment as permament accessions, subject to occasional loans for special exhibition, rotation on display in the continuing exhibition, and other normal uses to which regular acquisitions are put."

The Commission recommended acceptance of the following for the National Collection of Fine Arts:

Terracotta, *Myron T. Herrick* (1854–1929), by Paul Manship (1885–). Offered by the sculptor, New York City.

Marble, *Somnambula*, by Randolph Rogers (1825–92). Offered by Mr. and Mrs. Fortunato Porroto, Washington, D.C.

Oil, *Le Ravin de la Mort les Eparges*, by Joseph Victor Communal. Bequest of Frederick R. Wulsin through Lucien Wulsin, Jr., Co-executor of the estate.

Oil, *Self Portrait*, by Edmund C. Tarbell (1862–1938). Offered by Mrs. Josephine Tarbell Ferrell and Mrs. Mary Tarbell Schaffer.

Oil, *Mrs. Edmund C. Tarbell*, by Edmund C. Tarbell (1862–1938). Bequest of Mrs. Mercie Tarbell Clay.

An oil and 15 watercolors by William Henry Holmes (1846–1933), together with a watercolor by Kenneth C. Holmes. Offered by Anna Bartsch Dunn, Washington, D.C.: *Chestnut Trees in Bloom* (oil); *Field of Vari-colored Grasses; Flowery Meadow; Field of Wheat in Shock; Field of Jim Pie Weed; The Babbling Brook; The Open Sea; A Maryland Dirt Road; Field of Blossoms; In Holland; Royal Oak; Windmills; Michigan; Cherry Blossoms; Blossoms; On Sunset Hill;* and *Vase with Flower* by Kenneth C. Holmes.

A collection of 83 original sketches executed under the Work Projects Administration Program was accepted for its historical significance. The sketches were offered as a transfer from General Services Administration through the Internal Revenue Service and were represented by the following examples: *The Railroad Came to Town*, by Saul Berman (1899–); *Preliminary Study for Mural, Trinity, Texas, Post Office*, by Jerry Bywaters (1906–); *Deer* and *Buffalo Hunt*, by Woodrow Crumbo; *Tung Oil Industry*, by Xavier González (1898–); *Arrival of Colonel John Donaldson*, by F. Luis Mora (1874–); *Design for Mural for Post Office at Rockport, Massachusetts*, by William Lester Stevens, A.N.A. (1888–); and *Fruit Packing*, by Undetermined Artist.

A collection of 71 watercolors by Cass Gilbert, N.A. (1859–1934), was offered by Mrs. Walter A. Bastedo, New Canaan, Conn., through the U.S. National Museum, and was represented by five examples as follows: *Old House in Rouen; On the Canal, Bruges; Aqueduct; Battle Abbey; The Zwinger and Towers, Dresden.*

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Three silhouettes by undetermined artists were acquired from Mrs. Helen Moffat Langdon, Alexandria, Va.: *Phoebe Cook DeWitt* (1736–1824); *Hannah DeWitt Shaw* (1758–1844); and *Abigail Shaw Barkley* (1792–1871).

The Commission recommended that the following be held for submission to the National Portrait Gallery Commission:

Ten oil portraits offered by the International Business Machines Corp., New York City, through T. D. Jones, director: *President James Abram Garfield* (1831–81), by Ole Peter Hansen Balling (1823–1906); *Fleet Admiral Ernest Joseph King* (1878–1956), by Albert K. Murray (1906–); *Admiral Marc Andrew Mitscher* (1887–1947), by Albert K. Murray (1906–); *Fleet Admiral Chester William Nimitz* (1885–), by Albert K. Murray (1906–); *Admiral William Frederick Halsey* (1882–1959), by Albert K. Murray (1906–); *Admiral Thomas C. Kincaid* (1888–), by Robert S. Sloan (1915–); *Secretary of State Cordell Hull* (1871–1955), by Camir Gregory Stapko (1913–) after Albert K. Murray (1906–); *Henry Clay* (1777–1852), by Undetermined Artist; *General Ulysses S. Grant* (1822–1885), by Samuel B. Waugh (1814–1885); and *General of the Army George Catlett Marshall* (1880–1959), by J. Anthony Wills.

Two oils, *Cass Gilbert* (1859–1934), by Ernest Ludwig Ipsen (1869–1951), and *Mrs. Cass Gilbert*, by Sir Arthur Stockdale Cope (1875–1940), offered by Mrs. Walter A. Bastedo, New Canaan, Conn., through the U.S. National Museum.

THE CATHERINE WALDEN MYER FUND

The following miniatures, watercolor on ivory, were acquired from the fund established through the bequest of Catherine Walden Myer:

No. 140. *Ebenezer Williams* (1769–), attributed to Rembrandt Peale (1778–1860).

No. 141. *Mrs. Ebenezer Williams, nee Martha Porter* (1774–), attributed to Rembrandt Peale (1778–1860).

Nos. 140 and 141 acquired from Lt. Col. W. C. Williams, Arlington, Va., through Miss Vera Fisher.

No. 142. *Gentleman*, by Peregrine F. Cooper (ac. 1840–90).

No. 143. *Gentleman*, by Undetermined Artist.

Nos. 142 and 143 acquired from Dorsey Griffith, New Market, Md.

No. 144. *Lady*, by A. G. Rose.

No. 145. *Gentleman*, by A. G. Rose.

Nos. 144 and 145 acquired from James Anton, Washington, D.C.

No. 146. *Gentleman*, attributed to Edward Greene Malbone (1777–1807).

No. 147. *J. G. E.*, by Rudolph Huber (1770–).

No. 148. *Gentleman* in the manner of John Smart (1740/1–1811).

Nos. 146–148 acquired from Ethel K. Perdriau, Berkeley, Calif.

No. 149. *A Pioneer Woman* by George Catlin (1796–1872). Acquired from Mr. David Silvette, Richmond, Va.

LOANS ACCEPTED

Two oils, *Portrait of Ruel P. Tolman* (1878–1954) by Bjorn Egeli (1900–) and *Portrait of Louis XVI* by Undetermined Artist, were lent by Mrs. Edward Kemper, Arlington, Va., October 18, 1962.

ART WORKS LENT AND RETURNED, PERMANENT COLLECTION

Institutions	*Loans*	*Loans returned*
American Federation of Arts	3	3
Bureau of the Budget	25	2
Defense, Department of	1	1
Durlacher Brothers, New York City	2	2
Federal Communications Commission	--	1
Health, Education, and Welfare, Department of	2	2
Huntington Galleries	1	1
Immaculate Heart of Mary Retreat House	1	1
Interior, Department of the	2	1
Internal Revenue Service	1	--
Joslyn Art Museum	1	--
Justice, Department of	1	--
Naval Historical Foundation	--	1
Post Office Department	--	4
President's Advisory Committee on Narcotic and Drug Abuse	6	--
President's Committee on Equal Employment	10	--
President's Committee on Intergovernmental Relations	12	--
Public Buildings Service	1	--
State, Department of	--	4
Treasury, Department of	1	1
Un-American Activities Committee	--	1
United Nations	1	--
University of California	4	4
U.S. District Court for the District of Columbia	3	2
U.S. Supreme Court	--	2
Veterans' Administration	--	2
Washington County Museum of Fine Arts	1	1
The White House (Food for Peace)	3	--
Woodward & Lothrop	8	8
	90	44

SMITHSONIAN LENDING COLLECTION

The following were added to the lending collection December 4, 1962:

Oil, *Coming Storm*, by Ralph Iligan (1893–1960). Offered by Miss Agnes Iligan, East Elmhurst, N.Y.

Two oils, *Dordogne Valley* and *Dordogne Valley*, by William Didier-Pouget (1864–). Offered by Mrs. Lawrence S. Lesser, Chevy Chase, Md.

An oil, *Bigradoo*, by Owen J. Garde (1919–). Offered by Allan Gerdau, New York City.

Harold F. Cross restored the following paintings: *Laura in Black Hat*, by Juliet Thompson (–1934); *Natalie*, by Juliet Thompson; *Reclining Model*, by Carrier-Belleuse (1824–87); together with the following by Alice Pike Barney (1860–1931): *Alice Roosevelt; Arcady; Lady with Fan; A. P. Barney;* and *Laura Alice Barney*.

Frames for the paintings *Reclining Model* by Carrier-Belleuse, *Laura in Black Hat* by Juliet Thompson, and *Lady with Fan* by Alice Pike Barney, were renovated by Istvan P. Pfeiffer.

ART WORKS LENT AND RETURNED, LENDING COLLECTION

Institutions	*Loans*	*Loans returned*
Barney, James Perrine	--	1
Barney Neighborhood House	9	--
Howard University	20	--
Justice, Department of	--	2
Lehigh University	--	1
Post Office Department	--	1
U.S. Senate	2	--
	31	5

ALICE PIKE BARNEY MEMORIAL FUND

Additions to the principal during the year amounting to $2,301.50 increased the total invested sums in the Alice Pike Barney Memorial Fund to $45,424.49.

THE HENRY WARD RANGER FUND

According to a provision of the Henry Ward Ranger bequest, that paintings purchased by the Council of the National Academy of Design from the fund provided by the 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, the following paintings were recalled for action of the Smithsonian Art Commission at its meeting December 4, 1962:

No. 44. *Their Son*, by Oscar Edward Berninghaus, A.N.A. (1874–1952), was returned to the Art Club of Erie, Erie, Pa., where it was originally assigned in 1924.

No. 45. *The Wood Cart*, by Louis Paul Dessar, N.A. (1867–1952), was returned to Yale University Art Gallery, New Haven, Conn., where it was originally assigned in 1925.

No. 123. *Gravel, Fish, and Soya Beans*, by Carl Frederick Gaertner, A.N.A. (1898–1952), assigned in 1948 to the Swope Art Gallery, Terre Haute, Ind., was accepted to become a permanent accession.

The following paintings purchased previously but not assigned have been allocated to the institutions indicated:

Title and artist	*Assignment*
249. *Reflections*, by Adolf Konrad (1915–).	Newark Museum, Newark, N.J.
258. *The Fascination of Toledo*, by Carol M. Grant (1930–).	Chattanooga Art Association, Chattanooga, Tenn.
261. *Turn Around*, by Ed Graves (1917–).	Reading Public Museum and Art Gallery, Reading, Pa.
263. *Monday Morning*, by Herb Olsen (1905–).	Springfield Art Association, Springfield, Ill.

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*
265. *Dust to Dust*, by Robert Philipp (1895–).	Dayton Art Institute, Dayton, Ohio.
266. *From Breda*, by Xavier González (1898–).	Assignment pending.
267. *Young Guitarist*, by Leon Kroll (1884–).	The Berkshire Museum, Pittsfield, Mass.
268. *Low Tide* (watercolor), by William E. Preston (1930–).	Art Center in La Jolla, La Jolla, Calif.
269. *Ott Brenner's Barn*, by Robert Allan Gough (1931–).	Nebraska Art Association, Lincoln, Nebr.
270. *Conversation*, by John Koch (1909–).	Walker Art Museum, Bowdoin College, Brunswick, Maine.
271. *Grindstone Ledge* (watercolor), by Roy M. Mason (1886–).	Grand Rapids Art Gallery, Grand Rapids, Mich.
272. *Desolation* (watercolor), by D. Wu Ject-Key (1895–).	Assignment pending.
273. *Dilworthtown* (watercolor), by Philip Jamison (1925–).	Assignment pending.
274. *Sampans and Junks, Hong Kong* (watercolor), by Louis J. Kaep (1903–).	Assignment pending.
275. *Old Boat Yard* (watercolor), by Antonio P. Martino (1902–).	New Mexico State University, University Park, N. Mex.
276. *Off Season, St. Ives* (watercolor), by Tom Nicholas (1934–).	Georgia Museum of Art, University of Georgia, Athens, Ga.
277. *Autumn's Sentinels* (watercolor), by Robert H. Laessig (1913–).	Addison Gallery of American Art, Phillips Academy, Andover, Mass.

SMITHSONIAN TRAVELING EXHIBITION SERVICE

In addition to 102 exhibits held over from previous years as indicated below, 25 new shows were introduced. The total of 127 shows was circulated to 333 museums in the United States. Two exhibitions were delivered to the U.S. Information Service for circulation abroad.

EXHIBITS CONTINUED FROM PRIOR YEARS

1956–57: Japan II by Werner Bischof; and The World of Edward Weston.

1957–58: The American City in the 19th Century; Japanese Woodblock Prints; Theatrical Posters of the Gay Nineties; Burmese Embroideries; Japanese Dolls; Thai Painting; The Anatomy of Nature; and Drawings by European Children.

1958–59: Advertising in 19th Century America; Religious Subjects in Modern Graphic Arts; Our Town; Stone Rubbings from Angkor Wat; and Shaker Craftsmanship.

1959–60: Early Drawings of Toulouse-Lautrec; Watercolors and Drawings by Thomas Rowlandson; Prints and Drawings by Jacques Villon; American Prints Today; Brazilian Printmakers; Arts and Cultural Centers; Bernard Ralph Maybeck; Bazaar Paintings from Calcutta; Sardinian Crafts; Arctic Riviera; Photographs by Robert Capa I; Photographs by Robert Capa II; Pagan; Portraits of Greatness; Contrasts; Paintings by Young Africans; and Japan I.

1960–61: The Technique of Fresco Painting; Paintings by Ch'i Pai-Shih; Birds of Greenland; The America of Currier and Ives; Drawings by Sculptors; The Graphic Art of Edvard Munch; German Color Prints; Eskimo Graphic Art; Civil War Drawings I; Civil War Drawings II; American Art Nouveau Posters; American Industry in the 19th Century; America on Stone; Designed in Okinawa; Okinawa—Continuing Traditions; Prints by Munakata; Contemporary Japanese Drawings; Japan: by Werner Bischof; The Spirit of the Japanese Print; Americans—A View From the East; Swiss Industrial Architecture; Contemporary Swedish Architecture; Mies van der Rohe; Irish Architecture of the Georgian Period; One Hundred Years of Colorado Architecture; Brasilia—a New Capital; Design in Germany Today; Designed for Silver; Batiks by Maud Rydin; American Textiles; The Seasons, color photographs by Eliot Porter; The World of Werner Bischof; The Image of Physics; Charles Darwin: The Evolution of an Evolutionist; The Beginnings of Flight; The Magnificent Enterprise—Education Opens the Door; The New Theatre in Germany; Tropical Africa I; Tropical Africa II; Symphony in Color; Paintings and Pastels by Children of Tokyo; Children's Art from Italy; Hawaiian Children's Art; and Designs by Children of Ceylon.

1961–62: Tutankhamun's Treasures; Fourteen Americans in France; George Catlin, Paintings and Prints; Physics and Painting; UNESCO Watercolor Reproductions; Belgian Drawings; The Lithographs of Childe Hassam; Contemporary Italian Drawings; John Baptist Jackson; Contemporary Swedish Prints; Japanese Posters; The Face of Viet Nam; Architectural Photography (New Editions); Le Corbusier—Chapel at Ronchamp; The Family, The Neighborhood, The City; One Hundred Books from the Grabhorn Press; Wisconsin Designer-Craftsmen; Caribbean Journey; The Swedish Film; The Story of a Winery; This Is the American Earth; The Hidden World of Crystals; Hummingbirds; Brazilian Children's Art; Children Look at UNESCO; and My Friends.

EXHIBITIONS INITIATED IN 1963

Paintings and Sculpture

The Daniells in India	India Library, London, Mrs. Mildred Archer; P & O Lines.
Eskimo Carvings	Eskimo Art, Inc., Ann Arbor, Mich.; Canadian Embassy.
Holland: The New Generation	Municipal Museum of Amsterdam, W. J. H. B. Sandberg; The Embassy of the Netherlands.
John Sloan	Wilmington Society of the Fine Arts, Bruce St. John, Director.
Contemporary Japanese Sumi Paintings	Japan Society, New York; Kokusai Bunka Shinkokai, Tokyo.

Drawing and Prints

American Prints Today, 1962	Print Council of America, New York City.
Contemporary American Drawings	XXth American Drawing Annual, Norfolk; Addison Gallery of American Art, Bartlett Hayes.
Work by Ernst Barlach	German Barlach Society; Dr. Wolf Stubbe, Hamburger Kunsthalle.
Old Master Drawings from Chatsworth	Trustees of the Chatsworth Settlement; Devonshire Collection; Duke and Duchess of Devonshire; British Embassy.
English Watercolors and Drawings	Anonymous lender.
Eskimo Graphic Art II	Canadian Embassy; Eskimo Art, Inc., Ann Arbor, Mich., Eugene N. Power.
European Posters	Graphis Magazine, Zurich, Switzerland, Ken Baynes.

Oriental Art

Pakistan Stone Rubbings	Mrs. Ethel Jane Bunting, Washington, D.C.

Architecture

Contemporary Canadian Architecture	Royal Architectural Institute of Canada; Embassy of Canada.
Twelve Churches	California Redwood Association, San Francisco, Calif.
100 Sketches by Eric Mendelsohn	Mrs. Louis Mendelsohn, San Francisco, Calif.
Pre-Hispanic Mexico	Mexican Government Tourist Office; Organization of American States, Washington, D.C.

Design and Crafts

Today's American Wallcoverings	American Institute of Interior Designers; Resources Council, New York City.
Craftsmen of the City	Irving Sloane, International Business Machines Corp.
The Tradition of French Fabrics	Brunschwig and Fils; French Embassy.

Children's Art

A Child's World of Nature	Junior School, School of the Art Institute of Chicago, Ill.
West German Students' Art	United States Committee for Refugees; Germany Indivisible; German Embassy.

History

Historic Annapolis	Historic Annapolis, Inc., Annapolis, Md.
Civil War Drawings III	American libraries; Library of Congress, Washington, D.C.
The Old Navy, 1776–1860	Franklin D. Roosevelt Library, Hyde Park, N.Y.; National Archives, Washington, D.C.

STAFF ACTIVITIES

Special services were performed under contracts with Keyes Porter and Delight Hall. Unfortunately, death prevented the completion of a study begun by the late George C. Groce, author.

Contracts were let for the relining and restoring by Harold F. Cross of the following:

Portrait of a Lady, by Abbott H. Thayer (1849–1921); *Her Leisure Hour*, by Irving Wiles (1861–1948); *John Tyler* (1790–1862), by G. P. A. Healy (1808–94); *Sundown*, by George Inness (1825–94); *Large Landscape*, by Thomas Barker (1769–1847); *Adoration of the Kings*, by Bernard Van Orley (1485/93–1542); *Lady in White* (*No. 1*), by Thomas W. Dewing (1851–1938); *Lady in White* (*No. 2*), by Thomas W. Dewing (1851–1938); *The Happy Mother*, by Max Bohm (1868–1923); *Cardinal*, by Titian (1477–1576); and *Mrs. Houston*, by Thomas W. Dewing (1851–1938).

Henri G. Courtais contracted for renovation of the following paintings:

Venetian Scene, by Francesco de Guardi (1712–93); *Windstorm*, by John Constable (1776–1837); *Portrait of Thomas Hopkinson* (1709–51), by Robert Feke (1705/24–1750/69); *The Great Western*, by William Marsh (ac. 1844–58); *Stephen Decatur* (1779–1820), attributed to Gilbert Stuart (1755–1828); *The Smoker*, by Eugene Delacroix (1798–1863); *Mrs. Robert Wetmore*, by Henry Inman (1802–46); *New Year's Shooter*, by George Luks (1867–1933); *Head of a Young Woman* (*Leonori*), by James McNeill Whistler (1834–1903); *Water Carriers, Venice*, by Frank Duveneck (1848–1919); *John Gellatly* (1853–1931), by Irving R. Wiles (1861–1948); *The Sermon*, by Gari Melchers (1860–1932); and *The Holy Family, with St. Elizabeth*, by Peter Paul Rubens (1577–1640).

Nine original sketches executed under the Work Projects Administration were restored and remounted by Istvan P. Pfeiffer. Mr. Pfeiffer gilded frames for the following paintings: *Landscape with Figures*, by Thomas W. Dewing (1851–1938); *Lady in White* (*No. 1*), by Thomas W. Dewing (1851–1938); and *Head of a Young Woman* (*Leonori*), by James A. McNeill Whistler (1834–1903).

A physical inventory of paintings, sculptures, and prints accessioned by the National Collection of Fine Arts and a catalog listing of same were begun by staff members.

In addition to the approximately 20,500 requests for information received by mail and telephone, inquiries made in person at the office numbered 1,680. In all, 302 works of art were examined by the staff members.

Special catalogs were published for the following traveling exhibitions: Work by Ernst Barlach; Old Master Drawings from Chatsworth; and The Daniells in India. Folders announcing the following exhibits were also published: Pakistan Stone Rubbings; 100 Sketches by Eric Mendelsohn; History Exhibitions; Children's Art Exhibitions; Natural History and Science Exhibitions; Prints and Drawings Exhibitions; and Architectural Exhibitions.

Staff members served as jurors of a number of local art exhibitions and gave illustrated lectures to clubs.

As plans develop for the National Collection of Fine Arts' occupancy of the Civil Service Commission Building (the Old Patent Office), necessary additions are being made to staff. During the last year the following were named to the positions indicated: Donald R. McClelland, exhibits designer; Anne Castrodale, research assistant; Linwood Lucas, museum aide; and Nancy Brooks, clerk-stenographer.

SPECIAL EXHIBITIONS

July 8–September 3, 1962. A Centennial Exhibition of Paintings by Edmund C. Tarbell, N.A. (1862–1938), with the cooperation and assistance of Mrs. Josephine Tarbell Ferrell, Mrs. Mary Tarbell Schaffer, Mrs. John Staley, the Corcoran Gallery of Art, and the U.S. National Museum. The exhibition consisted of 26 paintings, 12 medals, and memorabilia.

September 15–October 11, 1962. Fifth Biennial Creative Crafts Exhibition, sponsored by The Kiln Club of Washington, D.C.; Ceramic Guild of Bethesda; Cherry Tree Textile Designers; Clay Pigeons Ceramic Workshop; Designers-Weavers; and Potomac Craftsmen. The exhibit contained 215 items including ceramics, textiles, weavings, enamels, sculpture, and jewelry. An illustrated catalog was privately printed.

September 17–November 11, 1962. Pre-Hispanic Mexico, sponsored by the Government of Mexico and the Pan American Union and circulated by the Smithsonian Institution Traveling Exhibition Service, was shown in the lobby of the Natural History Building. A brochure was privately printed.

October 20–November 8, 1962. The 69th Annual Exhibition of the Society of Washington Artists. The show consisted of 78 paintings and 23 sculptures. A catalog was privately printed.

November 17–December 9, 1962. The Art of Thailand, sponsored by the Ambassador of Thailand and the Washington-Bangkok Friendship Council, and with the cooperation of the Division of Ethnology, U.S. National Museum. The King's birthday was celebrated on December 5, 1962.

November 17–December 9, 1962. Contemporary Japanese Sumi Painting, organized by Kokusai Bunka Shinkokai, Tokyo, and circulated by the Smithsonian Institution Traveling Exhibition Service. The exhibition consisted of 30 paintings. An illustrated catalog was privately printed.

November 17–December 9, 1962. The Daniells in India [Thomas Daniell, R.A. (1749–1840), and William Daniell (1769–1837)], circulated by the Smithsonian Institution Traveling Exhibition Service. The show consisted of 50 watercolor paintings. An illustrated catalog was privately printed.

December 16, 1962–January 3, 1963. The 25th Metropolitan Art Exhibition sponsored by the American Art League. The exhibit consisted of 101 paintings and 12 sculptures. A catalog was privately printed.

January 12–February 3, 1963. European Posters, circulated by the Smithsonian Institution Traveling Exhibition Service. The show consisted of 39 posters by 19 artists. A catalog was privately printed.

January 12–February 3, 1963. 100 Books from the Grabhorn Press, circulated by the Smithsonian Institution Traveling Exhibition Service.

February 9–March 3, 1963. Eskimo Graphic Arts, circulated by the Smithsonian Institution Traveling Exhibition Service. The exhibit included 50 stone-block and sealskin prints.

February 9–March 3, 1963. Eskimo Carvings, circulated by the Smithsonian Institution Traveling Exhibition Service. The show consisted of 50 carvings in stone, bone, and ivory.

March 10–28, 1963. Contemporary German Books, sponsored by the Ambassador of Germany and the Boersenverein des Deutschen Buchhandels E.V. A catalog was privately printed.

April 7–25, 1963. The 66th Annual National Exhibition of the Washington Water Color Association. The exhibition consisted of 150 watercolors, prints, and drawings. An illustrated catalog was privately printed.

April 22–28, 1963. National Coin Week exhibition, sponsored by the Nation's Capital Coin Club.

May 5–24, 1963. The 30th Annual National Exhibition of the Miniature Painters, Sculptors, and Gravers Society of Washington, D.C. The exhibit consisted of 157 items including painting, sculpture, bookbinding, and graphics, and included a special showing of work of the founding members, Alyn Williams, Hattie E. Burdette, Benson B. Moore, Marian U. M. Lane, and Elizabeth Muhlhofer. An illustrated catalog was privately printed.

May 4–31, 1963. A Retrospective Exhibition of the work of John Sloan, organized by the Wilmington Society of the Fine Arts and circulated by the Smithsonian Institution Traveling Exhibition Service. The show included 37 paintings, 31 drawings, and 36 etchings. An illustrated catalog was privately printed.

June 8–30, 1963. The 1st National Exhibition of Art Directors sponsored by the Art Directors Club of Metropolitan Washington and the National Society of Art Directors. An illustrated 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 43d annual report on the Freer Gallery of Art, for the year ended June 30, 1963.

THE COLLECTIONS

Fifteen objects were added to the collections by purchase as follows:

PAINTINGS

62.26. Chinese, Ch'ing dynasty, by Wang Yüan-ch'i (1642–1715), dated 1704. Landscape in the manner of Ni Tsan. Ink and colors on paper. Two inscriptions and five seals of the artist on the painting. Kakemono: height: 0.955; width: 0.505.

62.29. Chinese, Ch'ing dynasty, by Wang Shih-min (1592–1680), dated 1670. Landscapes in old styles. Six paintings and one leaf of calligraphy, originally from an album. Ink and color on paper. Six inscriptions and 13 seals on paintings; 11 seals on leaf of calligraphy; colophon with one seal. Outside label inscribed. Handscroll: height: 0.318; length: 8.375. (Illustrated.)

62.27. Japanese, Edo period, Buddhist school. Scroll VII of the *Hoke Kyō* (Lotus *Sutra*). Gold with touches of color, on blue paper. Height: 0.280; width: 3.920.

62.28. Japanese, Ashikaga period, early 16th century, Muromachi-Suiboku school, by Shukō. Hawk. Ink on paper. Height: 0.959; width: 0.447.

62.30–62.31. Japanese, Momoyama period, Decorative school, by Nonomura Sōtatsu (fl. *ca.* 1600–1630). Trees. A pair of six-fold screens. Ink and colors on gold leaf. Height: 1.540; width: 3.578. (62.30 illustrated.)

62.32 Turkish, Ottoman school, early 17th century. A young prince and attendant of which two hemistiches in *nasta'līq* are given above painting. Mounted as album leaf with marginal designs of gold cloud bands and floral rinceaux on dark ground. Miniature: height: 0.085; width: 0.060. Album leaf: height: 0.210; width: 0.125.

POTTERY

62.33. Chinese, T'ang dynasty, white ware. Wide shallow bowl with turned-over rim and flat, unglazed base. Clay: light buff stoneware. Glaze: opaque white with fine crackle. Decoration: none. Height: 0.092; diameter: 0.315.

62.34. Chinese, Ming dynasty, about 1400, celadon ware. Wide bowl with foliate rim; small foot; circular hole in base underneath. Clay: fine-grained high-fired gray porcelain. Glaze: transparent, thick, grayish-green celadon. Decoration: bowl sides fluted inside and out to match foliation of rim; molded ornamental lotus plaque applied in relief inside center covering hole in base. Height: 0.126; diameter: 0.326.

62.22. Japanese, Momoyama period (1574–1602), Shino ware (red). Shallow, almost flat, circular dish with slightly recessed foot. Clay: coarse light gray stoneware fired red on the surface. Glaze: milky, semi-opaque, bubbly, uneven. Decoration: bamboo sprays painted in black. Height: 0.022; diameter: 0.213.

62.23. Japanese, Edo period, Kakiemon ware. Dish with fluted rim; five spur marks on base. Clay: white porcelain. Glaze: transparent, slightly bluish. Decoration: Chinese scene of two figures in a garden by a house, in slip relief under the glaze. Inscriptions, rim decoration, and *fuku* mark on base in underglaze blue. Height: 0.054; diameter: 0.315.

62.24. Japanese, Momoyama period, Shino-Oribe ware. Dish with foliate rim, scalloped cavetto, and low foot-rim. Clay: coarse gray stoneware. Glaze: buff, semiopaque, bubbly, rough. Decoration: a very sketchy flower in brown in center. Height: 0.032; diameter: 0.191.

62.25. Japanese, Momoyama period, Shino ware. Dish with flaring foliate rim; knobs on sides; three loop feet. Clay: coarse gray stoneware. Glaze: grayish white; semiopaque; crackled; spur marks inside. Decoration: grasses in the center and a fence around cavetto painted in brown. Height: 0.053; diameter: 0.171.

63.1. Japanese, Edo period, Kutani ware, 17th century. Vase, pear-shaped; decorated with overglaze enamels, in red, yellow, and turquoise. Height: 0.256; diameter: 0.146. (Illustrated.)

WOOD SCULPTURE

62.21. Japanese, Fujiwara period, late 12th century. Miroku Bosatsu. Mandorla shows gilt design. Arms restored. With pedestal. Figure: height: 0.980; width: 0.750; depth: 0.508. Overall: height: 2.060; diameter: 1.140. (Illustrated.)

REPAIRS TO THE COLLECTION

Forty Chinese and Japanese paintings and one Persian manuscript were restored, repaired, or remounted by T. Sugiura, Oriental picture mounter. F. A. Haentschke, illustrator, remounted 47 Persian, Indian, and Arabic paintings. Repairs and regilding of three frames for American paintings were done outside the Gallery. Dr. F. Zach of Catholic University repaired and rebound one Indo-Persian manuscript.

CHANGES IN EXHIBITIONS

Changes in exhibitions amounted to 237, which were as follows:

American art: Prints	35
Chinese art:	
Bronze	5
Lacquer	2
Painting	49
Pottery	12
Glass	8
Christian art:	
Manuscripts	14
Stone sculpture	2
Japanese art:	
Painting	7
Pottery	3
Near Eastern art:	
Glass	67
Metalwork	1
Painting	27
Pottery	5

LIBRARY

The library is principally a place for the acquisition and conservation of books. But it is also intrinsically a place for browsing or study in fields of interest to the individual so that he may become a contemporary of all ages. During the year 909 acquisitions (other than slides) were added to the library; 263 of these were by purchase and 646 by exchange and gift. Outstanding gifts were: *Modern Japanese Prints*, by James Michener, the gift of Mr. and Mrs. Felix Juda; *Chinese Calligraphy and Paintings in the Collection of John M. Crawford*, the gift of James Cahill; 265 photographs for the study collection, the gift of Bungaku Kenkyusho of Japan. An outstanding purchase was *Hasshu gafu* (the book of painting of eight varieties), a Japanese edition using the woodblocks dated 1672.

The year's record of cataloging included a total of 1,507 entries, of which 697 analytics were made and 365 new titles of books, pamphlets, and scrolls were cataloged. Additions to the continuations of sets of books numbered 32, and 4,087 cards were added to the card catalog. Only 7 percent of these were available as printed cards from the Library of Congress; this indicates the amount of original cataloging in the library.

The slide collection has continued to grow. A checklist for slides of the Freer collection was instituted. Acquisition of 1,329 slides was completed, and 3,120 slides were bound and labeled. This last process included the classification for filing in the slide cabinets. A total of 5,989 slides were lent, of which 4,764 were for the use of staff members in their lectures.

There were 181 requests for bibliographic information by telephone and letters. In all, 766 scholars and students who were not members of the Freer staff used the library. Ten of these saw and studied the Washington Manuscripts, and three came to see the library installation.

The library's holdings of the Dewing letters were laminated by the Archival Restoration Associates, Inc., and it is hoped to have the Whistler letters laminated soon.

Hale Lancaster Darby served as volunteer for the intern program for the summer. This program is to interest young people in museology.

Two archival gifts of study material were transferred to the library during this past year. The Aga-Oglu archives have been arranged in a file cabinet, and the Herzfeld archives remain to be studied and put in order.

PUBLICATIONS

Five publications were issued by the Gallery as follows:

Ancient glass in the Freer Gallery of Art, by Richard Ettinghausen, 44 pp. with 99 illus., bibliography. (Smithsonian Institution Publication 4509.)

Freer Gallery of Art. Pamphlet containing a brief history of the Gallery and collections, 16 pp., 8 illus., 3 plans. (Smithsonian Institution Publication 4504.)

Chinese Album Leaves, by James Cahill, 40 pp. with 32 illus. and descriptions, frontispiece. (Smithsonian Institution Publication 4476.)

The Field of Stones, by Richard Edwards, xxi+131 pp., 50 pls., frontispiece. Oriental Studies, No. 5. (Smithsonian Institution Publication 4433.)

The Whistler Peacock Room, reprint ed. 1962, 22 pp., 9 illus., bibliography. (Smithsonian Institution Publication 4024, revised.)

Publications of staff members were as follows:

CAHILL, JAMES F. Archibald G. Wenley, 1898–1962. *Artibus Asiae*, vol. 25 (1962), pp. 197–198.

———. Collecting paintings in China. *Arts Magazine*, vol. 37 (1963), pp. 66–72, illus.

———. Concerning the I-p' in style of painting, by S. Shimada. Translated by J. Cahill. *Oriental Art*, n.s., vol. 8, pp. 130–137, illus.

———. The Crawford collection; Chinese painting and calligraphy. *Oriental Art*, n.s., vol. 8 (1962), pp. 163–166, illus.

———. Some rocks in early Chinese painting. *Archives of the Chinese Art Society of America*, vol. 16 (1962), pp. 77–87, illus.

ETTINGHAUSEN, RICHARD. A. G. Wenley (1898–1962). Cosmos Club *Bulletin*, vol. 16, No. 2 (February 1962), p. 204, portrait.

———. Arabische Malerei. Geneva, Skira, 1962.

———. An early Ottoman textile. First International Congress of Turkish Arts, Ankara, 1959. *Communications presented to the Congress*. Ankara, 1961, pp. 134–140, pls. 78–94.

———. Estetica. *Enciclopedia Universale dell'Arte*, vol. 5 (1962), cols. 94–95.

———. The evergreen tradition of Moslem art. *Art News*, vol. 61 (1963), No. 9, pp. 26–29, 55–56, illus. (part col.).

———. Genere e Profane Figurazioni: Oriente. *Enciclopedia Universale dell'Arte*, vol. 5 (1962), cols. 670–671.

———. Iconismo e Aniconismo: Islamismo. *Enciclopedia Universale dell'Arte*, vol. 7 (1962), cols. 156–158.

———. La Peinture Arabe. Geneva, Skira, 1962.

———. Turkey: ancient miniatures. Preface by R. Ettinghausen. Greenwich, Conn., New York Graphic Society, 1961. 26 pp., illus., 32 col. pls.

———. Turkish elements on silver objects of the Seljuk period of Iran. First International Congress of Turkish Arts, Ankara, 1959. *Communications presented to the Congress*, Ankara, 1961, pp. 128–133, 32 figs. on pls. 77–87.

———. Review of "A bibliography of the Architecture, Arts and Crafts of Islam to 1st Jan. 1960," by K. A. C. Creswell. *Journal of the American Oriental Society*, vol. 82 (1963), pp. 395–396.

———. Review of "Persian gardens and garden pavilions," by Donald N. Wilber. *The Middle East Journal*, vol. 16 (1962), pp. 546–547.

———. Review of "The Seljuks in Asia Minor," by Tamara Talbot Rice. *The Middle East Journal*, vol. 16 (1962), p. 390.

GETTENS, R. J. Maya blue: an unsolved problem in ancient pigments. *American Antiquity*, vol. 27 (1962), pp. 557–564, tables.
———. Minerals in art and archeology. *Smithsonian Annual Report for 1961*, 1962, pp. 551–568, 8 pls.
———. Tumacacori interior decorations. In collaboration with Charles R. Steen. *Arizoniana, the Journal of Arizona History*, vol. 3 (1962), pp. 7–33, pls.
POPE, JOHN A. A Chinese Buddhist pewter with a Ming date. *Archives of the Chinese Art Society of America*, vol. 16 (1962), pp. 88–91, illus.
———. Review of "Archaeology in China; vol. I. Prehistoric China," by Cheng Te-k'un. *Journal of the American Oriental Society*, vol. 80 (1960), pp. 82–85.
———. Review of "Chinese and Japanese Cloisonné Enamels," by Sir Harry Garner. *Oriental Art*, n.s., vol. 9 (1963), pp. 41–42.
STERN, HAROLD P. The Perfumed Lady, by Moronobu. *Art Association of Indianapolis, Herron Museum of Art Bulletin*, vol. 49 (1962), pp. 4–8, illus.
———. Ukiyoe paintings of Tokugawa Japan. *Bulletin of the Japan Society, London*, vol. 3, No. 36 (1962), pp. 5–11.
———. Review of "The Folk Art of Japan," by Hugo Munsterberg. *Artibus Asiae*, vol. 25 (1962), pp. 213–214.
———. Review of "The Hokusai Sketchbook," by James A. Michener. *Artibus Asiae*, vol. 25 (1962), pp. 219–220.
TROUSDALE, W. B. Architectural landscapes attributed to Chao Po-chü. *Ars Orientalis*, vol. 4 (1961), pp. 11–19, illus.
———. A Chinese handle-bearing mirror from Northern Afghanistan. *Artibus Asiae*, vol. 24 (1961), pp. 11–19, illus.
WENLEY, ARCHIBALD G. A Chinese Sui dynasty mirror [with] "Note on the composition, fabrication and condition of this Sui dynasty mirror," by Rutherford J. Gettens. *Artibus Asiae*, vol. 25 (1962), pp. 141–148, plates.
WEST, ELISABETH H. Jade; its character and occurrence. University Museum, University of Pennsylvania. *Expedition*, vol. 5 (1963), pp. 2–11, illus.
———. A ring-mount for micro-cross-sections of paint and other materials. *Studies in Conservation*, vol. 4 (1959), pp. 27–31, illus.

PHOTOGRAPHIC LABORATORY AND SALES DESK

The photographic laboratory made 15,453 items during the year as follows: 11,072 prints, 722 negatives, 3,415 color slides, 160 black-and-white slides, and 84 color sheet films. At the sales desk 56,574 items were sold, comprising 4,727 publications and 51,847 reproductions (including postcards, slides, photographs, reproductions in the round, etc.). These figures indicate a marked increase in the work of both the photographic laboratory and sales desk over that of previous years.

BUILDING AND GROUNDS

The exterior of the building appears to be sound. The roof was repaired but further repairs will be necessary. The sidewalk at the north front of the building was replaced. The cleaning of the exterior stonework is scheduled to commence in the new fiscal year.

In the interior, the structural steel in the attic is in need of painting. A fluorescent lighting system was installed over the galleries.

The attic heating system was altered by the installation of steam-heated units in the air ducts. Work continued on the maintenance of the bronze doors and fittings. The director's office was partitioned, and decoration, with the exception of the galleries, was carried out wherever necessary. Floor-level sills were installed throughout the ground level, and the vault was replastered and painted. Panel-case storage was expanded, and additional fire precautions were instituted with the extension of the spray booth and construction of a storage area in the subbasement for flammable materials. The areas in need of repair in the auditorium are being replastered.

The cabinet shop continued to make and repair furniture and equipment as the need arose.

Seasonal plantings in the courtyard flourished, and the brick walks which had deteriorated were replaced.

ATTENDANCE

The Gallery was open to the public from 9 to 4:30 every day except Christmas Day. The total number of visitors to enter the main entrance was 183,359. The highest monthly attendance was in August: 31,417.

There were 3,062 visitors who came to the Gallery office for various purposes—for general information, to submit objects for examination, to consult staff members, to take photographs or sketch in the galleries, to use the library, to examine objects in storage, etc.

AUDITORIUM

The series of illustrated lectures was continued as follows:

1962

October 16. Dr. Michael Sullivan, University of London, England, "Realism in Chinese Art." Attendance, 181.

November 13. Prof. Oleg Grabar, University of Michigan, "Medieval Jerusalem." Attendance, 212.

1963

January 22. Prof. Donald Keene, Columbia University, "Japanese Books and Their Illustrations." Attendance, 205.

February 12. Prof. Pramod Chandra, University of Chicago, "Indian Painting of the Bundi School (17th and 18th Centuries)." Attendance, 64.

March 12. Dr. John A. Pope, Freer Gallery of Art, "Chinese Collectors." Attendance, 200.

April 16. Dr. James F. Cahill, Freer Gallery of Art, "Yüan Chiang and the Fantastic Landscape in China." Attendance, 203.

The Smithsonian Institution used the auditorium as follows:

1962

July 17. Museum Service. Lecture by Dr. Werner of the British Museum, "New Methods in Conservation." Attendance, 63.

62.21. Japanese wood sculpture, Fujiwara period, late 12th century; Miroku Bosatsu Freer Gallery of Art.

62.29. Chinese painting, Ch'ing dynasty, by Wang Shih-min (1592–1680), dated 1670; landscape. Freer Gallery of Art.

62.30. Japanese painting, Momoyama period, Decorative school, by Nonomura Sōtatsu (fl. *ca.* 1600–1630); trees. Freer Gallery of Art.

63.1. Japanese pottery, Edo period, Kutani ware, 17th century; vase. Freer Gallery of Art.

July 18. Museum Service. Lecture by Dr. Werner, "Scientific Examination in Conservation." Attendance, 53.

July 20. Museum Service. Public lecture by Dr. Werner, "The Scientific Examination of Paintings and Antiquities." Attendance, 170.

August 16. Museum Service. Showing of the film, "The Salvage of the Warship *Vasa*." For the Division of Naval History. Attendance, 151.

October 5. National Air Museum conference. Attendance, 85.

November 13. Committee on Oceanography conference. Attendance, 584. (Two sessions.)

1963

April 24. Museum Service. Lecture by Hugh Wakefield of the Victoria and Albert Museum, London, England, "English Victorian Glass." Attendance, 97.

Throughout the year, outside organizations used the auditorium as follows:

Washington Film Society, 15 times. Total attendance, 3,206.

U.S. Department of Agriculture, 34 times. Total attendance, 4,846.

U.S. Department of Health, Education, and Welfare, 13 times. Total attendance, 1,416.

The Peace Corps, once. Attendance, 151.

The Women's Committee of the National Symphony Orchestra, once. Attendance, 112.

The Washington Center for Metropolitan Studies and the Washington Art Council, once. Attendance, 121.

The Archaeological Institute of America, twice. Total attendance, 335.

Fashion Group, Inc., 5 times. Total attendance, 821.

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 collection of Chinese, Japanese, Persian, Arabic, and Indian materials. In all, 6,984 objects and 1,130 photographs were examined, and 451 Oriental language inscriptions were translated for outside individuals and institutions. By request, 29 groups totaling 786 persons met in the exhibition galleries for docent service by the staff members. Fourteen groups totaling 141 persons were given docent service by staff members in the storage rooms.

Among the visitors were 118 distinguished foreign scholars or persons holding official positions in their own countries who came here under the auspices of the Department of State to study museum administration and practices in this country.

During the year the technical laboratory examined the following objects by various methods, including microscopic and microchemical, X-ray diffraction, ultraviolet light, spectrochemical analysis, and specific gravity determination:

Freer objects examined	195
Outside objects examined	53

These include 52 objects cleaned and/or repaired; 19 inquiries were answered by letter.

The following projects were undertaken by the laboratory during the year:

1. For 6 weeks in October and December 1962, Miss E. West worked at the Conservation Center of the Institute of Fine Arts, New York University, where she continued spectrochemical analyses of Chinese bronzes from the Freer Collection.
2. Continued analyses by wet chemical methods of Chinese bronzes in the Freer Collection.
3. Continued systematic collection of data on technology of ancient copper and bronze in the Far East.
4. Continued studies on corrosion products of ancient metal objects.
5. Continued editorship of *IIC Abstracts* published by the International Institute for Conservation of Historic and Artistic Works, London, England.

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

1962

July 13.	Dr. Ettinghausen, at the International Glass Congress, Washington, D.C., "Ancient Glass in the Freer Gallery of Art." Attendance, 45.
September 13.	Mr. Gettens, at a symposium on archeological chemistry, American Chemical Society, Atlantic City, N. J., "Composition of Ancient Chinese Bronze Ceremonial Vessels." Attendance, 35.
October 11.	Dr. Pope, at the Royal Ontario Museum, Toronto, Canada, "Chinese Export Porcelain." Attendance, 400.
October 12.	Dr. Pope, at the University of Toronto, Toronto, Canada, "The Civilization of Angkor." Attendance, 40.
October 22.	Dr. Cahill, at Connecticut College, New London, Conn., "The Contemporary Relevance of Chinese Painting." Attendance, 130.
October 23.	Dr. Cahill, at Yale University, New Haven, Conn., "Subject and Expression in Chinese Painting." Attendance, 80.
October 23.	Dr. Ettinghausen, at the Lions Club, Vienna, Va., "Travels in the East." Attendance, 140.
October 24.	Dr. Cahill, at the Pierpont Morgan Library, New York City, "Subject and Expression in Chinese and Recent Western Painting." Attendance, 300.
October 26.	Dr. Ettinghausen, at the Baltimore Museum of Art, Baltimore, Md., "Treasures from the Near East in the Freer Gallery of Art." Attendance, 360.
October 30.	Dr. Pope, at the Pierpont Morgan Library, "Chinese Collectors." Attendance, 190.

1962

November 12. Dr. Cahill, at the University of Kansas, Lawrence, Kans., "Confucian Humanism and Chinese Art." Attendance, 75.

November 13. Dr. Cahill, at the University of Kansas, "The Contemporary Relevance of Chinese Painting." Attendance, 250.

November 14. Dr. Cahill, at the University of Kansas, "Subject and Expression in Chinese Painting." Attendance, 60.

November 14. Mr. Gettens, at the American Chemical Society, Stamford, Conn., "Minerals in Art and Archeology." Attendance, 50.

November 15. Dr. Ettinghausen, at the Hermitage Foundation, Norfolk, Va., "Persian Paintings." Attendance (lecture given twice), 65 and 75; total attendance, 140.

November 19. Dr. Stern, at the Pierpont Morgan Library, "The Chinese Influences in Japanese Painting." Attendance, 320.

December 4. Dr. Ettinghausen, at the Metropolitan Museum of Art, New York City, "Connoisseurship in Islamic Art." Attendance, 10.

December 20. Dr. Ettinghausen, at Asia House, New York City, "Formalism and Realism in Persian Painting." Attendance, 325.

1963

January 8. Dr. Cahill, at the State University of Iowa, Iowa City, "Yüan Dynasty Painting" and "The Contemporary Relevance of Chinese Painting." Attendance, respectively, 12 and 350.

January 10. Dr. Cahill, at the College of St. Theresa, Winona, Minn., "Values in Chinese Painting." Attendance (lecture given twice), 400 and 350; total attendance, 750. Also, "The Philosophical Background on Chinese Landscape Paintings." Attendance, 15.

January 11. Dr. Cahill, at the College of St. Theresa, "Forms and Materials of Oriental Painting" and "The Contemporary Relevance of Chinese Painting." Attendance, respectively, 20 and 400.

January 16. Dr. Ettinghausen, at St. Margaret's Episcopal Church, Washington, D.C., "Islamic Art." Attendance, 48.

January 23. Dr. Pope, at the annual dinner meeting of the Board of Regents of the Smithsonian Institution, "Freer Gallery Research Project on Ancient Chinese Ceremonial Bronzes."

February 12. Mr. Gettens, at the Marshall Laboratory of E. I. du Pont de Nemours & Co., Philadelphia, Pa., "The Blue Pigments of Antiquity." Attendance, 75.

February 13. Dr. Pope, at the Japan Society, New York City, "Japanese Porcelain and the Dutch Trade." Attendance, 150.

March 13. Dr. Cahill, at the Fogg Art Museum, Harvard University, Cambridge, Mass., "The Contemporary Relevance of Chinese Painting." Attendance, 150.

March 13. Dr. Pope, at the National Society of the Colonial Dames of America, Washington, D.C., "Chinese Blue-and-white." Attendance, 60.

1963	
March 20.	Dr. Stern, at the Philadelphia Museum of Art, Philadelphia, Pa., "Popular Painting of Tokugawa Japan." Attendance (lecture given twice), 55 and 200; total attendance, 255.
April 4.	Dr. Stern, at the Seattle Art Museum, Seattle, Wash., "Popular Painting of Tokugawa Japan." Attendance, 100.
April 8.	Dr. Stern, at the M. H. DeYoung Memorial Museum, San Francisco, Calif., "Popular Painting of Tokugawa Japan." Attendance, 150.
April 18.	Dr. Stern, at the Dickson Art Center, Los Angeles, Calif., "Hokusai." Attendance (lecture given twice), 200 and 150; total attendance, 350.
April 18.	Mr. Gettens, at the Conservation Center, New York University, New York City, "Corrosion of Ancient Copper and Bronze Metal Objects." Attendance, 12.
April 18.	Dr. Ettinghausen, at Southern Illinois University, Carbondale, Ill., "Old and New Testament Subjects in Islamic Art." Attendance, 95.
April 19.	Dr. Stern, at the Japan Society of Southern California, Los Angeles, "Popular Painting of Tokugawa Japan." Attendance, 250.
April 19.	Dr. Ettinghausen, at Southern Illinois University, "Idealism and Reality in Persian Miniatures." Attendance, 55.
April 22.	Dr. Ettinghausen, at the University of Michigan, Ann Arbor, Mich., "Miniatures of the Safavid Period" and "Unpublished Persian Miniatures of the Mongol Period." Attendance, respectively, 16 and 16.
April 25.	Dr. Stern, at the Chicago Art Institute, Chicago, Ill., "Popular Painting of Tokugawa Japan." Attendance, 75.
April 26.	Dr. Stern, at the University of Chicago, "Hokusai." Attendance, 100.
May 3.	Dr. Cahill, at the National League of American Pen Women, Washington, D.C., "Literary Artists of China." Attendance, 30.
May 8.	Mr. Trousdale, at the University of Michigan, Ann Arbor, Mich., "Central Asian Painting—Part I." Attendance, 16.
May 10.	Mr. Trousdale, at the University of Michigan, "Central Asia Painting—Part II." Attendance, 16.
May 17.	Dr. Pope, at the National Museum, Stockholm, Sweden, "History of the Early Trade in Chinese Porcelain." Attendance, 200.
May 20.	Dr. Stern, at the Cosmos Club, Washington, D.C., "Popular Painting of Tokugawa Japan." Attendance, 250.
June 6.	Miss E. H. West, at the annual meeting of the International Institute for Conservation—American Group, Institute of Fine Arts, New York University, "The Alteration of Early Chinese Jades." Attendance, 75.
June 9.	Dr. Stern, at the National Gallery of Art, Washington, D.C., "Innovations in Japanese Art." Attendance, 250.

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

1962	
July 13.	Dr. Stern, in New York City, met with representatives of Shorewood Press to discuss reproductions of Freer Gallery objects to be used in a forthcoming book on drawings. Examined objects at various dealers.
July 16.	Dr. Ettinghausen, in Corning, N.Y., attended meetings of the Sixth International Congress on Glass at the Corning Glass Center.
July 20.	Dr. Ettinghausen, in New York City, examined objects at several dealers.
August 3–5.	Dr. Stern, in New York City, attended a meeting at the Japan Society re: Restorer Training Program. Met with a representative of Shorewood Press to discuss overruns, prints, and quality control of reproductions of Freer objects. Attended the exhibition of Rockefeller porcelains at the Metropolitan Museum of Art.
August 8.	Miss E. H. West, in Philadelphia, Pa., visited the University Museum where she examined jades in the collection and helped plan a jade exhibition to be shown during the winter.
August 10–11.	Dr. Stern, in New York City, attended a meeting at Asia House re: Japanese Government Loan Exhibition (1965). Met with Prof. Donald Keene of Columbia University regarding his lecture to be given at the Freer Gallery in January 1963.
August 13–14.	Dr. Cahill, in Toronto, Canada, visited the Royal Ontario Museum, where he examined objects in storage and in a private collection.
August 24.	Mr. Gettens, at the Walters Art Gallery, Baltimore, Md., examined miscellaneous objects for the purpose of making a selection for color photography.
September 7–9.	Dr. Cahill, in New York City, attended the Rockefeller exhibition of Chinese porcelains and the Fabergé collection at the Metropolitan Museum of Art. Also examined Far Eastern objects at several dealers.
September 12–14.	Mr. Gettens and Miss E. H. West, at Atlantic City, N.J., attended a symposium on Archeological Chemistry sponsored by the American Chemical Society.
September 25.	Dr. Ettinghausen, in Winchester, Va., examined objects in a private collection.
September 26.	Dr. Pope, at the Baltimore Museum of Art, examined objects offered to the Museum.
October 2–5.	Dr. Cahill, at the Pierpont Morgan Library in New York City, attended the opening of the exhibition of John M. Crawford, Jr.'s collection of Chinese paintings. Served as chairman of a conference on Chinese painting held at Asia House. Attended a lecture by Dr. Michael Sullivan at the Institute of Fine Arts, New York University. Examined objects which were to be auctioned at the Parke-Bernet Galleries.

1962

October 11–14. Dr. Pope, in Toronto, Canada, examined Chinese porcelains at the Royal Ontario Museum, and in several private collections.

October 12–14. Mr. Gettens, in Toronto, Canada, visited the Royal Ontario Museum, where he made a technical examination of a number of objects and conferred with staff members.

October 17–18. Dr. Cahill, in New York City, attended a lecture by Prof. Max Loehr of the Fogg Art Museum at the Pierpont Morgan Library.

October 17–20. Dr. Stern, in New York City, saw the Crawford collection at the Pierpont Morgan Library. Discussed publication problems with representatives of Shorewood Press. Discussed the Restorer Program with Mrs. John D. Rockefeller III, Douglas Overton, and Kojiro Tomita. Examined a newly damaged Chinese painting at Rockefeller Center. Examined numerous objects at several dealers.

October 26–December 4. Miss E. H. West conducted research at the Conservation Center, Institute of Fine Arts, New York University, New York City.

November 8–9. Dr. Ettinghausen, in New York City, examined numerous objects at the Metropolitan Museum of Art. Assisted in giving a doctoral examination at Columbia University.

November 9–16. Dr. Cahill, at the University of Kansas, Lawrence, Kans., gave seven informal talks to classes, and an interview on the university radio station. In Kansas City, Mo., examined the Nü Wa Chai collection of Chinese paintings at the William Rockhill Nelson Gallery of Art and also examined a number of Far Eastern objects at the University of Kansas Art Museum.

November 13–15. Mr. Gettens, in New York City, visited the Kapp & Strobel Ivory Works and the New York University Conservation Center. In Stamford, Conn., attended a meeting of the Western Connecticut Section of the American Chemical Society. In Philadelphia, visited the University Museum to study sculpture in connection with his study of "Minerals in Art and Archeology."

November 15–16. Dr. Ettinghausen, in Norfolk, Va., examined objects at the Norfolk Museum, and visited the Hermitage Foundation.

November 17–20. Dr. Stern, in New York City, met with Prof. Donald Keene of Columbia University concerning the latter's forthcoming lecture at the Freer Gallery. Examined numerous objects at several dealers.

November 18–21. Dr. Ettinghausen, in Cambridge, Mass., examined objects at the Fogg Art Museum, and in several private collections. In Dublin, N.H., examined the Ray Winfield Smith collection of Near Eastern glass.

November 29–30. Mr. Gettens, in Philadelphia, attended the opening of the Chinese Jade Exhibition at the University Museum. Examined objects at the Philadelphia Museum of Art, where he also took samples from several pewter objects.

December 4. Mr. Gettens and Mr. Schwartz, at the Walters Art Gallery, examined and photographed numerous objects.

1962	
December 2–5.	Dr. Pope, with Dr. Osvald Sirén of Stockholm, Sweden, went to Mount Kisco, N.Y., to examine objects in the collection of Mrs. Eugene Meyer. In New York City, examined numerous objects at several dealers.
December 4–6.	Dr. Ettinghausen, in New York City, assisted in giving a doctoral examination at Columbia University and examined objects at several dealers. In Philadelphia, visited with Prof. S. D. Goitein at the University of Pennsylvania.
December 12–13.	William B. Trousdale, at the University Museum in Philadelphia, examined objects in the Chinese Jade Exhibition.
December 12–14.	Dr. Cahill, in Philadelphia, visited the Chinese Jade Exhibition at the University Museum. In New York City, attended the opening of the exhibition of Persian Painting at Asia House and examined objects at several dealers.
December 26.	Dr. Ettinghausen, in Baltimore, attended a luncheon meeting at the Walters Art Gallery.
December 31.	Dr. Stern, in New York City, examined numerous objects at several dealers.
1963	
January 9.	Dr. Cahill, in Minneapolis, Minn., examined Chinese objects in the Minneapolis Institute of Art.
January 12.	Dr. Cahill, in Chicago, saw the Chinese exhibitions at the Field Museum of Natural History and examined various Chinese and Japanese objects at the Art Institute of Chicago.
January 23–24.	Mr. Trousdale, at the University Museum in Philadelphia, arranged for the photographing of Chinese jades selected from the current exhibition, for a review to appear in *Oriental Art*.
January 24–25.	Dr. Pope, in Baltimore, attended a meeting of the board of directors, and the annual meeting of the College Art Association.
January 24–25.	Dr. Ettinghausen, in Baltimore, attended the annual meeting of the College Art Association.
February 1.	Martin P. Amt returned to a dealer in New York City two objects that had been under consideration at the Freer Gallery of Art.
February 1–2.	Mr. Gettens, in New York City, attended a symposium on "Teaching Microscopy" under the auspices of the New York Microscopical Society at the American Museum of Natural History. Examined objects at the Metropolitan Museum of Art, and at a dealer.
February 1–2.	Dr. Ettinghausen, in New York City, attended the exhibition of Persian Painting at Asia House and examined objects at several dealers.
February 1–4.	Dr. Pope, in New York City, served as chairman of A.C.L.S.–S.S.R.C. Joint Committee for Grants on Asia and examined objects at a dealer.
February 4.	Mr. Trousdale, at the University Museum in Philadelphia, measured and oversaw the photographing of Chinese jades for a review of the exhibition for *Oriental Art.*

1963	
February 4.	Miss E. H. West, at the University Museum in Philadelphia, examined and took samples from objects in the Chinese Jade Exhibition.
February 14–15.	Dr. Pope, in New York City, examined objects at several dealers. In New Haven, Conn., examined Chinese objects at the Yale University Art Gallery and, in Middletown, Conn., a large number of Japanese *tsuba* at the Davidson Art Center, Wesleyan University.
February 15–16.	Dr. Ettinghausen, in New York City, examined Near Eastern objects at several dealers.
February 20–23.	Dr. Stern, in New York City, attended the opening of the Tea Taste in Japanese Art Exhibition at Asia House. Examined numerous objects belonging to several dealers and one private collector.
February 26–27.	Dr. Pope, at the Cleveland Museum of Art, Cleveland, Ohio, examined numerous objects and photographs.
March 1.	Dr. Ettinghausen, in New York City, examined objects at several dealers and one private collector.
March 14.	Dr. Cahill, in New York City, examined objects at several dealers, and attended the Tea Taste in Japanese Art Exhibition at Asia House.
March 14–15.	Dr. Pope, in New York City, attended the Tea Taste in Japanese Art Exhibition at Asia House and examined objects at several dealers.
March 16.	Dr. Ettinghausen, in New York City, examined objects at several dealers.
March 20.	Dr. Stern, at the Philadelphia Museum of Art, examined numerous Far Eastern objects.
March 26.	Dr. Pope, in Philadelphia, attended the Founders' luncheon meeting of the Association for Asian Studies.
March 26.	Dr. Stern, in New York City, discussed publishing problems. with representatives of Shorewood Press.
March 29.	Dr. Ettinghausen, in New York City, examined objects at several dealers.
March 29–May 6.	Dr. Stern, in Seattle, Wash., visited the Seattle Art Museum, where he studied the Far Eastern collection. In San Francisco, Calif., studied the collections at the M. H. DeYoung Memorial Museum, and examined objects for several individual collectors. In Los Angeles, Calif., studied the collections at the Los Angeles County Museum, and examined objects for several individual collectors. In Kansas City, Mo., examined Japanese objects at the William Rockhill Nelson Gallery of Art, and for an individual collector. In Chicago, Ill., visited the Art Institute of Chicago to see the exhibitions and study Japanese objects in storage. In Cleveland, Ohio, visited the Cleveland Museum of Art to see the exhibitions and study Japanese and Chinese objects in the collection, and examined objects in a private collection. In New York City, met with the publisher of Shorewood Press and examined objects at a dealer.

1963

April 18. Mr. Gettens, in New York City, examined objects at the Metropolitan Museum of Art and at one dealer.

April 23. Dr. Ettinghausen, at the Cleveland Museum of Art, examined Sasanian silver and Indian miniatures.

April 27. Dr. Ettinghausen, in New York City, examined Persian and Sasanian objects at several dealers.

April 29. Dr. Pope left to attend the opening of the Museum of Far Eastern Antiquities in Stockholm, Sweden, and to study collections elsewhere in Europe; to return in July.

May 10–11. Dr. Ettinghausen, in New York City, met with Mr. N. Pevsner, publisher of the Pelican History of Art, and examined objects at several dealers.

May 22–24. Mrs. L. O. West and Mrs. M. H. Quail attended the annual meeting of the Museum Stores Association at the Minneapolis Institute of Arts and the Walker Art Center, Minneapolis, Minn.

June 5–12. Mr. Gettens, in New York City, attended meetings of the American Group of the International Institute for Conservation of Museum Objects at the Institute of Fine Arts, New York University. He also attended a meeting of the Board of Consulting Fellows of the New York University Conservation Center. Visited the New York Public Library for reference material, and the American Museum of Natural History in search of minerals in art. Examined a number of photographs of ancient Chinese bronzes belonging to the Royal Ontario Museum and examined several objects at a dealer in order to acquire pigment samples.

June 6–7. Miss E. H. West, in New York City, attended the annual meetings of the American Group of the International Institute for Conservation of Museum Objects at the Institute of Fine Arts, New York University.

June 13–14. Dr. Stern, in New York City, attended the Buddha Image Exhibition at Asia House, met with a representative of McGraw-Hill Book Co., Inc., concerning publication problems, and examined numerous objects at several dealers.

June 17. Mr. Trousdale left for the Far East and Europe to give lectures and do research. He will return in October.

As in former years, members of the staff undertook a wide variety of peripheral duties outside the Gallery, served on committees, held honorary posts, and received recognitions.

Respectfully submitted.

John A. Pope, *Director.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

Report on the National Gallery of Art

Sir: I have the honor to submit, on behalf of the Board of Trustees, the 26th annual report of the National Gallery of Art, for the fiscal year ended June 30, 1963. This report is made pursuant to the provisions of section 5(d) of Public Resolution No. 14, 75th Congress, 1st 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 three general trustees continuing in office during the fiscal year ended June 30, 1963, were Paul Mellon, John Hay Whitney, and John N. Irwin II. Chester Dale, who had been a general trustee since 1943 and president since 1955, died on December 16, 1962. Rush H. Kress, who had been a general trustee since 1955, died on March 22, 1963. On January 25, 1963, Paul Mellon was elected by the Board of Trustees to serve as president of the Gallery and John Hay Whitney was elected vice president.

The executive officers of the Gallery as of June 30, 1963, were as follows:

Earl Warren, Chief Justice of the United States, Chairman.
Paul Mellon, President.
John Hay Whitney, Vice President.
Huntington Cairns, Secretary-Treasurer.
John Walker, Director.
Ernest R. Feidler, Administrator.
Huntington Cairns, General Counsel.
Perry B. Cott, Chief Curator.

The three standing committees of the Board, as constituted at the annual meeting on May 2, 1963, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Earl Warren, Chairman.
Paul Mellon, Vice Chairman.
Secretary of the Smithsonian Institution, Leonard Carmichael.
John Hay Whitney.
John N. Irwin II.

FINANCE COMMITTEE

Secretary of the Treasury, C. Douglas Dillon, Chairman.
Paul Mellon.
Secretary of the Smithsonian Institution, Leonard Carmichael.
John Hay Whitney.
John N. Irwin II.

ACQUISITIONS COMMITTEE

PERSONNEL

At the close of fiscal year 1963, full-time Government employees on the staff of the National Gallery of Art numbered 301. The U.S. Civil Service regulations govern the appointment of employees paid from appropriated public funds.

Continued emphasis was given to the training of employees under the Government Employees Training Act.

APPROPRIATIONS

For the fiscal year ended June 30, 1963, the Congress of the United States in the regular annual appropriation and a supplemental appropriation required for pay increases under Public Law 87–793, approved October 11, 1962, provided $2,113,850 to be used for salaries and expenses in the operation and upkeep of the National Gallery of Art, the protection and care of works of art acquired by the Board of Trustees, and all administrative expenses incident thereto, as authorized by joint resolution of Congress approved March 24, 1937 (20 U.S.C. 71–75, 50 Stat. 51).

The following expenditures and encumbrances were incurred:

Personnel compensation and benefits	$1, 760, 670. 00
All other items	350, 099. 34
Unobligated balance	3, 080. 66
Total	2, 113, 850. 00

ATTENDANCE

There were 1,793,500 visitors to the Gallery during the fiscal year 1963, an increase of 460,994 over the total attendance of 1,332,506 reported for fiscal year 1962. The daily average number of visitors was 4,941. This increase was in large measure due to the exhibition, for a period of 27 days, of the *Mona Lisa* by Leonardo da Vinci. During that period 518,525 persons viewed the painting and total attendance was 673,872.

ACCESSIONS

There were 1,206 accessions by the National Gallery of Art as gifts, loans, or deposits during the fiscal year.

GIFTS

During the year the following gifts or bequests were accepted by the Board of Trustees:

PAINTINGS

Donor	*Artist*	*Title*
George Mathew Adams, New York, N.Y.	Legros	Hempstead Heath.
Do	do	A Lady with a White Collar and Cap.
Mrs. Mellon Bruce, New York, N.Y.	Orazio Gentileschi	The Lute Player.
Miss Alice Dodge, Washington, D.C.	Inness	Lake Albano, Sunset.
Mrs. Peter H. B. Frelinghuysen, Convent Station, N.J.	Goya	The Bookseller.
Do	do	Duke of Wellington.
Mrs. Olga Roosevelt Graves, Washington, D.C.	Sargent	Miss Grace Woodhouse.
National Gallery of Art Purchase Fund, Andrew W. Mellon Gift.	Joos van Cleve	Joris W. Vezeler.
Do	do	Margaretha Boghe, Wife of Joris W. Vezeler.

SCULPTURE

Frederick C. Oechsner, Washington, D.C.	German School, 20th Century	Death Mask of Ernst Barlach.

GRAPHIC ARTS

George Matthew Adams, New York, N.Y.	Legros	Three drawings and 22 prints.
The Ford Foundation, New York, N.Y.	Cusumano	Picnic on the Beach.
Mrs. James McBey, London, England.	James McBey	Eleven etchings.
Frederick C. Oechsner, Washington, D.C.	Kollwitz	Riot.
Lessing J. Rosenwald, Jenkintown, Pa.	Altdorfer	The Beautiful Virgin of Ratisbon.
Do	van Meckenem	The Nativity.
William H. Schab, New York, N.Y.	Swiss, 15th Century Woodcut.	The Crucifixion with the Virgin and St. John.
W. G. Wendell, Hartford, Conn.	Stow Wengenroth	Jacob Wendell House, Portsmouth, N.H.
Do	do	Warner House, Portsmouth, N. H.

OTHER GIFTS

In the fiscal year 1963 gifts of money were made by the Old Dominion Foundation, the A. W. Mellon Educational and Charitable Trust, Avalon Foundation, Calouste Gulbenkian Foundation, Andre

Meyer, Mr. and Mrs. Howard Jensen, the Washington Post Co., and the Eugene and Agnes Meyer Foundation. An additional distribution was received from the estate of William Nelson Cromwell.

Mrs. Mellon Bruce gave money and securities to establish the Ailsa Mellon Bruce Fund to be used by the Trustees for the purchase of works of art for the National Gallery of Art and for educational purposes related to works of art.

WORKS OF ART ON LOAN

The following works of art were received on loan by the Gallery:

From	*Artist*	*Title*
Chester Dale, New York, N.Y.	Bellows	Blue Morning.
Do	Monet	The Seine at Giverny.
Mrs. Charles R. Henschel, New York, N.Y.	do	Still Life: Game.
Mr. and Mrs. David Lloyd Kreeger, Washington, D.C.	Bonnard	Le Jardin de Bosquet.
Do	Van Gogh	Vase of Flowers.
Do	Monet	Varengeville.
Do	Picasso	Café de la Rotonde.
Do	Redon	Au Fond de la Mer.
Do	Renoir	Bather.
Mrs. Eugene E. Meyer, Washington, D.C.	Dufresne	Still Life.
Do	Renoir	Nude.
Do	do	Man Lying on a Sofa.

WORKS OF ART ON LOAN RETURNED

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

To	*Artist*	*Title*
Trustees for Harvard University (Robert Woods Bliss Collection), Washington, D.C.		547 objects of Pre-Columbian art.
Mrs. Charles R. Henschel, New York, N.Y.	Monet	Still Life: Game.
Mr. and Mrs. David Lloyd Kreeger, Washington, D.C.	Bonnard	Le Jardin de Bosquet.
Do	Van Gogh	Vase of Flowers.
Do	Monet	Varengeville.
Do	Picasso	Café de la Rotonde.
Do	Redon	Au Fond de la Mer.
Do	Renoir	Bather.
Mrs. Eugene E. Meyer, Washington, D.C.	Dufresne	Still Life.
Do	Renoir	Nude.
Do	do	Man Lying on a Sofa.

WORKS OF ART LENT

The American Federation of Arts, New York, N.Y., circulated the following works of art during the fiscal year to the Municipal Art Gallery, Los Angeles, Calif.; M. H. De Young Memorial Museum, San Francisco, Calif.; Atlanta Art Association, Ga.; Virginia Museum of Fine Arts, Richmond; Cincinnati Art Museum, Ohio; Carnegie Institute, Pittsburgh, Pa., and the Dallas Museum of Fine Arts, Texas:

To	*Artist*	*Title*
American Federation of Arts, New York, N.Y.	Joseph Badger	Mrs. Isaac Foster.
Do	John Bradley	Little Girl in Lavender.
Do	Bundy	Vermont Lawyer.
Do	Earl	Family Portrait.
Do	Hofmann	Berks County Almshouse.
Do	Linton Park	Flax Scutching Bee.
Do	Susanne Walters	Memorial to Nicholas M. S. Catlin.
Do	Unknown	Jonathan Benham.
Do	do	The Start of the Hunt.
Do	do	The End of the Hunt.
Do	do	The Sargent Family.
Do	do	Alice Slade.
Do	do	Joseph Slade.
Do	do	General Washington on White Charger.
Do	do	Blue Eyes.
Do	do	The Hobby Horse.
Do	do	Mahantango Valley Farm.
Do	do	Civil War Battle Scene.
Abby Aldrich Rockefeller Folk Art Collection, Williamsburg, Va.	Field	Ark of the Covenant.
Colby College, Waterville, Maine.	Unknown	Burning of Old South Church, Bath, Maine.
The Jewish Museum, New York, N.Y.	C. E. B	Moses Rescued from the Bulrushes.
North Carolina Museum of Art, Raleigh, N.C.	British School	Pocahontas.
Do	Peale	General William Moultrie.
Do	Stuart	Mrs. Richard Yates.
Do	Theus	Isaac Motte.
Oklahoma Art Center, Oklahoma City, Okla.	Healy	Daniel Webster.
Do	Henri	Catherine.
Do	Ryder	Mending the Harness.
Do	Sargent	Repose.
Do	Stuart	George Washington.
Do	Sully	Andrew Jackson.
Do	Zeliff	The Barnyard.

To	*Artist*	*Title*
Storm King Art Center, Mountainville, N.Y.	Homer	Hound and Hunter.
Historical Society of Talbot County, Md.	Unknown	At the Writing Table.
Do	do	Boy in Blue Coat.
Do	do	Burning of Old South Church, Bath, Maine.
Do	do	Civil War Battle Scene.
Do	do	Columbia.
Do	do	Mount Vernon.
Do	do	The Trotter.
Do	do	Twenty-two Houses and a Church.
Do	do	Village by the River.
Do	do	"We go for the Union."
Do	Hofmann	View of Benjamin Reber's Farm.
Do	Johnston	The Westwood Children.
Virginia Museum of Fine Arts, Richmond, Va.	Toole	Skating Scene.
Washington County Museum of Fine Arts, Hagerstown, Md.	Healy	Abraham Lincoln.
The White House, Washington, D.C.	Lamb	"Emancipation Proclamation."
Woodlawn Plantation, Mount Vernon, Va.	Polk	Washington at the Battle of Princeton.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year 1963:

Exhibition of the Collection of Mr. and Mrs. Andre Meyer. Continued from previous fiscal year through July 8, 1962.

Prints with Color. From the Rosenwald Collection. Continued from previous fiscal year through August 23, 1962.

Lithographs by George Bellows. From the Mellon, Rosenwald, and Addie Burr Clark Memorial collections. Continued from previous fiscal year through October 16, 1962.

Water Colors by Winslow Homer from the Collection of Mrs. Charles R. Henschel. July 6 through September 12, 1962.

Etchings and Lithographs by Edouard Manet. From the Rosenwald Collection. August 24 through December 13, 1962.

A General Selection of Material from the Index of American Design. September 21, 1962, to continue into the next fiscal year.

American Prints Today–1962. Sponsored by the Print Council of America. September 23 through October 14, 1962.

Drawings from the National Gallery of Art collections. October 27, 1962, through March 17, 1963.

Etchings by G. B. Tiepolo, G. D. Tiepolo, and Canaletto. From the Rosenwald Collection. October 27, 1962, through June 11, 1963.

Old Master Drawings from Chatsworth. From the Devonshire Collection. October 28 through November 25, 1962.

A Selection of Christmas Prints. From the National Gallery of Art collections. December 14, 1962, through February 26, 1963.

John Gadsby Chapman, A Retrospective Exhibition. From 21 public collections and private lenders. December 16, 1962, through January 13, 1963.

Mona Lisa by Leonardo da Vinci. Lent to the President of the United States and the American people by the Government of the French Republic. January 8 through February 3, 1963.

Jacques Callot: A Selection of Prints from the Collections of Rudolf L. Baumfeld and Lessing J. Rosenwald. February 3 through March 17, 1963.

Hercules and the Hydra and *Hercules and Antaeus* by Antonio del Pollaiuolo. Lent by the Republic of Italy. February 4 through February 10, 1963.

Industry and Ingenuity. From the Index of American Design. February 27 through May 2, 1963.

Landscape Prints. From the Rosenwald Collection. May 2, 1963, to continue into the next fiscal year.

Prints and Drawings by Mary Cassatt. From the Rosenwald Collection. June 13, 1963, to continue into the next fiscal year.

Exhibitions of recent accessions. "Oysters" by Manet, continued from previous fiscal year through August 9, 1962; "Street in Venice" by Sargent, August 10 through September 13, 1962; "Duke of Wellington" by Goya, November 19 through December 27, 1962; "The Lute Player" by Gentileschi, April 5 through May 13, 1963; "Joris W. Vezeler" and "Margaretha Boghe, Wife of Joris W. Vezeler" by Joos van Cleve, June 21, 1963, to continue into the next fiscal year.

TRAVELING EXHIBITIONS

Special exhibitions of graphic arts from the National Gallery of Art collections were circulated during the fiscal year to 29 museums, universities, schools, and art centers in the United States and abroad.

Index of American Design.—Forty-eight exhibitions (2,104 plates) of material from the Index were circulated to 18 States, the District of Columbia, and to Bath, England.

CURATORIAL ACTIVITIES

Under the direction of Dr. Perry B. Cott, chief curator, the curatorial department accessioned 53 gifts to the Gallery during the fiscal year 1963. Advice was given with respect to 1,716 works of art brought to the Gallery for expert opinion and 25 visits to collections were made by members of the staff in connection with offers of gifts. About 4,350 inquiries, many of them requiring research, were answered verbally and by letter.

Dr. Hereward Lester Cooke, curator of painting, acted as consultant to National Aeronautics and Space Administration with duties of organizing and supervising commissions to artists for paintings of themes relating to the space program.

Dr. Katharine Shepard, assistant curator of graphic arts, gave a graduate course in "Ancient Sculpture" the first semester and a graduate course in "Ancient Painting" the second semester, at Catholic University, during the past academic year.

Joos van Cleve: Joris W. Vezeler. National Gallery of Art Purchase Fund, Andrew W. Mellon Gift.

Joos van Cleve: Margaretha Boghe, Wife of Joris W. Vezeler. National Gallery of Art Purchase Fund, Andrew W. Mellon Gift.

Goya: The Duke of Wellington. National Gallery of Art. Gift of Mrs. P. H. B. Frelinghuysen.

Goya: The Bookseller. National Gallery of Art. Gift of Mrs. P. H. B. Frelinghuysen.

Gentileschi: The Lute Player. National Gallery of Art. Gift of Mrs. Mellon Bruce.

The Richter Archives received and cataloged over 133 photographs on exchange from museums here and abroad; 987 photographs were purchased and about 1,000 reproductions have been added to the archives. The Iconographical Index was increased by 500 photographs.

RESTORATION

Francis Sullivan, resident restorer of the Gallery, made regular and systematic inspection of all works of art in the Gallery and on loan to Government buildings in Washington, and periodically removed dust and bloom as required. He relined, cleaned, and restored 11 paintings and gave special treatment to 29. Twenty-seven paintings were X-rayed as an aid in research. Experiments were continued with synthetic materials suggested by the National Gallery of Art Fellowship at the Mellon Institute of Industrial Research, Pittsburgh, Pa. Technical advice on the conservation of paintings was furnished to the public upon request. Special treatment was given to works of art belonging to Government agencies, including the U.S. Capitol, Treasury, Supreme Court, Army Medical Museum, and General Services Administration. In other instances advice was furnished the various agencies concerning the care and conservation of paintings.

Mr. Sullivan made trips to various cities in connection with the loan of paintings to the Gallery for special exhibitions. He also made a trip to Los Angeles as a special representative of the Department of Justice in connection with the recovery of two paintings belonging to the Uffizi Gallery, Florence, Italy.

PUBLICATIONS

Dr. Cott wrote the foreword to the *National Gallery of Art and its Collections*, a booklet reproducing 40 paintings in the Gallery's collections.

William P. Campbell, assistant chief curator, wrote the catalogs for the Winslow Homer Water Color exhibition from the collection of Mrs. Charles R. Henschel and the John Gadsby Chapman exhibition.

Dr. Cooke wrote an article for the *National Geographic Magazine*, September 1962 issue, entitled "Early America as Seen by Her Native Artists" based on the collection of Edgar W. and Bernice Chrysler Garbisch. He also wrote the text for 16 National Gallery leaflets.

Mrs. Mary Elizabeth C. Burnet, museum curator, assisted in the preparation of the catalogs of the Winslow Homer Water Color exhibition and the John Gadsby Chapman exhibition. She also worked on the proposed Check List of American Paintings in the National Gallery of Art.

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PUBLICATIONS FUND

During the fiscal year 1963 the Publications Fund placed on sale four new books: *Treasures from the National Gallery of Art*, edited by Huntington Cairns and John Walker, the third in a series of large books containing 85 color reproductions of paintings in the National Gallery of Art collection; *The Eternal Present: The Beginnings of Art* by Sigfried Giedion, the A. W. Mellon Lecturer in the Fine Arts for 1957; *Prints* compiled by Carl Zigrosser, with an introduction by Lessing J. Rosenwald; and *One Hundred and One Masterpieces of American Primitive Painting*, with preface by John Walker. An English translation of Dr. Perry B. Cott's section on the National Gallery of Art in *Paintings of the World's Great Galleries* was made available, together with five new catalogs of temporary exhibitions: *Water Colors by Winslow Homer from the Collection of Mrs. Charles R. Henschel; American Prints Today, 1962; Old Master Drawings from Chatsworth; John Gadsby Chapman—American Painter and Illustrator;* and *Jacques Callot—A Selection of Prints from the Collections of Rudolf L. Baumfeld and Lessing J. Rosenwald.*

In addition to 6 new collotype reproductions of paintings by Inness, Renoir, Bellotto, Vlaminck, and Feti, the Publications Fund introduced 40 color reproductions in a new format, 19 by 25 inches in size. Thirty-seven new postcards and 44 new 11- by 14-inch subjects were published, bringing the total subjects available in these formats to 152 and 201, respectively.

EDUCATIONAL PROGRAM

The program of the Educational Department was carried out under the direction of Dr. Raymond S. Stites and his staff. The staff lectured and conducted tours on works of art in the Gallery's collections.

Attendance for the general tours, tours of the week, and picture-of-the-week talks amounted to 38,846. The attendance at the Sunday afternoon lectures in the auditorium totaled 14,209.

Special tours, lectures, and conferences were arranged for a total of 16,567 persons. These special appointments were made for Government agency groups, and at the request of congressional offices, for educators, foreign students, club and study groups, religious organizations, conventions, and women's organizations. These special services were also given to school groups from many parts of the country.

The program of training volunteer docents continued and special instruction was given to approximately 130 volunteers from the Junior League of Washington and the American Association of University Women. By special arrangement with the public and parochial schools of the District of Columbia and surrounding counties of Maryland and Virginia, these volunteers conducted tours for 66,528 children, representing an increase over last year of 7,279. The volunteers also guided 663 Safety Patrol girls on tours of the Gallery and special tours were given for 25,445 children who came to see the *Mona Lisa* while it was on exhibition at the Gallery. Altogether, 92,636 children benefited from the services of the volunteer docents.

Fifty-two lectures were given in the auditorium on Sunday afternoons. Of these, 22 were delivered by members of the staff of the National Gallery and 24 by guest lecturers. John Pope-Hennessy delivered the 12th Annual Series of the A. W. Mellon Lectures in the Fine Arts on six consecutive Sundays on "The Artist and the Individual: Some Aspects of the Portrait."

The slide library of the Educational Department has a total of 45,682 slides in its permanent and lending collections. During the year 1,408 slides were added to the collections. Altogether, 397 persons borrowed 11,964 slides from the collections. It is estimated that the slides were seen by 24,840 viewers. The Carnegie Slides, a group of 2,500 on American art, which are in the Educational Department slide library, were borrowed by 45 persons.

Members of the staff participated in outside activities delivering lectures and papers, and conducting meetings. One staff member taught a course at a local university. Staff members prepared material for the school tour program and the slide lending program, and prepared scripts for the Lectour recordings. Thirty-five radio talks were prepared, recorded, and broadcast on station WGMS.

A printed calendar of events was prepared and distributed monthly to a mailing list of more than 8,300 names, an increase of 1,000 names over last year's mailing list.

EXTENSION SERVICES

The Office of Extension Services, under the direction of the curator of the Index of American Design, Dr. Grose Evans, circulates to the public traveling exhibits, films, slide lectures, and filmstrip sets of works of art in the National Gallery of Art's collections. There are 27 traveling exhibits in circulation lent free of charge except for shipping expenses. These were circulated in 262 bookings and were seen by an estimated 131,000 viewers. The Extension Service circulated 33 framed collotype exhibits among the public schools of the District of Columbia and the general public. Two additional exhibits were prepared, and the Traveling Exhibition Service of the Smithsonian Institution circulated one to 14 borrowers. The other was prepared at the request of Senator Pell of Rhode Island and was shown in 18

Rhode Island cities and towns. Two films on the National Gallery of Art were circulated in 152 bookings and were seen by approximately 45,600 viewers. A total of 1,065 slide-lecture sets were circulated in 2,749 bookings and were seen by approximately 164,940 viewers. The Extension Service reached approximately 384,560 persons during the year; this is an increase of 143,710 over the number of persons served last year.

LIBRARY

During the year the library, under the supervision of Miss Ruth E. Carlson, accessioned 4,852 publications, of which 4,640 were obtained through exchange, by gift, or purchased from private funds. Government funds were used to purchase 19 books and 24 subscriptions to periodicals, and for the binding of 169 volumes of periodicals. A total of 1,610 photographs were added to the library's stock and were acquired by exchange or purchased from private funds.

During the year 2,475 publications were cataloged and classified, 8,568 cards were filed, and 2,609 periodicals were recorded. Library of Congress cards were used for 657 titles; original cataloging was done for 483 titles; and 18 cards were sent to the Union Catalog, Library of Congress. There were 11,455 periodicals circulated, and 5,353 charged out to the staff. There were 6,082 books shelved in routine work. The library borrowed 1,363 books and 1 microfilm on interlibrary loan.

The exchange program was continued during the year and 1,130 National Gallery publications were distributed in accordance with this arrangement. The Gallery received 2,251 publications of various types under the program.

The library is the depository for black-and-white photographs of works of art in the Gallery's collections. These are maintained for use in research by the staff, for exchange with other institutions, for reproduction in approved publications, and for sale to the public. Approximately 6,129 photographs were stocked in the library during the year and 1,310 orders for 7,607 photographs were filled. There were 386 permits for reproduction of 919 subjects processed in the library.

INDEX OF AMERICAN DESIGN

The Index of American Design, under the supervision of Dr. Grose Evans, circulated 116 sets of color slides (5,698) throughout the country; and 232 photographs of Index materials were used for exhibits, study, and publication. The photographic file has been increased by 82 negatives and 83 prints. Twenty-five permits to reproduce 117 subjects from the Index were used. Special exhibits of Index material were prepared at the request of various groups, including the U.S. Department of Labor. Ten exhibits were refurbished and three sets of slide notes were rewritten.

The material of the Index was studied during the year by 502 visitors conducting research, collecting material for publication and design, and gathering illustrations for publications.

The curator of the Index held conferences with important scholars, attended meetings, lectured on American folk art to USIA personnel and three other groups, and conducted tours for several foreign visitors interested in Index material.

MAINTENANCE OF THE BUILDING AND GROUNDS

The Gallery building, mechanical equipment, and grounds have been maintained throughout the year at the established standards.

Replacement of the sidewalk on the Mall side of the building, between Fourth Street and Seventh Street, was accomplished under a contract let by the National Park Service, Department of the Interior.

The Gallery entered into contracts for the conversion of a passenger elevator from manual to automatic operation and for the complete renovation of the skylight on the west wing of the building. Work under these contracts will be completed during the next fiscal year. The passenger elevator conversion will complete the program of converting all such elevators to automatic control.

Storm windows were installed at the windows in the Print Storage Room to eliminate the condensation which formed on the inside of the windows during cold weather. This treatment is planned for all other windows in the building as funds become available.

The Gallery greenhouse continued to produce flowering and foliage plants in quantities sufficient for all decorative needs of special openings and day-to-day requirements of the Garden Courts.

LECTOUR

During the fiscal year 1963 Lectour, the Gallery's electronic guide system, was used by 66,321 visitors. This reduction in the use of the system as compared with fiscal year 1962 is largely due to the fact that it was not feasible to operate the system during the 27 days of the *Mona Lisa* exhibition.

Lobby D, the room in which recent acquisitions are exhibited, was wired for Lectour by the Gallery staff; Lectour talks can now be provided for all new acquisitions.

OTHER ACTIVITIES

Forty Sunday evening Calouste Gulbenkian Foundation concerts were given during the year in the East Garden Court. The National Gallery of Art Orchestra, conducted by Richard Bales, played eight of these concerts. Two concerts were made possible in part by a grant from the Music Performance Trust Fund of the American Federation of Musicians. The National Gallery Strings, conducted by Mr. Bales, furnished music during the openings of two Gallery exhibitions during the year. The concert on Sunday evening, October 21, 1962, was dedicated to United Nations Day. Six Sunday evenings, from April 28 to June 2, were devoted to the Gallery's 20th American Music Festival. All concerts were broadcast in their entirety by radio station WGMS–AM and FM. Washington music critics continued their coverage of these concerts. During the intermissions of the concerts, talks were delivered by members of the staff of the Educational Department on art topics, and by Mr. Bales on the musical programs of the evening. The Gallery orchestra, conducted by Mr. Bales, played two concerts at Hammond High School in Alexandria, Va. Four 1-hour long concerts were taped by the National Gallery orchestra, Mr. Bales conducting, and were televised on WTOP–TV. Paintings from the Gallery's collections were featured. Mr. Bales spoke to three groups on music, and was commissioned by the Gregorian Institute of America to write six piano pieces entitled "Holiday at the White House." The National Gallery orchestra and Mr. Bales received a citation from the American Association of University Women for the cultural and educational contribution made to the community by their television programs.

In response to requests, 54,489 copies of "An Invitation to the National Gallery of Art" and 1,602 information booklets were distributed to Congressmen and various organizations holding conventions in Washington.

Henry B. Beville, head of the photographic laboratory, and his assistants, processed 20,347 items including negatives, prints, slides, color transparencies, and color separations.

A total of 200 permits were issued to persons to copy works of art, and 169 permits to photograph were issued.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit of the private funds of the Gallery will be made for the fiscal year ended June 30, 1963, by Price Waterhouse and Co., public accountants. A report of the audit will be forwarded to the Gallery.

Respectfully submitted.

HUNTINGTON CAIRNS, *Secretary.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Canal Zone Biological Area

SIR: It gives me pleasure to present herewith the annual report on the Canal Zone Biological Area for the fiscal year ended June 30, 1963.

SCIENTISTS, STUDENTS, AND OBSERVERS

Following is the list of 87 scientists, students, and observers who made use of the Canal Zone Biological Area facilities on the mainland, and/or visited Barro Colorado Island last year and stayed for several days in order to conduct scientific research or observe the wildlife of the area. In addition, scientists of other research and technical organizations in the Canal Zone and the Republic of Panama made use of station facilities.

Name	*Principal interest*
Akre, Mr. and Mrs. Roger D., Kansas State University.	Myrmecophiles associated with army ants.
Anderson, William, Gridley, Calif.	Ornithology.
Andrews, H. T., Washington University.	Botany.
Ayensu, Edward S., Smithsonian Institution.	Botany.
Barghoorn, Dr. and Mrs. Elso S., Harvard University.	Limnology.
Barth, Dr. Robert, Harvard University.	Behavior and physiology of cockroaches.
Bennett, Dr. and Mrs. Charles, Jr., University of California.	Ecology and microclimatology.
Bishop, Alison, Cornell University.	Behavior of primates.
Blake, Doris H. Smithsonian Institution.	Entomology.
Blest, Dr. Andrew David, University College, London.	Behavior of Lepidoptera.
Brown, Floyd, Washington University.	Behavior and ecology of amphibians and reptiles.
Brown, Dr. William L., Cornell University.	Behavior and ecology of ants.
Chapin, Dr. and Mrs. James P., American Museum of Natural History.	Ornithology.
Cochran, Dr. Doris, Smithsonian Institution.	Herpetology.

Name	*Principal interest*
Collier, Dr. George, San Diego State College.	Behavior and ecology of jaçanas.
Covich, Alan, Washington University.	Botany.
Dressler, Dr. Robert L., Washington University.	Botany.
Duellman, Dr. William E., University of Kansas.	Herpetology.
Eisenmann, Dr. Eugene, New York, N.Y.	Ornithology.
Eisendrath, Mrs. Erna, Washington University.	Botany.
Elofson, Dr. Olaf, Sundsvall, Sweden.	Observation of wildlife.
Eyde, Dr. Richard H., Smithsonian Institution.	Botany.
Fisher, Dr. and Mrs. Kenneth B., West Covina, Calif.	Observation of wildlife.
Flinn, Michael, Inst. of Laryngology and Otology, London.	Study of bats and acoustic organs of various neotropical animals.
Greenwell, Frank, Smithsonian Institution.	Assistant to Dr. Handley.
Handley, Dr. Charles, Smithsonian Institution.	Mammals.
Harty, Dr. Stephen T., Mount Holly, N.J.	Ornithology.
Heatwole, Dr. Harold, University of Puerto Rico.	Behavior and ecology of amphibians, reptiles, and arachnids.
Hecht, Dr. Max K., Queens College, New York.	Behavior and ecology of amphibia.
Hilger, Julie, Duke University.	Ornithology.
Holgerson, Dr. Holger, Stavanger, Norway.	Littoral marine entomology.
Hughes, Dr. and Mrs. B., Bogotá, Colombia.	Observation of wildlife.
Hunt, George, Harvard University.	Behavior and ecology of flycatchers.
Kamstedt, Brit, Stavanger, Norway.	Assistant to Dr. Holgerson.
Kremer, Dr. Peter, Washington University.	Algae.
Leen, Nina, Life Magazine, New York, N.Y.	Photography of primates.
Lewis, Harold, Life Magazine, New York, N.Y.	Assistant to Miss Leen.
Livermore, Mr. and Mrs. J. W., West Redding, Conn.	Observation of wildlife.
Livingston, Luzern G., Narberth, Pa.	Ornithology.

Name	*Principal interest*
Loftin, Horace, Florida State University.	Ecology of fresh-water fish.
MacArthur, John C., Marlboro College.	Ecology of birds.
MacArthur, John W., Marlboro College.	Ecology of birds.
Matthews, Henry, Lansdowne, Pa.	Ornithology.
McKitterick, Dr. Andy, Cornell University.	Behavior of cockroaches.
Meseth, Earl, Washington University.	Assistant to Dr. Sexton.
Myers, Charles W., University of Kansas.	Herpetology.
Nelson, Kurt, Chicago, Ill.	Observation of wildlife.
Nickerson, Dr. Norton, Washington University.	Botany.
Norcross, Mrs. Emily, Washington University.	Ornithology.
Ortleb, Edward, Washington University.	Behavior and ecology of amphibians and reptiles.
Outten, Dr. L. M., Mars Hill College.	Ichthyology.
Pavelko, Charlotte, Pasadena, Calif.	Observation of wildlife.
Prescott, Dr. and Mrs. G. W., University of Montana.	Phytoplankton.
Pye, Dr. and Mrs. David, Inst. of Laryngology and Otology, London.	Study of bats and acoustic organs of various neotropical animals.
Rassmussen, Mr. and Mrs., Washington University.	Ecology of amphibians and reptiles.
Raven, Mrs. Yvonne, American Museum of Natural History.	Observation of wldlife.
Rettenmeyer, Dr. and Mrs. Carl, Kansas State University.	Behavior and ecology of army ants.
Reynard, Dr. George B., Riverton, N.J.	Sound recordings of bird songs and calls.
Risebrough, Dr. R. W., Howard University.	Observation of wildlife.
Ross, Dr. and Mrs. R. D., Ambler, Pa.	Ornithology.
Ruckes, Dr. and Mrs. Herbert, American Museum of Natural History.	Hemiptera.
Sartori, Alexandra, Harvard University.	Observation of wildlife.
Sexton, Dr. Owen J., Washington University.	Behavior and ecology of amphibians and reptiles.

Name	*Principal interest*
Stern, Dr. William L., Smithsonian Institution.	Botany.
Strandtmann, Dr. and Mrs. R. W., Texas Technological College.	Entomology.
Swinebroad, Dr. Jeff, Rutgers State University.	Ornithology.
Taylor, Dr. Edward, Lawrence, Kans.	Herpetology.
Tyson, Edwin L., Florida State University.	Bat populations.
Wetmore, Dr. Alexander, Smithsonian Institution.	Ornithology.
Willis, Edwin O., University of California.	Ecology and behavior of birds and army ants.
Wilson, Mrs. Mae, Los Angeles, Calif.	Observation of wildlife.
Zweifel, Dr. and Mrs. Richard G., American Museum of Natural History.	Ecology of amphibians.

VISITORS

Approximately 155 visitors were permitted to visit the island for a day.

TABLE 1.—*Annual rainfall, Barro Colorado Island, Canal Zone*

Year	Total inches	Station average	Year	Total inches	Station average
1925	104.37		1944	111.96	109.30
1926	118.22	113.56	1945	120.42	109.84
1927	116.36	114.68	1946	87.38	108.81
1928	101.52	111.35	1947	77.92	107.49
1929	87.84	106.56	1948	83.16	106.43
1930	76.57	101.51	1949	114.86	106.76
1931	123.30	104.69	1950	114.51	107.07
1932	113.52	105.76	1951	112.72	107.28
1933	101.73	105.32	1952	97.68	106.94
1934	122.42	107.04	1953	104.97	106.87
1935	143.42	110.35	1954	105.68	106.82
1936	93.88	108.98	1955	114.42	107.09
1937	124.13	110.12	1956	114.05	107.30
1938	117.09	110.62	1957	97.97	106.98
1939	115.47	110.94	1958	100.20	106.70
1940	86.51	109.43	1959	94.88	106.48
1941	91.82	108.41	1960	140.07	107.41
1942	111.10	108.55	1961	100.21	106.95
1943	120.29	109.20	1962	100.52	107.07

TABLE 2.—*Comparison of 1961 and 1962 rainfall, Barro Colorado Island (inches)*

Month	Total		Station average	Years of record	1962 excess or deficiency	Accumulated excess or deficiency
	1961	1962				
January	1.23	1.86	2.14	37	−0.28	−0.92
February	.24	.67	1.31	37	−.64	−0.92
March	.71	.08	1.21	37	−1.13	−2.05
April	5.45	1.84	3.45	38	−1.61	−3.66
May	7.86	12.84	10.95	38	+1.89	−1.77
June	10.70	10.13	10.82	38	−.69	−2.46
July	6.94	13.26	11.55	38	+1.71	−.75
August	19.73	13.21	12.44	38	+.77	+.02
September	13.33	13.57	10.34	38	+3.23	+3.25
October	17.22	8.43	13.99	38	−5.56	−2.31
November	10.84	13.82	17.85	38	−4.03	−6.34
December	5.96	10.81	11.02	38	−.21	−6.55
Year	100.21	100.52	107.07			−6.55
Dry season	7.63	4.45	8.11			−3.66
Wet season	92.58	96.07	98.96			−2.89

BUILDINGS, EQUIPMENT, AND IMPROVEMENTS

The only major construction on Barro Colorado last year was a new boathouse. This will provide additional space for protection of the launches, speedboats, and canoes.

Maintenance activities on the island continued as usual. All houses were painted and their roofs repaired; new rain gutters were installed; the motor of the launch *Snook* and the three generators were completely overhauled; all the trails were cleared; and extensive repairs to the animal cages and pens were completed.

The expansion of the library also continued. New equipment was provided for both the library and the office.

Two guards were hired to maintain a constant patrol of the island. This has greatly alleviated the problem of poaching.

OTHER ACTIVITIES

The director continued research on the behavior of passerine birds and primates. Edwin L. Tyson completed his study of bat populations on the island, and Robert M. King finished work on the cytotaxonomy of Panamanian Compositae. A new scientific aide, Thomas Crebbs of Rutgers University, has begun a study of the ecology, population structure, and behavior of several species of Fringillidae in the Canal Zone and adjacent parts of the Republic of Panama.

FINANCES

Trust funds for the maintenance of the island and its living facilities are obtained by collections from visitors and scientists, table subscriptions, and donations.

The following institutions continued their support of the laboratory through the payment of table subscriptions: Eastman Kodak Co., New York Zoological Society, and Smithsonian Institution. A new table subscription was received this year from Kansas State University. Donations are also gratefully acknowledged from Dr. Eugene Eisenmann and C. M. Goethe.

PLANS AND REQUIREMENTS

The research program of the bureau will expand considerably in the coming year.

Two new scientists will be added to the permanent staff: Dr. Robert L. Dressler and Dr. Neal G. Smith. Dr. Dressler is a botanist and Dr. Smith will work on ecology and animal behavior.

The National Science Foundation has approved a grant to install an electric cable from the mainland to the island. This will provide a reliable and abundant supply of electric power for the laboratory, replacing the costly and deficient generators which have always been a serious problem. The Panama Canal Company, which will install the cable, has already started preliminary work. It is hoped that the whole project will be completed before the end of the year.

As a result of these additions, it will be possible to install new equipment in the laboratory, keep more extensive records of scientific data, and build up collections of specimens. In particular, it is planned to reorganize and enlarge the herbarium and the botanical section of the library as rapidly as possible.

ACKNOWLEDGMENTS

The Canal Zone Biological Area can operate only with the excellent cooperation of the Canal Zone Government and the Panama Canal Company. Thanks are due especially to the former Lieutenant Governor, Col. Walter P. Leber; the Executive Secretary, Paul M. Runnestrand, and his staff; the Customs and Immigration officials; and the Police Division. Also deeply appreciated are the technical advice and assistance provided by P. Alton White, former chief of the Dredging Division, and members of his staff, and C. C. Soper of the Eastman Kodak Co.

Respectfully submitted.

Martin H. Moynihan, *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, 1963:

Staff studies and planning for the new National Air Museum Building and exhibit continued. The fiscal 1964 budget presented to the Congress included planning funds for the new building.

Public interest in the historical air and space flight exhibit of the Museum continued to increase. The visitor count in the Air and Space Building for fiscal year 1963 was 2,673,618. For fiscal year 1962 it was 1,986,319. The largest single day's count was 38,355 (July 15, 1962).

Many historically significant accessions were received by the Museum during the year. Among them were: memorabilia of Col. Harold B. Willis, member of the Lafayette Escadrille, from Harold B. Willis, Jr.; original thermometer and barometer used by Dr. John Jeffries, first American to fly in a balloon ascension in England, November 30, 1784, from Dr. James Howard Means; multiple-stage rocket engine cluster for the space probe launch vehicle *Juno II*, from the Jet Propulsion Laboratory; bronze bust of Wilbur Wright, from Elmo N. Pickerill; the original *Friendship 7*, first U.S. orbital manned spacecraft, and flight clothing and gear from the *Friendship 7* orbital space flight, from NASA; American flag carried by astronaut Glenn on the *Friendship 7* flight, from John H. Glenn, Jr.; four engines used on the X–15 aircraft, from the Department of the Air Force; bronze sculpture of pioneer Charles S. (Casey) Jones, from the Academy of Aeronautics; medals and other memorabilia of Gen. Claire L. Chennault, from Mrs. Chennault; original oil portraits of astronauts Alan B. Shepard, Jr., and John H. Glenn, Jr., by artist Bruce Stevenson, from Mrs. Stevenson and son; and the original Sperry airplane Gyro Stabilizer and Sperry Gyro Horizon instruments, from the Sperry Gyroscope Co.

Information service continues as an active function of the Museum. Historical, technical, and biographical information on air and space flight is furnished to authors, researchers, historians, schools, Government agencies, students, and the public.

ADVISORY BOARD

No meetings of the Advisory Board were held during the year. Member Vice Admiral P. D. Stroop, USN, assigned to duties away from Washington, D.C., was replaced by Vice Adm. William A. Schoech. Capt. E. P. Aurand, USN, was appointed alternate for Admiral Schoech.

SPECIAL EVENTS

Many distinguished visitors came to the Museum to see the exhibit or to participate in special presentation and commerative ceremonies during the year. Among these were President John F. Kennedy; Attorney General and Mrs. Robert Kennedy; Astronaut and Mrs. John H. Glenn, Jr.; U.S. Senator Clinton P. Anderson; James E. Webb, Administrator of NASA; Edmund Converse, president of Bonanza Airlines; His Excellency, Antonio Garrigues, Ambassador of Spain, His Excellency, Dr. Roberto T. Alemann, Ambassador of the Argentine Republic; and Lafayette Escadrille pilot, Col. Charles H. (Carl) Dolan.

The director attended several annual meetings of aviation, aerospace, and educational organizations and societies. He also visited a number of Air Force and Navy bases, the FAA Academy, NASA space centers, and contractors of these agencies in the aerospace flight program. He lectured frequently on these visits. Much new historical material for the museum has resulted.

Paul E. Garber, head curator and historian, and curators Louis S. Casey and Kenneth E. Newland represented the Museum at a number of aviation and aerospace meetings during the year and spoke on the work of the Museum. Mr. Garber delivered 40 lectures.

IMPROVEMENTS IN EXHIBITS

Continuing experiments with display techniques in the Air and Space Building provide valuable experience in planning the exhibits for the new building.

REPAIR, PRESERVATION, AND RESTORATION

Storage, restoration, preservation, and the preparation of specimens for display in the new building continue at the Silver Hill, Md. facility.

ASSISTANCE TO GOVERNMENT DEPARTMENTS

A variety of services were extended during the year to the Federal Aviation Agency, NASA, the Library of Congress, the Department of Justice, the U.S. Navy, and the U.S. Air Force.

REFERENCE MATERIAL AND ACKNOWLEDGMENTS

The library, reference files, and photographic files of the Museum have increased in valuable research materials during the year. As space permits, these are being integrated into the files for the use of the Museum staff and other researchers.

The cooperation of the following persons and organizations in providing this material is sincerely appreciated and acknowledged:

AIR FORCE, DEPARTMENT OF THE, AIR NATIONAL GUARD BUREAU, Washington, D.C.: Photostats, clippings, and typed pages, describing activities of the Air National Guard in Arkansas.

AIR FORCE, DEPARTMENT OF THE; CHARLES V. EPPLEY, Edwards AFB, Calif.: Photos of Air Force parachutes, aircraft, and engines.

ALLEN, MAJ. GEN. BROOKE E., Washington, D.C.: 1 booklet, *The Bolling Story.*

AMERICAN AVIATION PUBLICATIONS, INC., Washington, D.C.: Book, *Aviation Age*, June 1953, "Key to Survival—Research and Development."

ARMY MISSILE COMMAND, Redstone Arsenal, Ala.: *Jupiter C* drawings.

BAKER, MISS MARY C., San Diego, Calif.: Four pages of photostats of a letter to Miss Baker from her brother regarding the construction of the floats for the entire Curtiss hydroplane.

BALDWIN, LEON C., Fulton, N.Y.: Photostatic copy of a letter to the donor from Miss Ruth Curtiss, pertaining to the Baldwin airship, Signal Corps No. 1, which was designed and built by Thomas Scott Baldwin and powered by an engine developed by Glenn Curtiss.

BALZER, VERNON W., Palos Verdes Estates, Calif.: Approximately 250 papers, being mostly correspondence, between Stephen M. Balzer (the donor's father) and Samuel P. Langley, Secretary of the Smithsonian Institution, his assistants including Charles M. Manly, and his successors including Dr. Charles G. Abbot, for the period November 5, 1898, to January 25, 1932.

BELLANCA, MRS. DOROTHY, Galena, Md.: Periodicals, "L'Aeroteconica" Italian technical reports; "Air Ministry Aeronautical Research Committee Report and Memoranda"; "Commissariala Dell Aeronautica"; "Monografie Scientifiche Di Aeronautica"; "The Journal of the Royal Aeronautical Society"; "American Helicopter"; 1 book, *The Fighting Tanks Since 1916*, by R. E. Jones, G. H. Rarey, and R. J. Icks; photos and lists of Bellanca Aircraft; brochure, etc.

BOEDECKER, KENNETH S., East Orange, N.J.: *Boedy's Album*, mounted photos of aviation personalities including negatives and index to mounted collection.

BRAZALTON, DAVID, Bartonville, Ill.: 3 plate tracings of the Naval Aircraft Factory's N3N–3 convertible seaplane and Curtiss SOC–1 *Seagull.*

BRITISH EMBASSY, Washington, D.C.: 3 photos, A–49,499 Vickers Vimy; A–49,-499–A Vickers Vimy; A–49–499–B Alcock and Brown; photostat of The New York Herald, Monday, June 16, 1919, front page.

BURTON, SQD. LDR. JOHN, BRITISH EMBASSY, Washington, D.C.: Manuals on the *Mosquito* MK 35 (De Havilland).

CAPRONI DITALIEDO, COUNTESS GIANNI, Italy: 3 books, Timina Caproni Guasti and Achille Bartarelli, *L'Aeronautica Italiana Nell' Imagine 1487–1875* (Milan, Museo Caproni, 1938); Timina Caproni Guasti and Achille Bertarelli, *Francesco Zambeccari Aeronauta*, Bologna (1752–1812) (Milan, Museo Caproni, 1932); *Gli Aeroplani Caproni.*

CARCORAN, DONALD, Burns, Oreg.: Scrapbook containing 11 photos, 6 newspaper clippings of Henry Toneray and his helicopter.

CASSOGNERES, EVERETT F., East Haven, Conn.: Photocopies of articles describing the Ryan Aeronautical Co., their ST trainer airplane, and the Menasco D–4 engine used to power this airplane; 1 photo of the Ryan STA airplane built in 1936, now owned and flown by the donor.

CLARK, BARRETT, New York, N.Y.: 4 records, RLP 3401 "Wonderland of Science," a child's introduction to the automobile and the airplane; Riverside 5508 "World War I Fighter Planes in Action"; Riverside RLP 5505 "Air Force"; Riverside RLP 5510 "World War II Combat Planes in Action."

CLARK, EDWIN R., Fitchburg, Mass.: Two newspapers, Springfield Republican, Monday, June 18, 1928; Boston Traveler, Tuesday, June 19, 1928.

CLEVENGER, CLOYD P., D.F., Mexico: A multiautographed book, *Modern Flight*, by Cloyd P. Clevenger, illustrated by Clayton Knight.

COFFYN, KINGSLAND A., Philadelphia, Pa.: 1 photo album; 1 scrapbook containing newspaper articles and photographs.

CROSS, JOHN W., Washington, D.C.: 28 issues of the Official Airline Guide.

CROWTHER, G. RODNEY, III, Chevy Chase, Md.: 2 photographic prints 8 by 10 inches taken of *Echo I* satellite at 1,000 miles altitude, September 3, 1960.

DAY, CURTISS, Elkhart, Ind.: Holterman scrapbook.

DAY, MRS. GLADYS, Pacific Palisades, Calif.: Charles H. Day memorabilia; 1 scrapbook from Charles Healy and Gladys Day.

DOUBLEDAY & CO., INC., Garden City, N.Y.: 4 flat-disk phonograph records, 33⅓ rpm longplaying records, "Sounds of the U.S. Air Force, 1916–1960, Blast Off"; "America's First Man in Orbit," astronaut John Glenn in *Friendship 7; Aurora-7*, astronaut Scott Carpenter; *Sigma-7* astronaut Wally Schirra.

FISKE, MRS. GARNDER, Boston, Mass.: Scrapbook of G. H. Fiske; front page of May 22, 1927, issue of "La Presse" showing purported photo of Lindbergh; framed print containing two pictures, one showing ascent of Englishman, Cocking, in parachute basket; second shows tragic collapse of parachute during descent; framed print showing an exact representation of the first aerial ship *Eagle*.

FRANTZ, HARRY W., UNITED PRESS INTERNATIONAL, Washington, D.C.: Articles on early press flights, "Atlantic Clipper Pioneers Air Route Through Pillars of Hercules," June 22, 1939; "Trans-Atlantic Press Flight, Atlantic Clipper," June 17–25, 1939; "Across the Andes," dated November 4, 1943.

GAINER, J. E., AMERICAN AIRLINES, Washington, D.C.: A group of Glenn L. Martin aircraft specifications in the form of press releases; a report on the German commercial airline the *Deutsche Luft-Hansa* by O. E. Kirchner.

GENERAL PRECISION, INC., LINK DIVISION, Binghamton, N.Y.: Data on Link Corporation.

HALL, MRS. ROGER T., Cabin John, Md.: Framed color print of Montgolfier free flight balloon; framed color print of Charles balloon landing after first free flight.

HILDES-HEIM, ERIK, Fairfield, Conn.: A 32-page illustrated leaflet titled, "Aeronautics in New York State" by Preston R. Bassett, reprinted from "New York History" journal; papers and photos pertaining to Dr. William W. Christmas.

I.A.S. STUDENT ACTIVITIES, DAVID KAUFMAN, New York, N.Y.: 37 films.

IPLAND, J. C., St. Petersburg, Fla.: 2 photos, J. D. Hill's airplane at Hadley Airport: Mr. Hill and Col. John Brown.

JARRETT, COL. G. B., Aberdeen Proving Ground, Md.: Copies of drawings of British, German, and French World War I aerial bombs; copy of drawing of Flechettes.

JUPTNER, JOSEPH P., Orange, Calif.: Book, *U.S. Civil Aircraft, ATC Number–1 to 100, Vol. I* by donor.

KERLEY, ROBERT V., Detroit, Mich.: Air Service Engineering Division Report, September 16, 1924, *Engine Performance Curves and Sectional Views; Development of Aircraft Engines* by R. Schlaifer and *Development of Aviation Fuels* by S. D. Heron, bound in one volume; *Aviation Fuels and their Effects on Engine Performance*, NAVAER—02–1–511; *Aviation Fuels and their Effects on Engine Performance* and *Research on Aviation Spark Plug Problems* by the Ethyl Corp.

KERNAN, STAFFORD, Washington, D.C.: 2 books, *World Aviation Annual, 1948; American Heroes of the War in the Air.*

KEY, WILLIAM G., Washington, D.C.: 2 books, *Gli Aeroplani Caproni;* also other material on Caproni.

LAIRD, E. M., Boca Raton, Fla.: Laird Airplane Co., brochure.

LAMB, DR. W. KAYE, DOMINION ARCHIVIST, PUBLIC ARCHIVES OF CANADA, Ottawa, Canada: 2 drawings of general arrangements FC–2W2 landplane, general arrangements FC–2W2 seaplane (modified FC–2W).

LEWIS, FREDERIC, New York, N.Y.: Fifteen 5- by 7-inch glass negatives of Wright 1911 glider at Kitty Hawk, N.C.

MANNING, WING CMDR. R. V., ROYAL CANADIAN AIR FORCE, Ottawa, Canada: 2 volumes containing excerpts from RFC and RAF communiques of World War I.

MCCALL, MRS. E. F., Oxford, Miss.: 31 pieces of correspondence from Chanute, W. Wright, Dr. Abbot, and Bellanca; 140 pages of assorted papers on "The Soaring Flight of Birds" and "The Construction of a Small Aeroplane."

MCCAULEY, ERNEST G., Fort Lauderdale, Fla.: 2-page report by Mr. McCauley titled "Commemorating the Flight of the Spirit of St. Louis"; "Thrust for the Air Age" by Ted Durosko, a reprint from "Flying," November 1958, Ziff-Davis Publishing Co.

MCCOMB, ROBERT P., Moultrie, Ga., and MILLER, HOWARD M., Fort Wayne, Ind.: 71 copies of outdated magazines, "Popular Aviation"; "Aerial Age Weekly"; "Western Flying"; "Sperryscope"; "Flight"; "Model Airplane News"; "U.S. Air Services."

MEYER, ROBERT B., Bethesda, Md.: Book, *An Airplane in Every Garage,* by Daniel R. Zuck.

MOOREHOUSE, HAROLD E., Williamsport, Pa.: 48 5- by 4-inch photos from the flying pioneers biographies used in A.A.H.S.

MURPHY, SHERWIN, St. Joseph, Mich.: Copy of unfinished biography on Augustus Herring.

NATHANSON, HARRY D., Brooklyn, N.Y.: 2 manuals, *Details of Aerial Bombs* by Air Ministry, February 1918; *Silhouettes of Aeroplanes* by Unknown.

NAVY, DEPARTMENT OF THE, Washington, D.C.: 441 photographs from Adm. J. L. Callan's photograph album.

NEWLAND, KENNETH E., Alexandria, Va.: Book, *Spitfire,* by John W. R. Taylor and Maurice F. Allward, 1946.

NORMAN, WALLACE, Warren, Mich.: Three-view drawing of Curtiss Robin Airplane.

OAKES, ROBERT S., NATIONAL GEOGRAPHIC SOCIETY, Washington, D.C.: Handbook titled *Instructions for the Care and Operation of Model A–1–E Hispano-Suiza Aeronautical Engines.* It was published during July 1918 by the Wright-Martin Aircraft Corp. of New Brunswick, N.J.

PARRISH, WAYNE W., AMERICAN AVIATION PUBLICATIONS, Washington, D.C.: Assorted aviation material.

PAWLEY, WILLIAM D., Miami, Fla.: Booklet, *Americans Valiant and Glorious,* a brief history of The Flying Tigers by William D. Pawley.

PRINCE, FREDERICK H., Jr., Old Westbury, N.Y.: 3 bound volumes of "La Guerre Aerienne" for the period of November 1916 to May 1918.

READ, REAR ADM. ALBERT C., Miami, Fla.: 1 book, *The Flight Across the Atlantic,* by Curtiss Aeroplane & Motor Corp.; a biographical sketch and service record of Rear Admiral Read; numerous cablegrams and naval signal dispatches; N–C–4 flight reports; pilots report, N–C–4; Radio Report-Trans Atlantic flight; newspaper clippings; magazine articles; U.S. Department of Agriculture Weather Bureau maps.

REYNOLDS, BRUCE C., Santa Barbara, Calif.: *Barnstorming with Barnhart* as told to Bruce Reynolds by George E. Barnhart.

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Spangler, Charles B., Mountain View, Calif.: A book, *America's First Spaceman*, by Jewel Spangler Smaus and Charles B. Spangler. An autographed copy.

Spargo, John, Old Bennington, Vt.: Postcards from the Caproni Aeroplant in Italy collected in 1918.

Springer, Thomas Eric, Los Angeles, Calif.: 60 photos; 1 souvenir issue of Douglas Aircraft 50th Anniversary of Naval Aviation; various newspaper clippings on Mr. Springer; biographical sketch.

Stadlman, Anthony, San Francisco, Calif.: Photos, drawing, biographical sketch, and newspaper clippings.

Talbott, Mrs. H. E., New York. N.Y.: Album of photos of the Dayton Wright Co.

Trainor, George E., Ford Motor Co., Washington, D.C.: Films, "This is Aeronautronic" and "Blue Scout."

Truitt, James M., The Washington Post, Washington, D.C.: Memorabilia of James R. McConnell.

Vernon, Victor, St. Petersburg, Fla.: Scrapbook of Victor Vernon.

Vincent, Sydney A., St. Petersburg, Fla.: 4- by 5-inch photos of Park A. Van Tassell's balloon; Ivy Baldwin's balloon; S. A. Vincent gliders; Ivy Baldwin's biplane.

Walker Company, L. L., Houston, Tex.: 15 books and pamphlets on airport, aircraft, and engines, etc.

Winter, Henry, San Clemente, Calif.: 1 canceled check of the Aeronautical School of Engineers (June 1911).

Young, Edward H., St. Louis, Mo.: Booklet, *Instone Air Line Time Table*, distributed in the fall of 1921.

Zonta International, Chicago, Ill.: Photo of Amelia Earhart; portrait, head and shoulders.

ACCESSIONS

Additions to the National Aeronautical and Space Collections received and recorded during the fiscal year 1963 totaled 443 specimens in 81 separate accessions, as listed below. Those from Government departments are entered as transfers unless otherwise indicated; others were received as gifts or loans.

Academy of Aeronautics, La Guardia Airport, New York, N.Y.: Life-size bronze bust of Charles S. (Casey) Jones, pioneer aviator, educator, and founder of the Academy of Aeronautics (N.A.M. 1381).

Air Force, Department of the, McClellan Air Force Base, Calif.: Collection of 213 models, 1:72 size, modeled by Roy S. Stone (N.A.M. 1360). Andrews Air Force Base, Md.: Gun camera from F–86A aircraft (N.A.M. 1364). Systems Command, Washington, D.C.: XN–1, first U.S. all-inertial autonavigator to be successfully flight tested on a system; XN–2, first U.S. stellar-inertial autonavigator to successfully track stars in daylight flight (N.A.M. 1382). Systems Command, Wright-Patterson Air Force Base, Ohio: Thiokol XLR–11 Rocketjets with serial Nos. 5, 6, 13, and 14. These engines powered the X–15 aircraft (N.A.M. 1379).

American Airlines, Washington, D.C.: Diorama-type model of an American Airlines Boeing 707, showing interior layout of aircraft (N.A.M. 1344).

Avco Research and Advanced Development, Wilmington, Mass.: Original nose cap of the RVX1–5 nose cone test vehicle (N.A.M. 1401).

Bonanza Airlines, Las Vegas, Nev.: Model of the Fairchild F–27 as flown by Bonanza Airlines (N.A.M. 1357).

BROWN, MAJ. KIMBROUGH S., Bedford, Mass.: Contemporary French tapestry commemorating Lindbergh's flight to Paris (N.A.M. 1345).

BRYANT, GLENN D., MISSISSIPPI STATE COLLEGE, State College, Miss.: Roll of gas cell material from airship *Shenandoah* (N.A.M. 1347).

CHAMPLIN, WILLIAM H., JR., Rochester, N.H.: Verville Sports Trainer aircraft, single engine, two-place biplane (N.A.M. 1392).

CHENNAULT, MRS. CLAIRE L., Washington, D.C.: Memorabilia of General Claire L. Chennault including 20 medals and awards plus a Chinese scroll recounting the history of the Flying Tigers (N.A.M. 1387).

CHRYSLER MOTORS CORP., Detroit, Mich.: Scale model of Mercury Redstone launch vehicle used in flight by Astronaut Alan Shepard, May 5, 1961 (N.A.M. 1406).

COCHRAN, MISS JACQUELINE, New York, N.Y.: 1961 General Electric Trophy for outstanding achievement in aviation, Distinguished Service Medal, and Medal of the French Legion of Honor, all awarded to the donor (N.A.M. 1343).

DAVIES, COL. JOHN M., Falls Church, Va.: Crash helmet worn by donor in Italy, World War I (N.A.M. 1374).

DESIBOUR, MRS. ROBINSON, Washington, D.C.: Bronze medal commemorating the first North Pole flight of Richard E. Byrd, May 9, 1926 (N.A.M. 1353).

DI TALIEDO, DR. GIOVANNI CAPRONI, Milano, Italy: Caproni Commemorative Gold Medal (N.A.M. 1352).

DOOLITTLE, GEN. JAMES H., Redondo Beach, Calif.: Five personal watches either used by or awarded to the donor (N.A.M. 1398).

DORNIER-WERKE, Germany: Model of Dornier DO–28 aircraft (N.A.M. 1355).

DOUGLAS AIRCRAFT CO., Washington, D.C.: Model of a Douglas DC–2 aircraft (N.A.M. 1369).

DRUCKER, LESLIE, Chicago, Ill.: Copy of gold Glenn Flight Commemorative Medallion which was presented to Mrs. Glenn (N.A.M. 1410).

FOURTEENTH AIR FORCE ASSOCIATION, Allentown, Pa.: Original American Flag used by "Flying Tigers" at General Chennault's headquarters in China, and original design of 14th Air Force shoulder patch (N.A.M. 1380).

FRANKLIN INSTITUTE, Philadelphia, Pa.: Aircraft engine combustion starter (N.A.M. 1362).

GALBRAITH, FRED E., SR., Rutherford, N.J.: Parts and fragments from the *America* used on Admiral Byrd's transatlantic flight (N.A.M. 1367).

GALL, CAPT. DONALD F., Newark, Del.: Piece of outer skin fabric from airship *Shenandoah* (N.A.M. 1384).

GENERAL MOTORS CORP., ALLISON DIVISION, Garden City, N.J.: Model of Lockheed Electra II, 1:79 size (N.A.M. 1335).

GLENN, JOHN H., JR., Manned Spaceflight Center, Houston, Tex.: Flag carried by Glenn on flight of *Friendship 7* (N.A.M. 1414).

GRUMMAN AIRCRAFT CORP., Bethpage, Long Island, N.Y.: Three models of Grumman Aircraft: A2F–1 *Intruder;* AO–1 *Mohawk;* and XF5F–1 *Skyrocket* (N.A.M. 1336). Model of a Grumman W2F–1 aircraft (N.A.M. 1366). Model of a Grumman XF10F–1 *Jaguar* aircraft (N.A.M. 1370).

HALL, MRS. ROBERT T., Cabin John, Md.: Purchase of two contemporary prints of first Montgolfier flight and the first Charles flight (N.A.M. 1396).

HARTWICK, HERBERT D., Cayucos, Calif.: Model of Junkers-Larson JL–6, single engine monoplane (purchase) (N.A.M. 1342).

HOFFMAN, MRS. CORA BENNETT, Estate of; New York, N.Y.: Memorabilia of J. Floyd Bennett (N.A.M. 1371).

IVEY, ROBERT C., Parma, Ohio: Model, 1:24 size of Fokker F7/3m *Southern Cross* (N.A.M. 1395).

JET PROPULSION LABORATORY, Pasadena, Calif.: Second, third, and fourth stage rocket cluster for the space-probe launch vehicle *Juno II* (N.A.M. 1346).

KAYLAS, ALEXANDER J., New Haven, Conn.: Memorabilia connected with donor's activities as a member of the 14th Air Force in World War II (N.A.M. 1400).

KELLY, KENNETH, Bethesda, Md.: Two World War I aircraft machineguns: one, a German Spandau with ammunition belt and case; the other, a British Vickers aircraft machinegun (N.A.M. 1337).

KLEAN, LESTER E., Bensenville, Ill.: Model of Wright brothers' 1903 Flyer (purchase) (N.A.M. 1399).

KLIEGLE, R. P., Hampton Falls, N.H.: Bowlus Baby Albatross sailplane single-place pod fuselage with tubular boom support for empenage (N.A.M. 1388).

McKNEW, DR. THOMAS, NATIONAL GEOGRAPHIC SOCIETY, Washington, D.C.: Seven framed color portraits and pictures of astronauts (N.A.M. 1338).

MARTIN COMPANY, Baltimore, Md.: Martin Matador Missile (N.A.M. 1372).

MASSIN, ALEX, Toronto, Canada: Four USAF uniform insignia, World War II (N.A.M. 1391).

MEANS, DR. JAMES HOWARD, Boston, Mass.: An original holograph manuscript by Francis Herbert Wenham of England, "On Some Conditions of Aerial Flight," delivered by Octave Chanute before the Boston Aeronautical Society, March 1, 1897 (N.A.M. 1340). Thermometer and barometer used by Dr. John Jefferies in a balloon ascension in England, November 30, 1784, and January 7, 1785, for first flight across the English Channel. First American to fly (N.A.M. 1341).

MEMBERS OF WAF AND USAF NURSES, New York, N.Y.: Wood inlay picture by Paul Spindler of a McDonnell F-101 *Voodoo* airplane flying over a French village (N.A.M. 1363).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, LANGLEY RESEARCH CENTER, Hampton, Va.: Model of Bell X-1 wind tunnel (N.A.M. 1393). LEWIS RESEARCH CENTER, Cleveland, Ohio: General Electric TG-180 turbojet engine (N.A.M. 1413). General Electric I-40 turbojet engine (N.A.M. 1412). Washington, D.C.: *Friendship* 7 spacecraft with manikin and display-rig; also astronaut's personal equipment (N.A.M. 1368). John Glenn's flight clothing (N.A.M. 1375).

NAVY, DEPARTMENT OF THE, Washington, D.C.: Propeller and drive assembly for a fuel pump used on the NC-3 during 1919 flight across Atlantic (N.A.M. 1349). BUREAU OF NAVAL WEAPONS, Washington, D.C.: Aichi M6A1 Sieron Aircraft (Japanese), a J-35 aircraft engine and a Liberty engine propeller (N.A.M. 1365). Aichi B7A-1 *Grace* Aircraft, a Japanese Navy carrier bomber (N.A.M. 1377). Curtiss N-9 Navy training aircraft, World War II, missing components (N.A.M. 1405). NAVAL ACADEMY, Annapolis, Md.: General Electric electrically operated TG-100 turboprop cutaway (N.A.M. 1356). NAVAL OBSERVATORY, Washington, D.C.: A select group of navigation instruments illustrative of developmental steps in historical technical progress (N.A.M. 1351). NAVY AIR MATERIAL CENTER, Philadelphia, Pa.: Group of five models of U.S. Navy types to random scales—N-1, NC-7, HS-3, H-16, and ZR-1 *Shenandoah* (N.A.M. 1354).

NEWCOMB, CHARLES J., Trappe, Md.: Wright brothers Model K, 1:16 size model of 1915 aircraft (purchase) (N.A.M. 1404).

NEWLAND, KENNETH E., Alexandria, Va.: Scale model of Thor-Able launch booster with model of RVX1-5 nose cone on top (N.A.M. 1402). Scale model of Jupiter Rocket Launch vehicle used in Able-Baker project (N.A.M. 1407).

NORTHROP AIRCRAFT CORP., Hawthorne, Calif.: 1:30 model of Northrop T-38 aircraft in which Jacqueline Cochran established speed records August–October 1961 (N.A.M. 1376).

PAN AMERICAN AIRWAYS SYSTEM, New York, N.Y.: Six flags and two poles from the *Yankee Clipper* used on transatlantic flights (N.A.M. 1350).

PICKERILL, E. N., Mineola, N.Y.: Life-size bronze bust of donor (N.A.M. 1359). Bronze bust of Wilbur Wright (N.A.M. 1358).

RAMSEY, MRS. DEWITT, Washington, D.C.: Bas-relief portrait in Wedgwood of Sir John Alcock and a collection of seven prints of watercolors illustrating famous flights (N.A.M. 1373).

ROCHESTER CITY SCHOOL DISTRICT, Rochester, N.Y.: Continental Motors Corp. Engine, model A65–8, 4-cylinder, air cooled; equipped with starter, Stromberg carburetor and Sensenich propeller (N.A.M. 1378). Link Aviation Devices, Binghamton, N.Y., Trainer No. S–W C–37142 *Jitter Bug, Jr.* (N.A.M. 1409).

ROCKWELL, COL. PAUL, Asheville, N.C.: French Voluntaire World War I medal awarded to Kiffen Rockwell, a member of the Lafayette Escadrille (N.A.M. 1408).

SHOWERS, MRS. ELSIE F.: Aircraft float light, World War II (N.A.M. 1348).

SOARING SOCIETY OF AMERICA, Los Angeles, Calif.: The "Gold C" and "Diamond C" plaques awarded by the Soaring Society of America (N.A.M. 1361).

SPANISH AIR FORCE, Washington, D.C.: Model of Dornier Wal *Plus Ultra*, first aircraft to complete crossing of South Atlantic from Spain to Argentina, January 21–31, 1926 (N.A.M. 1385).

SPERRY GYROSCOPE CO., Great Neck, N.Y.: Gyro stabilizer for airplanes. Used in tests aboard a Curtiss "S" Flying Boat at Hammondsport, N.Y., by Lawrence Sperry in 1913. Immediate predecessor of the 1914 model which won the 50,000-fr. safety prize in Paris (N.A.M. 1390).

STEVENSON, MRS. BRUCE AND SON, New York, N.Y.: Life-size portrait in oils; one of John H. Glenn, Jr., and the other of Alan B. Shepard, Jr. (N.A.M. 1389).

TALBOT, MRS. HAROLD E., New York, N.Y.: Propeller with clock in hub (N.A.M. 1411).

THAW, A. BLAIR, Washington, D.C.: Marlin Rockwell machine gun said to have been used by Col. William Thaw on his Spad aircraft in World War I (N.A.M. 1386).

TRACY, DANIEL, Cleveland, Ohio: Model of Deperdussin aircraft (purchase) (N.A.M. 1394).

VIRGINIA POLYTECHNIC INSTITUTE, Blacksburg, Va.: Lycoming air-cooled radial aviation engine (9 cyl.) Model R–680–BA, serial No. 2,751.240 h.p. (N.A.M. 1397).

WILLARD, KENNETH A., Los Altos, Calif.: Radio-controlled, gasoline-powered model airplane (N.A.M. 1403).

WILLIS, HAROLD B., JR., Boston, Mass.: Memorabilia of Col. Harold B. Willis as a member of the Lafayette Escadrille (N.A.M. 1339).

WISE, MRS. DOROTHY, Washington, D.C.: Memorabilia of "Flying Tigers" Operations in China, World War II, including silk map of Western and Eastern China used by Capt. John Birch (N.A.M. 1383).

WRIGLEY, PHILIP K., Chicago Ill.: Curtiss 1911 flight control, Westmore propeller manufactured in Chicago, Curtiss propeller (World War I), Paragon propeller (N.A.M. 1415).

Respectfully submitted.

PHILIP S. HOPKINS, *Director.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the National Cultural Center

Sir: I have the honor to submit, on behalf of the Board of Trustees, a status and financial report on the National Cultural Center for the period April 1959 through June 30, 1963.

ORGANIZATION

Public Law 85–874, September 2, 1958, established the National Cultural Center as a bureau of the Smithsonian Institution, to be directed by a Board of Trustees to be composed as follows: The Secretary of Health, Education, and Welfare; the Librarian of Congress; the Assistant Secretary of State for Public Affairs; the Chairman of the Commission of Fine Arts; the President of the Board of Commissioners of the District of Columbia; the Chairman of the District of Columbia Recreation Board; the Director of the National Park Service; the Commissioner of U.S. Office of Education; the Secretary of the Smithsonian Institution; 3 Members of the Senate appointed by the President of the Senate and 3 Members of the House of Representatives appointed by the Speaker of the House of Representatives ex officio; and 15 general trustees who must be citizens of the United States.

Mrs. John F. Kennedy and Mrs. Dwight D. Eisenhower serve as honorary cochairmen.

In addition, the act provided for the establishment of an Advisory Committee on the Arts, composed of such members as the President may designate to serve at the pleasure of the President. The members of this committee are individuals who are recognized for their knowledge of, or experience or interest in, one or more of the performing arts.

At the present time, the Board of Trustees and elected officers of the Center are as follows:

As directed in the act, the Board shall (1) present classical and contemporary music, opera, drama, dance, and poetry from this and other countries; (2) present lectures and other programs; (3) develop programs for children and youth and the elderly in such arts designed specifically for their participation, education, and recreation; and (4) provide facilities for other civic activities at the Cultural Center.

While congressional action provided the site upon which the Center will be built, it was specified that construction funds should be raised by the voluntary contributions of the American people. Congress therefore authorized a nationwide fund-raising campaign, the first such national campaign committed to a cultural enterprise.

PROGRESS DURING 1962–63

Since the beginning of 1962, the Center has been vigorously engaged in a number of varied fund-raising programs:

(1) *President's business committee.*—Under the chairmanship of Ernest R. Breech, formerly chairman, Ford Motor Co., and now director and chairman of Trans World Airlines, Inc., a committee has been formed to seek contributions to the Center from American industry and business. The goal set is $6 million, or one-fifth of the total cost of the Center. Some of the most prominent businessmen in the United States have agreed to serve upon this committee and to solicit industrial contributions within those areas with which they are identified.

(2) *Seat endowment campaign.*—The President has appointed Edgar M. Bronfman, president of Joseph E. Seagram & Sons, Inc., as chairman of the Seat Endowment Committee. By means of this program, individuals and organizations are able to endow a permanent seat in one of the Center's three halls. A tax-deductible donation of $1,000 will entitle the donor to lasting recognition as a virtual founder of the Center and his gift will be acknowledged by a bronze plaque affixed to the back of the seat.

(3) *Service band recordings.*—For the first time, the music of the four U.S. military bands has been recorded for sale to the public, and all profits from the sale of the albums are being given to the Cultural Center. The records were released by RCA Victor in May 1963 and to date have sold nearly 150,000 copies. The Center receives 95 cents per album after the initial overhead of approximately $20,000 has been deducted.

(4) *Washington area campaign.*—The Greater Washington area, under the chairmanship of Mrs. Hugh D. Auchincloss, has been charged with the responsibility of raising $7.5 million, or one-fourth of the total cost of the Center. The committees have now been formed and all fund-raising projects in this area put into vigorous action. Involving some 5,000 workers, the programs include a Special Gifts Campaign to solicit donations of $1,000 and over, and a General Campaign enlisting support from the area's schools and universities, businesses, labor unions, the professions, fraternal orders, etc., for contributions of up to $1,000.

ARCHITECTURAL PLANNING

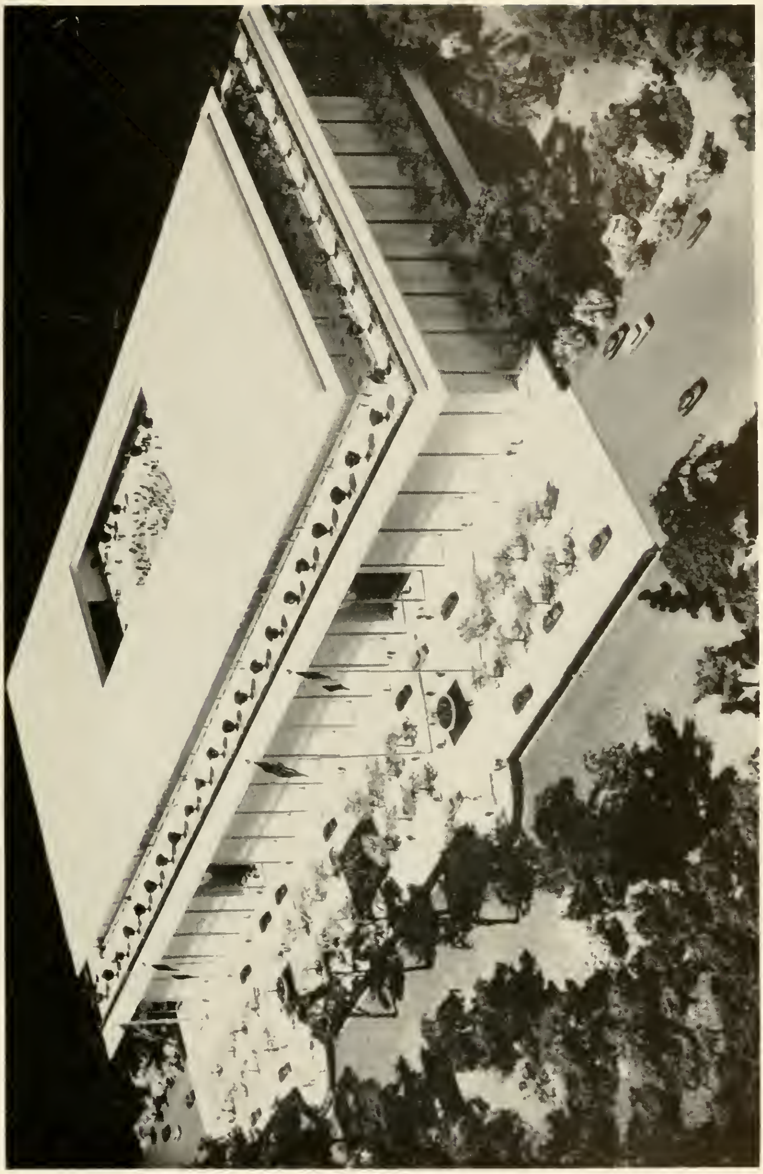
With the advent of 1962 the Trustees, feeling that the original $75 million concept of the Center was unnecessarily costly, asked the architect, Edward Durell Stone, to furnish an alternative design. In the summer of that year, Mr. Stone provided a series of plans for grouping the three halls (1,200-seat theater; 2,750-seat symphony hall; and 2,500-seat hall for opera, ballet, and musical theater) under a single roof—at less than one-half the original cost. In addition, a garden-like roof area, with retractable roof insuring use in all weather, was designed to accommodate band concerts, art exhibits, festivals, children's theater, theater-in-the-round, and two restaurants.

In September 1962 the new model was presented to the Center's two honorary cochairmen, Mrs. Kennedy and Mrs. Eisenhower, as well as to the Board of Trustees and the Commission of Fine Arts. It was received with unanimous enthusiasm and approval.

The site designated by Congress for the Center is the area in the District of Columbia bounded by the Inner Loop Freeway on the east, the Theodore Roosevelt Bridge approaches on the south, Rock Creek Parkway on the west, and New Hampshire Avenue and F Street on the north.

FUTURE PROSPECTS

By June 1963, all the aforementioned fund-raising programs were well launched, and prospects of attaining individual program quotas were promising. In March 1963 a conditional grant of $5 million was secured from the Ford Foundation, payable when the Center's fund-raising total reaches $15 million.



Model of National Cultural Center.

In addition to this welcome boost to the campaign, the Center was fortunate in receiving a most generous gift of marble from the Government of Italy.

Approaching the expiration of the 5-year term for fund-raising specified in the original act, a 3-year extension, to September 1966, was pending in Congress at the end of the fiscal year. Under the terms of the extension, the number of general trustees will be increased from 15 to 30.

While the outset of a national fund-raising campaign of this magnitude must inevitably be slow, the time has now arrived—when we have one-third of the total funds required—when we can anticipate with confidence the rapid realization of our ultimate goal to create in the Nation's Capital a national center for the performing arts.

Respectfully submitted.

Roger L. Stevens, *Chairman.*

Dr. Leonard Carmichael,
Secretary, Smithsonian Institution.

The National Cultural Center Financial Report for the period July 1, 1963, through November 30, 1963, follows:

AUDIT

December 4, 1963
Washington, D.C.

To The Board of Trustees of
The National Cultural Center
Washington, D.C.

Gentlemen:

We have examined the books and records of THE NATIONAL CULTURAL CENTER for the period July 1, 1963, through November 30, 1963, and submit our report herewith as follows:

Exhibit A—Balance Sheet as of November 30, 1963.

Exhibit B—Statement of Income, Expenses, and Fund Balance for the Month of November 1963 and the Five Months Ended November 30, 1963.

Exhibit C—Statement of Income, Expenses, and Fund Balance for the Period from Inception April 1, 1959 through November 30, 1963.

Exhibit D—Analysis of Cash in Banks for the Period from Inception April 1, 1959 through November 30, 1963.

Schedule 1—Schedule of Time Deposits.

Schedule 2—Public Relations and Fund Raising Fees for the Period from Inception April 1, 1959 through November 30, 1963.

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.

In our opinion the accompanying report presents fairly the financial position of THE NATIONAL CULTURAL CENTER at November 30, 1963 and the results of its operation for the period then ended in conformity with generally accepted accounting principles.

Respectfully submitted,

(S) John J. Addabbo
Certified Public Accountant

EXHIBIT A

BALANCE SHEET

November 30, 1963

ASSETS

Cash in banks:			
General accounts:			
National Cultural Center—general account		$1, 006, 548. 96	
Time deposits—Schedule 1		1, 690, 321. 47	$2, 696, 870. 43
Reserve accounts:			
National Cultural Center—reserve account		46, 156. 37	
Time deposits—Schedule 1		201, 678. 53	247, 834. 90
Petty cash			619. 37
Deposit with airlines			850. 00
Pledges receivable:			
National General Account		5, 439, 167. 00	
National tangible property		1, 168, 000. 00	
National Seat Reserve Account		7, 500. 00	
President's Business Committee		579, 800. 01	
T.V. National		9, 210. 00	
Washington Area Building Fund—general account		325, 333. 46	
Washington Area Building Fund—reserve account		369, 683. 77	
Washington Area Seat Reserve Account		30, 236. 24	
Washington Area Federal Employee Drive		4, 335. 50	
Washington Area Federal Employee Drive—Seat Endowment		2, 075. 00	
Washington area tangible property		35, 000. 00	
School Children's Reserve Fund		300. 00	7, 970, 640. 98
Fixed assets:			
Cost of land		146, 000. 00	
Construction costs		348, 870. 57	
Furniture and equipment	$6, 466. 67		
Less: Reserve for depreciation	2, 131. 71	4, 334. 96	499, 205. 53
Other assets:			
Videotape—Closed Circuit Telecast assigned value		150, 000. 00	
Deferred charges—Creative America		107, 000. 00	257, 000. 00
Total assets			11, 673, 021. 21

EXHIBIT A—Continued

BALANCE SHEET—Continued

LIABILITIES AND NET WORTH

Payroll taxes accrued		$551. 89
New worth:		
Pledges receivable	$7, 970, 640. 98	
Fund balance	3, 701, 828. 34	
Total net worth		11, 672, 469. 32
Total liabilities and net worth		11, 673, 021. 21

EXHIBIT B

STATEMENT OF INCOME, EXPENSES, AND FUND BALANCE
For the Month of November 1963 and Five Months Ended November 30, 1963

Income	November	Five Months
Contributions and pledges paid in:		
General accounts:		
National General Account	$507, 897. 66	$1, 531, 492. 95
President's Business Committee	300, 233. 99	689, 149. 99
Fine Arts Gifts Committee	----------	5, 000. 00
Closed Circuit Telecast—net proceeds	470. 00	908. 90
Washington Area Building Fund—general account	2, 268. 90	40, 896. 07
Washington Area Federal Employee Drive	2, 159. 92	113, 444. 03
Austrian Embassy Benefit—net proceeds	(110. 88)	11, 247. 11
Peter Pan Benefit	3, 375. 00	3, 875. 00
Total general accounts	816, 294. 59	2, 396, 014. 05
Reserve accounts:		
National Seat Reserve Account	1, 200. 00	7, 000. 00
Washington Area Building Fund—reserve account	2, 051. 69	65, 176. 92
Washington Area Seat Reserve Account	1, 400. 00	7, 905. 95
Washington Area Federal Employee Drive—seat endowment	1, 000. 00	12, 200. 00
School Children's Reserve Fund	457. 67	18, 840. 18
John F. Kennedy Memorial Fund	1, 145. 00	1, 145. 00
Total reserve accounts	7, 254. 36	112, 268. 05
Total income	823, 548. 95	2, 508, 282. 10

EXHIBIT B—Continued

STATEMENT OF INCOME, EXPENSES, AND FUND BALANCE—Continued
For the Month of November 1963 and Five Months Ended November 30, 1963

Income	November	Five Months
Expenses:		
Salaries—major	$3, 889. 57	$24, 403. 29
Salaries—D.C	1, 736. 18	13, 836. 75
Extra help	79. 26	805. 41
Depreciation—furniture and equipment	52. 06	260. 30
Equipment—rental and repairs	55. 75	345. 38
Meetings		26. 00
Office supplies and postage	61. 90	3, 047. 84
D.C. area expenses—general	418. 52	4, 048. 19
College Drama Festival	1, 000. 00	1, 000. 00
Band recording		(1. 25)
Sousa Memorial Fund	58. 00	58. 00
Seat endowment		129. 90
Printing and publicity	578. 93	1, 772. 52
Promotion	1, 943. 92	13, 193. 95
Publications	159. 60	658. 63
Telephone and telegraph	1, 273. 88	4, 156. 84
Travel and maintenance	1, 300. 80	7, 894. 63
Taxes—payroll and Civil Service	46. 82	1, 499. 41
Unclassified	150. 00	987. 53
Accounting		1, 200. 00
Insurance		1, 329. 45
President's Business Committee		25, 025. 25
Federal Employee Drive		2, 012. 50
Public relations fees	3, 000. 00	18, 000. 00
Total expenses	15, 805. 19	125. 690. 52
Excess of receipts over expenses	807, 743. 76	2, 382, 591. 58
Fund balance—beginning of period	2, 894, 084. 58	1, 319, 236. 76
Fund balance November 30, 1963	3, 701, 828. 34	3, 701, 828. 34

EXHIBIT C

STATEMENT OF INCOME, EXPENSES, AND FUND BALANCE

For the Period From Inception April 1, 1959, Through November 30, 1963

Income:		
Contributions and pledges paid in:		
General accounts:		
National General Account	$1,778,157.44	
President's Business Committee	1,193,074.99	
Fine Arts Gifts Committee	12,500.00	
Closed Circuit Telecast—net proceeds	362,205.44	
Washington Area Building Fund—general account	1,147,526.59	
Washington Area Federal Employee Drive	128,223.28	
Austrian Embassy Benefit—net proceeds	11,247.11	
Peter Pan Benefit	3,875.00	
Total general accounts		$4,636,809.85
Reserve accounts:		
National Reserve Account	510.00	
National Seat Reserve Account	17,666.58	
Washington Area Building Fund—reserve account	170,202.60	
Washington Area Seat Reserve Account	26,375.90	
Washington Area Endowment Fund	894.64	
Washington Area Federal Employee Drive—Seat Endowment	12,200.00	
School Children's Reserve Fund	18,840.18	
John F. Kennedy Memorial Fund	1,145.00	
Total reserve accounts		247,834.90
Total income		4,884,644.75
Expenses:		
Salaries—major	362,899.28	
Salaries—D.C	78,187.14	
Salaries—Fine Arts	10,475.87	
Extra help	5,830.82	
Depreciation—furniture and equipment	2,131.71	
Equipment—rental and repairs	4,047.61	
Meetings	2,213.71	
Office supplies and postage	20,243.32	
D.C. area expenses—general	9,912.49	
Fine Arts Gifts Committee	9,057.88	
College Drama Festival	1,000.00	
Band recording	1,655.29	
Sousa Memorial Fund	58.00	
Seat endowment	1,997.84	
Printing and publicity	42,205.19	

EXHIBIT C—Continued

STATEMENT OF INCOME, EXPENSES, AND FUND BALANCE—Continued
For the Period From Inception April 1, 1959, Through November 30, 1963

Expenses—Continued		
Promotion	$51, 958. 05	
Publications	8, 365. 26	
Telephone and telegraph	36, 191. 94	
Travel and maintenance	83, 255. 38	
Taxes—payroll and Civil Service	14, 728. 45	
Unclassified	1, 973. 37	
Accounting	11, 900. 00	
Insurance	4, 347. 48	
Interest	5, 088. 89	
President's Business Committee	87, 818. 95	
Federal Employee Drive	2, 012. 50	
Public relations fees—Schedule 1	320, 009. 99	
Miscellaneous fees	3, 250. 00	
Total expenses		$1, 182, 816. 41
Excess of receipts over expenses—fund balance		3, 701, 828. 34

EXHIBIT D

ANALYSIS OF CASH IN BANKS

For the Period From Inception April 1, 1959, Through November 30, 1963

Cash in banks—general account:		
Contributions and pledges paid into general account—Exhibit C		$4, 636, 809. 85
Payroll taxes withheld		551. 89
Total received		4, 637, 361. 74
Deduct:		
Operating expenses—Exhibit C	$1, 182, 816. 41	
Expenditures to acquire assets:		
Petty cash—Exhibit A	619. 37	
Deposit with airline—Exhibit A	850. 00	
Fixed assets—Exhibit A	499, 205. 53	
Other assets—Exhibit A	257, 000. 00	1, 940, 491. 31
Cash in banks—general account		2, 696, 870. 43
Cash in banks—reserve accounts:		
Contributions and pledges paid into reserve accounts—Exhibit C		247, 834. 90
Cash in banks—reserve accounts		247, 834. 90

SCHEDULE 1

SCHEDULE OF TIME DEPOSITS

November 30, 1963

Time Deposits per Exhibit A—Balance Sheet:	
General accounts	$1, 690, 321. 47
Reserve accounts	201, 67 . 53
Total time deposits per balance sheet	1, 892, 000. 00

Schedule of time deposits

Depositary	Date deposited	Maturity date	Percent interest rate per annum	Amount deposited
American Security & Trust Co.	2/21/63	2/21/64	3½	$40, 000. 00
Washington, D.C.	3/1/63	3/1/64	3½	100, 000. 00
	6/20/63	12/20/63	3¼	9, 000. 00
	8/16/63	2/17/64	3½	18, 000. 00
	8/16/63	2/17/64	3½	125, 000. 00
	11/18/63	2/17/64	3¾	100, 000. 00
Perpetual Building Association, Washington, D.C.	11/15/63	12/15/64	4	200, 000. 00
Manufacturers Hanover Trust Co., New York, N.Y.	11/18/63	11/18/64	3⅞	200, 000. 00
Irving Trust Co., New York, N.Y.	11/18/63	5/17/64	3¾	200, 000. 00
National Bank of Detroit, Detroit, Mich.	11/18/63	11/18/64	4	200, 000. 00
Morgan Guaranty Trust Co., New York, N.Y.	11/18/63	11/18/64	3¾	200, 000. 00
Manufacturers Nat'l Bank of Detroit, Detroit, Mich.	11/18/63	11/18/64	3⅞	200, 000. 00
Home Savings and Loan Association, Beverly Hills, Calif.	11/18/63	11/18/64	4. 85	300, 000. 00
Total time deposits				1, 892, 000. 00

SCHEDULE 2

PUBLIC RELATIONS AND FUND RAISING FEES

For the Period From Inception April 1, 1959, Through November 30, 1963

Tamblyn and Brown—April 1959 to January 1960	$58, 250. 00
George A. Brakeley and Co.—April 1960 to June 1961	106, 000. 00
Randolph G. Bishop—April 1959 to June 1961	25, 749. 99
Carleton Sprague Smith—August 1960 to February 1961	7, 860. 00
Lobsenz and Co.—December 1961 to August 1962	68, 000. 00
Ruder and Finn—August 1962 to January 1963	27, 150. 00
Thomas Deegan and Co.—February 1963 to November 1963	27, 000. 00
Total	320, 009. 99

720-018—64——17

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, 1963:

ACQUISITIONS

The acquisitions section received 118,101 publications during the year. Included in this total were 3,065 purchased items and 1,057 journal subscriptions. The rest were received as gifts and exchanges. Arrangements were established with 142 scientific and learned organizations for the exchange of additional publications, and 1,540 items required special search to obtain.

Interested donors presented the library with valuable and difficult to locate publications. Some of the outstanding are:

"Colonial Records, 1660–1790," and "Pennsylvania Archives, 1661–1790," from Mrs. William A. McGuire, Johnstown, Pa.

"Susquehanna Company Papers," edited by Julian P. Boyd, from the Cornell University Press.

Cortesao, Armando, and Avelino Teixeira da Mota. Portugaliae Monumenta Cartographica. Lisbon, 1960. 5 vols. and index, from the Commissão Executiva do V Centena'rro da Morte do Infante D. Henrique, Lisbon, Portugal.

34 volumes from the estate of Mrs. Helen Augusta Mosher, Marblehead, Mass.

28 volumes on art from the library of the late Henry Salem Hubbell, Miami, Fla.

647 volumes from the estate of Mrs. Dora W. Boettcher, Washington, D.C.

972 periodicals on electronics from Mrs. J. B. Brady, Somerset, Md.

Ross, Marvin C. "Catalogue of the Byzantine and Early Mediaeval Antiquities in the Dumbarton Oaks Collection," vol. 1, Metalwork, Ceramics, Glass, Paintings, from the author, Washington, D.C.

45 issues of the Baltimore Sun Almanac, 1876–1925, from Miss Ruby Smith, Washington, D.C.

American Topical Society. Flowers and botanical subjects on stamps, from Dr. Willard F. Stanley, Fredonia, N.Y.

Bruce, A. W. "The Steam Locomotive in America," from Thomas T. Taber, Madison, N.J.

Antrim, Earl. "Civil War Prisons and Their Covers," from the author. Nampa, Idaho.

Dredge, James. "A Record of the Transportation Exhibits at the World's Columbian Exposition of 1893," from Mrs. B. B. Bierer, Jr., Washington, D.C.

Greenwell, G. C. "A Practical Treatise on Mine Engineering, 1855," from Cornelius U. S. Roosevelt, Washington, D.C.

Perlman, Bernard B. "The Immortal Eight, American Painting from Eakins to the Armory Show (1870–1913)." 1962.

Brooks, Van Wyck. "John Sloan, a Painter's Life." 1955. From Mrs. John Sloan, Wilmington, Del.

Duplicate and extraneous materials sent to other libraries amounted to 58,818. Of this, 51,512 pieces went to the Library of Congress, 3,018 to the National Library of Medicine, and 1,375 went to other agencies. The section handled a total of 176,919 pieces of material during the year.

CATALOGING AND BINDING

The catalog section cataloged 7,146 volumes, recataloged 234 items, transferred 203 publications, discarded 583 volumes, recorded 32,981 serials in the Serial Record, and filed 31,270 cards into the card catalog. In addition, 563 trade catalogs and 1,945 titles of short-form cataloging were added to the collection. Cataloging of newly acquired publications on a current basis was emphasized.

The binding unit prepared 6,600 volumes of books and journals for binding by a commercial binder. The hand-binding staff preserved 2,957 volumes and pamphlets which were either too fragile or valuable to be sent outside the Institution for repair.

REFERENCE AND CIRCULATION

The reference librarians answered 31,769 requests for specific types of information, replied to 2,511 pieces of correspondence, circulated 35,781 books and journals, and cleared the loan records on 28,874 volumes. No record is kept of the circulation of books and journals assigned to the division collections where they circulate freely within the division. Publications borrowed from other libraries, chiefly the Library of Congress, totaled 6,423, and 992 volumes were lent. The reading and reference facilities of the central and branch libraries were used by 27,267 persons.

BRANCH LIBRARIES

The branch library for the Museum of History and Technology answered 13,057 reference questions, circulated 13,509 books and journals, and added 563 trade catalogs to the collection. Visitors using the library facilities totaled 6,212.

The Bureau of American Ethnology branch library answered 1,964 reference questions, circulated 1,100 books and journals, and provided assistance of 1,300 visitors. With improved physical rearrangement of the collection, addition of new equipment, and a revised system of book selection, the use and importance of this library are developing.

Procedures for ordering and binding of books and journals were revised for the branch library of the Smithsonian Astrophysical Observatory, Cambridge, Mass. The number of visitors using this library was 7,083, reference questions answered numbered 2,521, and 1,998 books and journals were circulated.

A plan to organize and control the collection in the entomology branch library was put into operation. A. J. Spohn, formerly with the National War College, was appointed librarian to succeed Miss Emily Bennett.

PROGRAMS AND FACILITIES

With the addition of the east wing to the Natural History Building, the central library acquired new space adjacent to its present location. Renovation of this entire area was completed in April.

Features that contribute to the usefulness of the library consist of new equipment, adequate workspace for the staff, reading and browsing areas, new bookstacks with sliding reference shelves, study carrels, electric book lifts, bibliographical and packing areas, a rare book room, air conditioning, and good natural and artificial lighting.

The library for the National Collection of Fine Arts was moved to the second floor of the Natural History Building. Floor plans for this library, and for the library of the National Portrait Gallery in the Patent Office Building, were reviewed, and an estimate for furniture and equipment was submitted.

STAFF CHANGES AND ACTIVITIES

Mrs. Mary A. Huffer was appointed chief of the reference and circulation section and Jack Marquardt assumed the duties of reference librarian in charge of the central reference section. Salvador Waller, formerly with the Office of Technical Services, joined the catalog section, and Miss Mildred Raitt, formerly with the Chamber of Commerce, was appointed order librarian.

Staff members attended the Special Libraries Association and American Library Association annual conferences. Special courses and seminars provided the staff with an opportunity for growth and development.

SUMMARIZED STATISTICS

ACCESSIONS

	Volumes	Total recorded volumes, 1963
Smithsonian central library including the Museum of Natural History	2, 520	353, 774
Museum of History and Technology	5, 322	
Astrophysical Observatory (SI)	3	13, 407
Smithsonian Astrophysical Observatory, Cambridge, Mass	642	2, 342
Radiation and Organisms	128	2, 167
Bureau of American Ethnology	714	39, 894
National Air Museum	192	1, 143
National Collection of Fine Arts	128	14, 519
National Zoological Park	5	4, 302
Total	9, 654	431, 548

Unbound volumes of periodicals and reprints and separates from serial publications, of which there are many thousands, have not been included in the above totals.

Exchanges:	
New exchanges arranged	142
Specially requested publications received	1,540
Cataloging:	
Volumes cataloged	9,888
Catalog cards filed	31,270
Serials: Number of serials recorded	32,981
Circulation: Loans of books and periodicals	35,781
Binding and repair:	
Volumes sent to the bindery	6,705
Volumes repaired in the library	2,957

Respectfully submitted.

RUTH E. BLANCHARD, *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 Institution and its branches for the year ended June 30, 1963:

The publications of the Smithsonian Institution are issued partly from federally appropriated funds (Smithsonian Reports and publications of the National Museum, the Bureau of American Ethnology, 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. In addition, the Smithsonian publishes for sale to visitors a guidebook, a picture pamphlet, postcards and a postcard folder, color slides, a filmstrip on Smithsonian exhibits, a coloring book for children, and popular publications on scientific and historical subjects related to its important exhibits and collections. Through its publication program the Smithsonian endeavors to carry out its founder's expressed desire for the diffusion of knowledge.

The chief of the division continued to represent the Smithsonian Institution on the board of trustees of the Greater Washington Educational Television Association, Inc., of which the Institution is a member, and served on its executive committee. He and the assistant chief of the division represented the Institution at the annual meeting of the Association of American University Presses held in June at Cambridge, Mass.

Miss Ruth B. MacManus, assistant editor, who had been associated with the editorial operations of the Smithsonian Institution since 1928, died on November 17, 1962.

Ernest E. Biebighauser, a member of the editorial staff since 1953, left the Institution on January 7, 1963, to accept a position with the Coast and Geodetic Survey of the Department of Commerce.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

In this series there were issued 3 papers as follows:

Volume 145

No. 3. The problem of the Viduinae in the light of recent publications, by Herbert Friedmann. 10 pp. (Publ. 4506.) July 20, 1962. (50 cents.)

No. 4. Uniformity among growth layers in three ponderosa pine, by Waldo S. Glock, Paul J. Germann, and Sharlene R. Agerter. xiv+375 pp., 71 figs., 13 pls. (Publ. 4508.) February 21, 1963. ($6.)

Volume 146

No. 1. Aboriginal cultural development in Latin America: An interpretative review, edited by Betty J. Meggers and Clifford Evans. vi+148 pp., 20 figs. (Publ. 4517.) June 17, 1963. ($5.)

SMITHSONIAN ANNUAL REPORTS

REPORT FOR 1961

The complete volume of the Annual Report of the Board of Regents for 1961 was received from the printer on November 15, 1962.

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, 1961. x+579 pp., illus. (Publ. 4478.)

The general appendix contained the following papers (Publ. 4479–4499):

Some astronomical aspects of life in the universe, by Su-Ssu Huang.
X-rays from the sun, by Herbert Friedman.
The challenge of space exploration, by Robert C. Seamans, Jr.
The Smithsonian's satellite-tracking program, by E. Nelson Hayes.
The main lines of mathematics, by J. L. B. Cooper.
Early experiments in instrument flying, by James H. Doolittle.
Three famous early aero engines, by Robert B. Meyer, Jr.
Organic chemistry: a view and a prospect, by Sir Alexander Todd.
The new age of the sea, by Philip B. Yeager.
Drilling beneath the deep sea, by William E. Benson.
A natural history of trilobites, by H. B. Whittington.
Chromosomes and the theory of heredity, by C. D. Darlington.
Tropical climates and biology, by G. S. Carter.
Outdoor aerobiology, by P. H. Gregory.
The detection and evasion of bats by moths, by Kenneth D. Roeder and Asher E. Treat.
The honey bee, by James I. Hambleton.
Evolution, genetics, and anthropology, by A. E. Mourant.
Australopithicines and the origin of man, by J. T. Robinson.
The skull of Shanidar II, by T. D. Stewart.
Heyerdahl's Kon-Tiki theory and its relation to ethnobotany, by F. P. Jonker.
Minerals in art and archeology, by Rutherford J. Gettens.

REPORT FOR 1962

The report of the Secretary, which will form part of the 1962 Annual Report of the Board of Regents, was issued January 24, 1963.

Report of the Secretary and financial report of the Executive Committee of the Board of Regents for the year ended June 30, 1962. x+241 pp., 16 pls. (Publ. 4514.)

SPECIAL PUBLICATIONS

Brief guide to the Smithsonian Institution, new ed. 80 pp., illus. (Publ. 4507.) October 9, 1962. (25 cents.)

Preliminary field guide to the birds of the Indian Ocean, by George E. Watson, Richard L. Zusi, and Robert E. Storer. x+214 pp., 19 pls., 17 maps. (Publ. 4541.) February 28, 1963.

Correspondence between Spencer Fullerton Baird and Louis Agassiz—Two pioneer American naturalists, collected and edited by Elmer Charles Herber. 237 pp., 16 pls. (Publ. 4515.) June 21, 1963. ($5.)

Author-subject index to articles in Smithsonian Annual Reports, compiled by Ruth M. Stemple and the Editorial and Publications Division. vi+200 pp. (Publ. 4503.) January 30, 1963.

REPRINTS

A biographical sketch of James Smithson. 20 pp., illus. (Publ. 2276.) April 23, 1963. (50 cents.)

Anthropology as a career, by William C. Sturtevant. 20 pp. (Publ. 4343.) April 12, 1963. (20 cents.)

The story of transportation, by E. John Long. 36 pp., illus. (Publ. 4312.) May 25, 1963. (50 cents.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum continued during the year under the immediate direction of John S. Lea, assistant chief of the division. The following publications were issued:

REPORT

The United States National Museum annual report for the year ended June 30, 1962. viii+195 pp., illus. January 24, 1963.

BULLETINS

100, volume 14, parts 1–4. Title page, table of contents, and index. vii+443–461 pp., May 16, 1963.

228. Contributions from the Museum of History and Technology: Papers 19–30, by members of the staff and others.

    Paper 29. The development of electrical technology in the 19th century: 2. The telegraph and the telephone, by W. James King. Pp. 273–332, 80 figs. Sept. 17, 1962.

    Paper 30. The development of electrical technology in the 19th century: 3. The early arc light and generator, by W. James King. Pp. 333–407, 92 figs. Sept. 17, 1962.

233. Host relations of the parasitic cowbirds, by Herbert Friedmann. ix+276 pp. June 13, 1963.

235. American military insignia, 1800–1851, by J. Duncan Campbell and Edgar M. Howell. xv+124 pp., 277 figs. June 27, 1963.

PROCEEDINGS

Volume 113

Title page, table of contents, and index. Pp. i–v+637–660. Jan. 9, 1963.

No. 3459. Plectrotaxy as a systematic criterion in lithobiomorphic centipedes (Chilopoda: Lithobiomorpha), by Ralph E. Crabill, Jr. Pp. 399–412, 1 fig. July 12, 1962.

No. 3461. Synopsis of the Neotropical cockroach genus *Macrophyllodromia* (Orthoptera: Blattoidea, Epilampridae), by Isolda Rocha e Silva Albuquerque. Pp. 421–428, 14 figs. Aug. 29, 1962.

No. 3465. The heleomyzid flies of America north of Mexico (Diptera: Heleomyzidae), by Gordon D. Gill. Pp. 495–603, 96 figs. Aug. 30, 1962.

No. 3466. The non-brachyuran decapod crustaceans of Clipperton Island, by Fenner A. Chace, Jr. Pp. 605–635, 7 figs. Aug. 29, 1962.

Volume 114

No. 3467. Scarab beetles of the genus *Onthophagus* Latreille north of Mexico (Coleoptera: Scarabaeidae), by Hendy F. Howden and Oscar L. Cartwright. Pp. 1–135, 11 figs., 9 pls. Jan. 9, 1963.

No. 3468. New species of spider wasps, genus *Auplopus*, from the Americas south of the United States (Hymenoptera: Psammocharidae), by R. R. Dreisbach. Pp. 137–211, 13 pls. Mar. 19, 1963.

No. 3469. Some North American moths of the genus *Acleris* (Lepidoptera: Tortricidae), by Nicholas S. Obraztsov. Pp. 213–270, 7 figs., 18 pls. May 7, 1963.

No. 3470. A revision of the North American annelid worms of the genus *Cambarincola* (Oligochaeta: Branchiobdellidae), by Richard L. Hoffman. Pp. 271–371, 79 figs. Mar. 6, 1963.

No. 3471. Geographic variation in the thrush *Hylocichla ustulata*, by Gorman M. Bond. Pp. 373–387, 1 fig. Mar. 6, 1963.

No. 3472. Review of the hawkfishes (family Cirrhitidae), by John E. Randall. Pp. 389–451, 16 pls. May 28, 1963.

No. 3473. Studies of Neotropical caddisflies, I: Rhyacophilidae and Glossosomatidae (Trichoptera), by Oliver S. Flint, Jr. Pp. 453–478, 8 figs. Apr. 16, 1963.

No. 3474. Weevils of the genus *Maemactes*, by David G. Kissinger. Pp. 479–486, 1 fig. Mar. 19, 1963.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau continued under the immediate direction of Mrs. Eloise B. Edelen. The following publications were issued during the year:

Seventy-ninth Annual Report of the Bureau of American Ethnology, 1961–62. ii+29 pp., 2 pls. 1963.

Bulletin 181. Isleta paintings, with introduction and commentary by Elsie Clews Parsons. Edited by Esther S. Goldfrank. xvi+299 pp., 142 pls. (incl. 12 pls. in color). 1962.

Bulletin 182. River Basin Surveys Papers, No. 25. Archeology of the John H. Kerr Reservoir Basin, Roanoke River, Virginia-North Carolina, by Carl F. Miller. With appendix: Human skeletal remains from the Tollifero (He6) and Clarksville (Mc14) sites, John H. Kerr Reservoir Basin, Virginia, by Lucile E. Hoyme and William M. Bass. xvi+447 pp., 110 pls., 65 figs., 20 maps. 1962.

Bulletin 184. The Pueblo of Sia, New Mexico, by Leslie A. White. xii+358 pp., 12 pls., 55 figs. 1962.

Bulletin 185. River Basin Surveys Papers, Nos. 26–32. xii+344 pp., 57 pls., 43 figs., 5 maps. 1963.

No. 26. Small sites on and about Fort Berthold Reservation, Garrison Reservoir, North Dakota, by George Metcalf.

No. 27. Star Village: A fortified historic Arikara site in Mercer County, North Dakota, by George Metcalf.

No. 28. The dance hall of the Santee Bottoms on the Fort Berthold Reservation, Garrison Reservoir, North Dakota, by Donald D. Hartle.

No. 29, Crow-Flies-High (32MZ1), a historic Hidatsa village in the Garrison Reservoir area, North Dakota, by Carling Malouf.

No. 30. The Stutsman Focus: An aboriginal culture complex in the Jamestown Reservoir area, North Dakota, by R. P. Wheeler.

No. 31. Archeological manifestations in the Toole County section of the Tiber Reservoir Basin, Montana, by Carl F. Miller.

No. 32. Archeological salvage investigations in the Lovewell Reservoir area, Kansas, by Robert W. Neuman.

Bulletin 188. Shonto: A study of the role of the trader in a modern Navaho community, by William Y. Adams. xi+329 pp., 10 pls., 3 figs., 3 maps, 12 charts. 1963.

PUBLICATIONS OF THE ASTROPHYSICAL OBSERVATORY

The editorial work of the Smithsonian Astrophysical Observatory continued under the immediate direction of Ernest E. Biebighauser, until his transfer to the Department of Commerce. The year's publications in the series Smithsonian Contributions to Astrophysics are as follows:

Volume 5

No. 12. North-south asymmetry in solar spottedness and in great-storm sources. Pp. iii+187–208, 13 figs. 1962.

A long-term north-south asymmetry in the location of solar sources of great geomagnetic storms, by Barbara Bell.

On the unequal spottedness of the two solar hemispheres, by John G. Wolbach.

On short-period relations between north-south asymmetry in spottedness and in great-storm sources, by Barbara Bell and John G. Wolbach.

No. 13. Neutral hydrogen between galactic longitudes 200° and 265°, by R. J. Davis. Pp. 209–230, 6 figs. 1962.

No. 14. The space density of atmospheric dust in the altitude range 50,000 to 90,000 feet, by Paul W. Hodge and Frances W. Wright. Pp. 231–238, 2 figs., 1 pl. 1962.

No. 15. Solar radio bursts of spectral types II and IV: Their relations to optical phenomena and to geomagnetic activity, by Barbara Bell. Pp. 239–257, 2 figs. 1963.

Volume 7

Proceedings of the symposium on the astronomy and physics of meteors, held at Smithsonian Astrophysical Observatory, Cambridge, Mass., August 28–September 1, 1961. Whole volume. iv+314 pp., 117 figs., 22 pls. 1963.

PUBLICATIONS OF THE NATIONAL COLLECTION OF FINE ARTS

The following catalogs were issued by the Smithsonian Traveling Exhibition Service during the year:

The Daniells in India, 1786–1793. [44] pp., illus. (Publ. 4513.) 1962.
Old Master drawings from Chatsworth. 46 pp., 144 illus. 1962.

PUBLICATIONS OF THE FREER GALLERY OF ART

The field of stones: A study of the art of Shen Chou (1427–1509), by Richard Edwards. Freer Gallery of Art Oriental Studies, No. 5, xxi+131 pp., 51 pls. (Publ. 4433.) Nov. 7, 1962. ($11.)

Ancient glass in the Freer Gallery of Art, by Richard Ettinghausen. 44 pp., with 99 illus. (incl. 3 pls. in color). (Publ. 4509.) July 16, 1962. ($1.65.)

Chinese album leaves in the Freer Gallery of Art, by James Cahill. 48 pp., with 35 illus. (incl. 2 pls. in color). (Publ. 4476.) Nov. 30, 1962. ($1.)

The Whistler Peacock Room (rev. ed.). vii+22 pp., 7 pls. (Publ. 4024.) Dec. 11, 1962. (35 cents.)

The Freer Gallery of Art of the Smithsonian Institution (reprint). 16 pp., illus. (Publ. 4504.) Aug. 8, 1962. (15 cents.)

REPORTS 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 report was issued during the year:

Annual Report of the American Historical Association for 1961. Vol. 1, Proceedings. 1962.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

In accordance with law, the manuscript of the 65th annual report of the National Society, Daughters of the American Revolution, was transmitted to Congress on May 16, 1963.[1]

DISTRIBUTION

Requests for publications and information continued to increase during the year. The publications distribution section, under the immediate supervision of Mrs. Eileen M. McCarthy, received 38,397 requests for publications from foreign and domestic libraries, universities, research institutions, educational establishments, and individuals throughout the world. Visitors to the office and replies to inquiries numbered 30,053.

A total of 899,788 copies of publications and miscellaneous items were distributed: 67 Contributions to Knowledge; 13,207 Smithsonian

[1] D.A.R. reports are published as Senate documents and are not available from the Smithsonian Institution.

Miscellaneous Collections; 8,576 Annual Report volumes and 31,025 pamphlet copies of Report separates; 50,136 special publications; 164 reports of the Harriman Alaska Expedition; 43,257 publications of the National Museum; 17,722 publications of the Bureau of American Ethnology; 112,343 catalogs and leaflets of the National Collection of Fine Arts; 546 publications of the Freer Gallery of Art;[2] 18 Annals of the Astrophysical Observatory; 9,646 Smithsonian Contributions to Astrophysics; 679 War Background Studies; 1,763 reports of the American Historical Association; and 11,928 publications not issued by the Smithsonian Institution. Miscellaneous items: 15 sets of North American Wild Flowers and 127 North American Wild Flower prints; 8 Pitcher Plant volumes; 75,365 Guide Books; 17,529 picture pamphlets; 359,232 postcards; 25,626 postcard folders; 19,993 color slides; 96,230 information leaflets; 228 statuettes; 4,355 View-master reels.

The following titles were issued and distributed to libraries as a result of the Institution's participation in the National Science Foundation translation program: *Mammals of Eastern Europe and Northern Asia* (*Insectivora and Chiroptera*), vol. 1, by S. I. Ognev; *Mammals of Eastern Europe and Northern Asia* (*Carnivora Fissipedia*), vol. 2, by S. I. Ognev; *Mammals of U.S.S.R. and Adjacent Countries* (*Carnivora Fissipedia and Pinnipedia*), vol. 3, by S. I. Ognev; *Mammals of U.S.S.R. and Adjacent Countries* (*Rodents*), vol. 5, by S. I. Ognev; *Forty Years of Soviet Anthropology*, by G. F. Debets; *Short-Ears and Long-Ears on Easter Island*, by N. A. Butinov; *Problems in the History of Primitive Society*, by N. A. Butinov; *Terrestrial Mollusks of the Fauna of the U.S.S.R.*, by I. M. Likharev and E. S. Rammel'meier; *Fauna of Russia and Adjacent Countries* (*Amphibians*), by A. M. Nikol'skii; *Fauna of U.S.S.R.* (*Crustacea, Anomura*), vol. 10, No. 3, by V. V. Makarov; *The Chalcid Fauna of the U.S.S.R.* (*Chalcidoidea*), by M. N. Nikol'skaya; *Flora of the U.S.S.R.*, vol. 2, V. L. Komarov, editor; *Special Ichthyology*, by G. V. Nikol'skii; *Freshwater Fishes of the U.S.S.R. and Adjacent Countries*, vol. 1, by Leo S. Berg; *Fauna of U.S.S.R.—Fishes* (*Gadiformes*), vol. 9, No. 4, by A. N. Svetovidov; *Fundamentals of Paleontology*, Yu. A. Orlov, editor.

Respectfully submitted.

PAUL H. OEHSER,
Chief, Editorial and Publications Division.

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

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[2] In addition to those distributed by the Gallery itself.

Other Activities

LECTURES

C. Fayette Taylor, emeritus professor of automotive engineering, Massachusetts Institute of Technology, delivered the fourth Lester D. Gardner lecture, on "Aircraft Propulsion: A Review of the Evolution of Aircraft Powerplants," in the auditorium of the Freer Gallery of Art on the evening of October 5, 1962. This lecture was published in full in the general appendix of the Annual Report of the Board of Regents of the Smithsonian Institution for 1962 (pp. 245–298).

Dr. John Howard Young, W. H. C. Vickers associate professor of archeology, Johns Hopkins University, lectured on "The Royal Sculptures of Commagene" in the auditorium of the Freer Gallery of Art on the evening of February 8, 1963. This lecture was sponsored jointly by the Smithsonian Institution and the Archaeological Institute of America.

Hugh Wakefield, keeper of circulation, Victoria and Albert Museum, London, England, lectured on "English Victorian Glass" in the auditorium of the Freer Gallery of Art on the evening of April 24, 1963.

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

SCIENCE INFORMATION EXCHANGE

The Science Information Exchange receives, organizes, and disseminates information on scientific research in progress. Its mission is to facilitate planning and management of scientific research activities supported by Government and non-Government agencies and institutions by promoting the exchange of information that concerns subject matter, distribution, level of effort, and other data pertaining to current research in the prepublication stage. It helps program directors and administrators to avoid unwanted duplication and to determine the most advantageous distribution of research funds. It serves the entire scientific community by informing individual investigators about who is currently working on problems in their special fields.

The reorganization and expansion of the Exchange to provide current research information in the physical sciences, in addition to the life sciences, have constituted the major task during the past year and have progressed quite satisfactorily. The new physical sciences division now has 15 members. The total staff has grown to about 115, and the plant capability and capacity have been almost doubled.

The acquisition of current research projects and proposals increased sharply from an annual rate of about 56,000 in 1962 to almost 75,000 in 1963. The total number of active projects on file has risen from 33,000 to almost 58,000.

Many new research programs have been added, and many new agencies, such as the Departments of Agriculture, Commerce, and Interior, have begun to register their current research activities. All Federal agencies with substantial research programs in basic and applied research are now participating. As the coverage of Federal programs approaches comprehensive proportions, increasing attention is being directed to securing the cooperation of universities, private foundations, State and city government research organizations, and industrial laboratories.

The January 10, 1963, report of the President's Scientific Advisory Committee, entitled "Science, Government, and Information," noted the work of the Exchange and recommended its continued activity on a stronger and broader base. The expanded scope in physical sciences and the increasing participation by Federal and non-Government agencies, as noted above, are well underway.

The Federal Council for Science and Technology has agreed that on July 1, 1963, the National Science Foundation will undertake the responsibility for the support of the Exchange through contractual arrangements for its continued operation by the Smithsonian Institution. Government-wide interests will be served by an advisory board of representatives from each of the participating Federal agencies.

SMITHSONIAN MUSEUM SERVICE

The Smithsonian Museum Service, through appropriate educational media, interprets to museum visitors and to the general public the objects, specimens, and exhibits in the several Smithsonian museums and develops interpretative and educational material relating to the work of the Institution in the fields of science, natural history, art, and history. The Museum Service also cooperates with the volunteers of the Junior League of Washington, D.C., who conduct the Junior League Guided Tour Program at the Smithsonian. A more complete report of this activity, directed by G. Carroll Lindsay, curator, is carried in the Report on the U.S. National Museum (pp. 59–60).

The Museum Service provided assistance to professional groups and individuals visiting the museums of the Institution or planning to do so. Assistance in the form of lectures, answers to inquiries, and special tours of certain museum areas was rendered to college and university groups visiting the Institution and to other groups and individuals from the United States and abroad, visiting or planning to visit the Smithsonian in a professional capacity. Mr. Lindsay served as consultant on museum organization and practices to representatives from other museums on several occasions.

The Audioguide or radio lecture system in the Museum of Natural History was expanded to include two additional exhibit halls: Life in the Sea, and Dinosaurs and Other Fossil Reptiles. A total of 37 Audioguide lectures are now available in the Museum of Natural History.

During the year Mrs. Linda S. Gordon joined the Museum Service staff as museum technician in zoology and Mrs. Marjorie M. Halpin as museum technician in anthropology. Mrs. Gordon and Mrs. Halpin serve as docents and carry on related work to improve the Museum Service program of interpreting the museum exhibits to the visitor.

The assistant curator, Mrs. Sophy Burnham, wrote, produced, and directed a 16-mm. color motion picture which depicts the construction of the life-size model of the great blue whale exhibited in the new Hall of Life in the Sea. Mrs. Burnham, in cooperation with the various subject specialists involved, also continued her work in the preparation of the Audioguide lectures.

Special "touch" tours for several groups of blind students were arranged during the year. Specimens and objects from the reference collections as well as selected portions of the public exhibits are included in the programs arranged for blind persons.

One-page guide maps which provide floor plans and brief summaries of the exhibits shown in the Museum of Natural History and in the Arts and Industries Building were prepared. These proved most useful in visitor orientation and in answering written inquiries regarding the exhibits in these buildings.

The Museum Service continued to assist radio and television producers wishing to feature Smithsonian exhibits and scientific work. In addition to several local radio and television productions based on various aspects of Smithsonian activity, two half-hour programs featuring the transportation collections were broadcast on a national television network.

The Museum Service again conducted, in cooperation with the University of Maryland, a 5-day workshop on the educational resources of the Institution. This workshop is designed to acquaint graduate students in education with the broad scientific and cultural resources of the Smithsonian of value in school curricula.

The program carried out in cooperation with the Urban Service Corps under the direction of Mrs. Arthur Goldberg proved successful. Local junior high school students were provided with lectures and tours of museum exhibits designed to increase their knowledge of the exhibits and work of the Institution.

More than 400 35-mm. slides of objects, specimens, and exhibits in the various museums were accessioned, cataloged, and added to the slide library. Slides from this library were used extensively by the Smithsonian staff and by borrowers from the United States, Canada, and Europe.

The Museum Service made arrangements for various Smithsonian public functions and events, including films, lectures, and the opening of new halls and exhibits. Mailing lists for announcements of these events were maintained and kept current.

The Smithsonian Calendar of Events, a listing of special events of the Institution, was prepared and distributed monthly.

The curator attended the following conferences and gatherings: The Southeastern Museums Conference in Richmond, Va.; the Conference of the Society of Architectural Historians in Baltimore, Md.; Annual Winterthur Seminar on Museum Operation and Connoisseurship at Winterthur, Del.; the Museum Store Association Annual Meeting, Minneapolis, Minn.; and the opening of the Mellon Collection of British Paintings, Virginia State Museum of Fine Arts. He also attended and gave a slide lecture to the National Trust Conference for Historic Museum Associates, held at Woodlawn Plantation, Va., and participated in a panel discussion at the convention in Denver, Colo., of the Department of Audiovisual Education, National Education Association.

The curator and the assistant curator traveled to Cambridge, Mass., to speak to the staff of the Smithsonian Astrophysical Observatory on the work and history of the Smithsonian Institution and to view operations there. They also visited museums in the Boston area.

The assistant curator traveled to Baltimore, Md., to view facilities of five museums.

Report of the Executive Committee of the Board of Regents of the Smithsonian Institution

For the Year Ended June 30, 1963

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 INSTITUTION

PARENT 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.

The gift of James Smithson was "lent to the United States Treasury, at 6 per centum per annum interest" (20 USC 54), and by the Act of March 12, 1894 (20 USC 55), the Secretary of the Treasury was "authorized to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may from time to time see fit to deposit, not exceeding, with the original bequest, the sum of $1,000,000."

The maximum of $1,000,000 which the Smithsonian Institution was authorized to deposit in the Treasury of the United States was reached on January 11, 1917, by the deposit of $2,000.

Under the above authority the amounts shown below are deposited in the United States Treasury and draw 6 percent interest:

	Unrestricted funds		*Income 1963*
James Smithson	$727, 640		$43, 658. 40
Avery	14, 000		840. 00
Habel	500		30. 00
Hamilton	2, 500		150. 00
Hodgkins (General)	116, 000		6, 960. 00
Poore	26, 670		1, 600. 20
Rhees	590		35. 40
Sanford	1, 100		66. 00
Total		$889, 000	53, 340. 00

	Restricted funds		*Income 1963*
Hodgkins (Specific)	100,000		6,000.00
Reid	11,000		660.00
Total		111,000	6,660.00
Grand total		1,000,000	60,000.00

In addition to the $1,000,000 deposited in the Treasury of the United States there has been accumulated from income and bequests the sum of $4,489,870.56 which has been invested. Of this sum, $4,254,290.71 is carried on the books of the Institution as the Consolidated Fund, a policy approved by the Regents at their meeting on December 14, 1916. The balance is made up of several small funds.

CONSOLIDATED FUND

(Income for the unrestricted use of the Institution)

Fund	Investment 1963	Income 1963
Abbott, W. L., Special	$23,595.27	$1,195.47
Avery, Robert S. and Lydia*	62,556.92	3,169.51
Gifts, royalties, gain on sale of securities	437,288.17	22,155.81
Hachenberg, George P. and Caroline	6,369.45	322.73
Hamilton, James*	639.29	32.38
Hart, Gustavus E	771.40	39.07
Henry, Caroline	1,915.42	97.03
Henry, Joseph and Harriet A	77,636.17	3,933.55
Higbee, Harry, Memorial Fund	18,918.26	713.50
Hodgkins, Thomas G. (General)*	47,975.50	2,430.75
Morrow, Dwight W	122,469.22	6,205.05
Olmsted, Helen A	1,269.73	64.33
Poore, Lucy T. and George W.*	257,760.56	13,059.81
Porter, Henry Kirke	453,575.46	22,980.99
Rhees, William Jones*	749.28	37.95
Sanford, George N.*	1,409.80	71.45
Smithson, James*	1,933.47	97.99
Taggart, Gansen	566.45	28.72
Witherspoon, Thomas A	204,383.08	10,355.33
Total	1,721,782.90	86,991.42

*In addition to funds deposited in the United States Treasury.

CONSOLIDATED FUND

(Income restricted to specific use)

Fund	Investment 1963	Income 1963
Abbott, William L., for investigations in biology	$165, 109. 55	$8, 365. 46
Armstrong, Edwin James, for use of Department of Invertebrate Paleontology when principal amounts to $5,000	2, 089. 87	100. 80
Arthur, James, for investigations and study of the sun and annual lecture on same	63, 339. 47	3, 209. 16
Bacon, Virginia Purdy, for traveling scholarship to investigate fauna of countries other than the United States	79, 347. 09	4, 020. 23
Baird, Lucy H., for creating a memorial to Secretary Baird	58, 066. 07	2, 930. 34
Barney, Alice Pike, for collection of paintings and pastels and for encouragement of American artistic endeavor	45, 424. 49	2, 301. 50
Barstow, Frederick D., for purchase of animals for Zoological Park	1, 583. 31	80. 21
Brown, Roland W., endowment fund for study, care, and improvement of the Smithsonian paleobotanical collections	51, 587. 95	1, 769. 32
Canfield collection, for increase and care of the Canfield collection of minerals	60, 573. 77	3, 069. 03
Casey, Thomas L., for maintenance of the Casey collection and promotion of researches relating to Coleoptera	19, 851. 46	1, 005. 81
Chamberlain, Francis Lea, for increase and promotion of Isaac Lea collection of gems and mollusks	44, 599. 17	2, 259. 67
Dykes, Charles, for support in financial research	68, 185. 96	3, 454. 71
Eickemeayer, Florence Brevoort, for preservation and exhibition of the photographic collection of Rudolph Eickemeayer, Jr	17, 214. 51	872. 21
Hanson, Martin Gustav and Caroline Runice, for some scientific work of the Institution, preferably in chemistry or medicine	14, 079. 36	713. 34
Higbee, Harry, income for general use of the Smithsonian Institution after June 11, 1967	75. 40	2. 60
Hillyer, Virgil, for increase and care of Virgil Hillyer collection of lighting objects	10, 408. 64	527. 35
Hitchcock, Albert S., for care of the Hitchcock Agrostological Library	2, 499. 05	126. 60
Hrdlička, Aleš and Marie, to further researches in physical anthropology and publication in connection therewith	83, 754. 55	4, 038. 91
Hughes, Bruce, to found Hughes alcove	30, 315. 09	1, 535. 92
Johnson, E. R. Fenimore, research in underwater photography	11, 608. 94	559. 84
Loeb, Morris, for furtherance of knowledge in the exact sciences	138, 028. 26	6, 993. 40

CONSOLIDATED FUND—Continued

Fund	Investment 1963	Income 1963
Long, Annette and Edith C., for upkeep and preservation of Long collection of embroideries, laces, and textiles	$859.93	$43.58
Maxwell, Mary E., for care and exhibition of Maxwell collection	31,063.94	1,573.88
Myer, Catherine Walden, for purchase of first-class works of art for use and benefit of the National Collection of Fine Arts	31,990.18	1,620.85
Nelson, Edward W., for support of biological studies	35,220.43	1,784.50
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	1,521.54	77.07
Pell, Cornelia Livingston, for maintenance of Alfred Duane Pell collection	11,739.42	594.76
Petrocelli, Joseph, for the care of the Petrocelli collection of photographic prints and for the enlargement and development of the section of photography of the U.S. National Museum	11,740.81	594.87
Rathbun, Richard, for use of division of U.S. National Museum containing Crustacea	16,844.71	853.47
Reid, Addison T., for founding chair in biology, in memory of Asher Tunis*	28,170.38	1,427.32
Roebling Collection, for care, improvement, and increase of Roebling collection of minerals	191,139.84	9,684.34
Roebling Solar Research	39,714.73	2,012.21
Rollins, Miriam and William, for investigations in physics and chemistry	231,028.56	11,416.13
Smithsonian employees' retirement	36,863.17	1,869.30
Springer, Frank, for care and increase of the Springer collection and library	28,401.10	1,439.00
Strong, Julia D., for benefit of the National Collection of Fine Arts	15,835.07	802.31
Walcott, Charles D. and Mary Vaux, for development of geological and paleontological studies and publishing results of same	759,454.03	38,440.22
Walcott, Mary Vaux, for publications in botany	91,675.71	4,644.87
Younger, Helen Walcott, held in trust	117,024.81	6,201.46
Zerbee, Francis Brinckle, for endowment of aquaria	1,502.30	76.12
Total	2,649,532.62	133,092.67

*In addition to funds deposited in the United States Treasury.

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 $10,596,154.61.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes	$2,610,782.90
Invested endowment for specific purposes other than Freer endowment	2,879,087.56
Total invested endowment other than Freer	5,489,870.46
Freer invested endowment for specific purposes	10,596,154.61
Total invested endowment for all purposes	16,086,025.07

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	$1,640,161.47	
Stocks	2,721,044.83	
Real estate and mortgages	115,006.00	
Uninvested capital	13,658.66	4,489,870.46
Total investments other than Freer endowment		5,489,870.46
Investments of Freer endowment (cost or market value at date acquired):		
Bonds	$5,480,542.36	
Stocks	5,114,287.57	
Uninvested capital	1,324.68	10,596,154.61
Total investments		16,086,025.07

EXHIBIT A

BALANCE SHEET OF PRIVATE FUNDS

June 30, 1963

ASSETS

Current funds:			
General:			
Cash:			
United States Treasury current account			$920, 365. 77
In banks and on hand			531, 701. 82
			1, 452, 067. 59
Travel and other advances			22, 126. 88
Total general funds			1, 474, 194. 47
Restricted:			
Cash—United States Treasury current account		$3, 340, 087. 03	
Investments—stocks and bonds (quoted market value $1, 622, 254. 85)		1, 634, 613. 56	
Total restricted funds			4, 974, 700. 59
Total current funds			6, 448, 895. 06
Endowment funds and funds functioning as endowment:			
Investments:			
Freer Gallery of Art:			
Cash		$1, 324. 68	
Stocks and bonds (quoted market value $15, 687, 715. 55)		10, 594, 829. 93	
		10, 596, 154. 61	
Consolidated:			
Cash	$13, 322. 98		
Stocks and bonds (quoted market value $5, 619, 651. 94)	4, 240, 967. 73		
	4, 254, 290. 71		
Loan to United States Treasury	1, 000, 000. 00		
Other stocks and bonds (quoted market value $168, 188. 86)	120, 238. 07		
Cash	335. 68		
Real estate at book value	115, 006. 00	5, 489, 870. 46	
Total endowment funds and funds functioning as endowment			16, 086, 025. 07
			22, 534, 920. 13

EXHIBIT A—Continued

FUND BALANCES

Current funds:			
General:			
Unexpended funds—unrestricted			$1, 474, 194. 47
Total general funds			1, 474, 194. 47
Restricted (Exhibit C):			
Unexpended income from endowment		$1, 384, 769. 95	
Funds for special purposes (gifts, grants, etc.)		3, 589, 930. 64	
Total restricted funds			4, 974, 700. 59
Total current funds			6, 448, 895. 06
Endowment funds and funds functioning as endowment (Exhibit D):			
Freer Gallery of Art		$10, 596, 154. 61	
Other:			
Restricted	$2, 879, 087. 56		
General	2, 610, 782. 90	5, 489, 870. 46	
Total endowment funds and funds functioning as endowment			16, 086, 025. 07
Total			22, 534, 920. 13

EXHIBIT B

PRIVATE FUNDS

STATEMENT OF CURRENT GENERAL FUND RECEIPTS AND DISBURSEMENTS AND CHANGES IN CURRENT GENERAL FUND BALANCES

Year ended June 30, 1963

	Operations	Publications	Gifts and grants
Current receipts:			
Endowment income:			
Freer Gallery of Art	$440, 732. 83		
Other restricted funds	56, 742. 24		
Unrestricted	139, 974. 67		
Investment income	69, 209. 35		
Gifts and grants, including administrative overhead	128, 812. 83		$6, 854, 937. 05
Publications and photographs		$91, 292. 43	
Miscellaneous	9, 372. 45		
Total current receipts	844, 844. 37	91, 292. 43	6, 854, 937. 05

EXHIBIT B—Continued

PRIVATE FUNDS—Continued

STATEMENT OF CURRENT GENERAL FUND RECEIPTS AND DISBURSEMENTS AND CHANGES IN CURRENT GENERAL FUND BALANCES—Continued

Year ended June 30, 1963

	Operations	Publications	Gifts and grants
Current expenditures:			
Salaries:			
Administrative	$118, 210. 85		
Research	17, 629. 76		$3, 081, 622. 19
Other	220, 979. 97		
Total salaries	356, 820. 58		3, 081, 622. 19
Purchase for collection	117, 772. 13		
Researches and exploration and related administrative expenses:			
Travel	18, 666. 44		
Equipment and supply	8, 437. 20		
Other	5, 460. 40		3, 773, 314. 86
Publication and photographs	38, 726. 56	49, 231. 30	
Buildings, equipment and grounds:			
Buildings and installations	17, 872. 25		
Court and grounds maintenance	946. 77		
Technical laboratory	1, 958. 97		
Contractual services—custodian and legal fees	22, 203. 30		
Supplies and expenses:			
Meetings, special exhibits	16, 846. 36		
Lectures	2, 637. 41		
Photographs and reproductions	5, 148. 12		
Library	4, 571. 27		
Sales desk	9, 443. 07		
Stationery and office supplies	96. 50		
Postage, telephone, and telegraph	89. 35		
Employees' withholding payments, net	(1, 582. 99)		
Total current expenditures	626, 113. 69	49, 231. 30	6, 854, 937. 05
Excess of current receipts over current expenditures	$218, 730. 68	42, 061. 13	$260, 791. 81
Balance at beginning of year			1, 213, 402. 66
Balance at end of year			1, 474, 194. 47

EXHIBIT C

PRIVATE FUNDS

STATEMENT OF CHANGES IN CURRENT RESTRICTED FUND BALANCE

Year ended June 30, 1963

	Unexpended income	Funds for special purposes (gifts, grants etc.)	Total
Balance at beginning of year	$1,210,899.50	$2,993,960.51	$4,204,860.01
Add:			
Income from restricted endowment:			
Freer Gallery of Art	496,274.53		496,274.53
Other restricted funds	281,941.04		281,941.04
	778,215.57		778,215.57
Less custodial costs	34,766.08		34,766.08
Net income from restricted endowment	743,449.49		743,449.49
Sale of publications	30,028.25	1,091.17	31,119.42
Gifts and grants		7,062,356.85	7,062,356.85
Other	17,626.04	450,644.31	468,270.35
	2,002,003.28	10,508,052.84	12,510,056.12
Deduct:			
Transfer to current income, net of custodial cost:			
Freer Gallery of Art	407,462.20		407,462.20
Other restricted funds	55,246.79	6,854,937.05	6,910,183.84
Unrestricted	139,974.67		139,974.67
	602,683.66	6,854,937.05	7,457,620.71
Transfer		66,185.15	66,185.15
Income added to principal, net	11,549.67		11,549.67
Transfer to (from) gifts and grants	3,000.00	(3,000.00)	
	617,233.33	6,918,122.20	7,535,355.53
Balance at end of year	1,384,769.95	3,589,930.64	4,974,700.59

EXHIBIT D

PRIVATE FUNDS

STATEMENT OF CHANGES IN PRINCIPAL OF ENDOWMENT FUNDS AND FUNDS FUNCTIONING AS ENDOWMENT

Year ended June 30, 1963

Balance at beginning of year		$15, 236, 651. 39
Add:		
Gifts and bequests	$126, 799. 50	
Income added to principal as prescribed by donor	11, 549. 67	
Proceeds from sale of Table Mountain installations	12, 000. 00	
Net gain on investments	699, 024. 51	849, 373. 68
		16, 086, 025. 07
Balance at year end consisting of:		
Unrestricted	2, 610, 782. 90	
Restricted for:		
Freer Gallery of Art	10, 596, 154. 61	
Other collections and research	2, 879, 087. 56	
	16, 086, 025. 07	

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 $12,764.30.

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:

Academic Press, a gift to the Rathbun Fund.

American Chicle Co., a contribution for the improvement of the United States National Herbarium collection.

American Philosophical Society:

Grant for the support of research entitled "Life History and Taxonomic Studies of the Water Beetles of Puerto Rico and the Virgin Islands."

Grant for the entomological collecting and research in British West Indies.

Grant for the entomological collecting and research in Mexico.

Anniston Public Library, a gift to prepare a scientific evaluation of a collection of birds.

Appalachian Power Co., additional grant for archeological surveys in the Smith Mountain Reservoir on the Roanoke River.

Atomic Energy Commission, additional grant for support of research entitled "A Study of the Biochemical Effects of Ionizing and Nonionizing Radiation of Plant Metabolism during Development."

Lucy H. Baird, in settlement of bequest.

Bredin Foundation:

Grant for research entitled "Ocean Food Chain Cycle."

Grant for research entitled "Biological Survey of Dominica Project."

Roland W. Brown, a bequest for the care and improvement of the paleobotanical collection.

James Campbell, a contribution to the Zoo Animal Fund.

De Beer Consolidated Mines, Ltd., a gift to defray expenses in exhibiting the Hope Diamond in France.

Department of Air Force:

Additional grant for research directed toward the study of stellar scintillation.

Additional grant for upper atmosphere image study.

Additional grant for research directed toward the studies of rate of accretion of interplanetary matter by the earth.

Additional grant for the study of atmospheric entry and impact of high velocity meteorites.

Department of the Army:

Grant for the support of research entitled "Mammals and Their Ectoparasites from Iran."

Grant for support of research entitled "Potential Vectors and Reservoirs of Disease in Strategic Overseas Area."

Grant for support of research on the analysis of bird migration in the Pacific area and the study of ecology of birds and mammals on one or more Pacific islands.

Department of Interior, a grant for service on the taxonomy of Peruvian fishes.

Eistophas Science Club, a contribution to the Zoo Animal Fund.

Fashion Group of Washington, a gift to the Historic Dress Fund.

Ford Foundation:

Grant for the support of the preparation of an up-to-date history of the United States Flag over a 3-year period.

A gift to the Freer Gallery of Art for the publication and distribution of an illustrated scholarly catalogue of the collection of Armenian manuscripts.

General Atomic Division, a donation to the Meteorite Fund.

General Motors Corp., a gift for the construction of two dieselectric locomotive models.

Esther Goddard, a gift to help struggling scientists.

Graham Foundation, a gift to the Smithsonian Traveling Exhibition Service for the Alvar Aalto Exhibition.

Ethel R. Holmes:

Gift to the Milton A. Holmes Memorial Numismatics Fund.

Gift to the Milton A. Holmes Memorial Philately Fund.

Institute of International Education, a contribution for matters pertaining to International Exchange program.

Edwin A. Link, a gift to the Marine Archeology Fund.

Link Foundation:

Grant for the 1963 Edwin A. Link Lecture.

Grant for the publication of "Famous Firsts of Space Flight."

For support to the James Means Memorial Fund:

Cabot Foundation

Ward M. Canady Educational and Charitable Trust Co.

Ward M. and Marian C. Canady Trust Co.

Ellen Loomis

Edward Mallinckrodt, Jr.

Paul Mellon and Kaufmann Charitable Foundation, a gift to the Smithsonian Traveling Exhibition Service.

Miami University, a grant for the preserving of the collection of herbaceous stems in Panama.

Museum of France, a contribution toward exhibition of the Hope Diamond.

National Aeronautics and Space Administration:

- Additional grant for support of research entitled "The Motion of Artificial Satellites."
- Additional grant for the scientific and engineering study for instrumenting an orbiting telescope.
- Additional grant for research entitled "Optical Satellite Tracking Program."
- Grant for the systematic recovery of meteorites and the photography of meteorites in flight.
- Grant for consultant services to be provided to the California Museum of Science and Industry.

National Institutes of Health:

- Additional grant for support of research entitled "Studies of Asian Biting Flies."
- Grant for support of research entitled "Anthropology of Chronic Disease in Relation to Social Efficiency."
- Grant for support of research entitled "Chronic Diseases in Relation to Social Efficiency."

National Science Foundation:

- Grant for the support of research entitled "Tertiary Forests of the Tonasi-Santiago Basin of Panama."
- Grant for the support of research entitled "Systematic Significance of Schinoid Spines."
- Grant for the support of research entitled "Phanerogams of Colombia."
- Grant for the support of research entitled "Systematic and Distribution of North American Calanoid and Harpacticoid Copepoda."
- Grant for the support of research entitled "Ecology and Behavior of *Suncus murinus*."
- Grant for the support of research entitled "Photoresponses and Optical Properties of Phycomyces Sporangiophores."
- Grant for the support of research entitled "Taxonomy of Bamboos."
- Grant for the support of research entitled "Lower Cretaceous Ostracoda of Israel."
- Grant for the support of research entitled "Marine Mollusks of Polynesia."
- Grant for the support of research entitled "Tertiary Echinoids of the Eastern United States and the Caribbean."
- Grant for the support of research entitled "Monographic Revision of Carcharinid Sharks of the Tropical Indo-Pacific Oceans."
- Grant for the support of research entitled "Zoogeography of Southern Ocean Scleractinian Coral Faunas."
- Grant for the support of research entitled "Magalithic Structures of Nan Mandol, Ponape."
- Grant for the support of research entitled "Frogs of Western Brazil and of Colombia."
- Grant for the support of research entitled "Prehistory of Southwest Virginia."

National Science Foundation—Continued
- Grant for the support of research entitled "Indo-Australian Vespidae sens. lat. and Sphecidae."
- Grant for the support of research entitled "Publication of an English Translation of Flora of Japan, by Jisaburo Ohwi."
- Grant for the support of research entitled "An Archeological Investigation of the Key School Site, Georgia."
- Grant for the support of research entitled "Collection of Meteorites and Tektites in Australia."
- Grant for the support of research entitled "Revision of the Genera of Paleozoic Bryozoa."
- Grant for the support of research entitled "Oldest Fossil Bryozoa of the United States."
- Grant for the support of research entitled "The Flora of Fiji."
- Grant for the support of research entitled "Mammals of Southeastern United States."
- Grant for the support of research entitled "Permo-Triassic Reptiles of South America."
- Grant for the support of research entitled "South Asian Microlepidoptera, particularly the Philippine Series."
- Grant for the support of research entitled "The Mammals of Panama."
- Grant for the support of research entitled "Scientific Community in England 1820–1860."
- Grant for the support of research entitled "Shanidar IV–VI Neanderthals."
- Grant for the support of research entitled "European Tertiary Dicotyledon Floras."
- Grant for the support of research entitled "Revision of the Beetles of the Genus *Neobrotica* Jacoby."
- Grant for the support of research entitled "The American Commensal Crabs of the Family Pinnotheridae."

Northwest Federation of Mineralogical Societies, a gift for lectures given by Dr. Paul E. Desautel in Portland and Spokane.

Office of Naval Research:
- Additional grant to provide advisory and consultant services.
- Additional grant to perform psychological research studies.
- Additional grant for research of information of shark distribution and distribution of shark attack all over the world.
- Additional grant for studies concerning the development of a proposal for an institute for laboratory of human performance standards.
- Additional grant for support of research entitled "Microlepidoptera of the Island of Rapa."
- Additional grant for support of research entitled "A Study of Anatomy and Taxonomy of Hawaiian Woods."
- Additional grant to perform aeronautical research studies.
- Additional grant for the purpose of conducting systematic zoological research on the marine fauna of Tropical Pacific Area.
- Additional grant for research and development task order.

B. T. Rocca, Sr., donation for the purchase of crystal tourmaline from Brazil.

Rockefeller Foundation, grant for the support of research entitled "Cooperative Field Studies of Relationship of Birds to Arthropod-transmitted Virus Disease in the Region of Braganca, Brazil."

Frank R. Schwengel, a gift toward the study of mollusks of Polynesia.

For support of Science Information Exchange:
- Atomic Energy Commission
- Department of Defense
- Federal Aviation Agency
- National Aeronautics and Space Administration
- National Institutes of Health
- National Science Foundation
- Veterans Administration

Social Science Research Council, a gift for the conference on Transcultural Studies of Cognitive System in Mérida, Mexico.

Theodore Szybowicz, a contribution toward the Moonwatch Study.

Tucson Gem and Mineral Society, grant for the inspection of an exhibit of gems and minerals.

The United Educators, Inc., a gift for the use by the National Air Museum for reference materials.

UNESCO, a gift to defray costs on UNESCO Visiting Committee for Tropical Herbaria.

University of Hawaii, a gift for research on mollusks at Eniwetok, Marshall Islands.

University of Michigan, a gift to defray costs on publication of Ars Orientalis.

Ellen Bayard Weeden Foundation, a gift for the Freer Gallery of Arts Library Fund.

Wilmington Society of Fine Arts, a contribution to the Smithsonian Traveling Exhibition Service.

Woods Hole Oceanographic Institution:
- Additional grant for the study of plankton collections.
- Grant for the Indian Ocean Expedition training program in Bermuda.
- Gift to provide funds to permit the participation in the International Indian Ocean Expedition.

Charles M. Wormser, a gift to provide acquisitions for the division of numismatics.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1963:

Salaries and expenses	$11,060,550.00
National Zoological Park	1,504,997.00
The appropriation made to the National Gallery of Art (which is a bureau of the Smithsonian Institution) was	2,113,850.00

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	$271,000.00

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:

THE BOARD OF REGENTS,
Smithsonian Institution
Washington, D.C., 20560

We have examined the balance sheet of private funds of Smithsonian Institution as of June 30, 1963, and the related statement of current general private funds receipts and disbursements and the several statements of changes in funds for the year then ended. 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.

Land, building, furniture, equipment, works of art, living and other specimens and certain sundry property are not included in the accounts of the Institution; likewise, the accompanying statements do not include the National Gallery of Art, the National Cultural Center and other departments, bureaus and operations administered by the Institution under Federal appropriations. The accounts of the Institution are maintained on the basis of cash receipts and disbursements, with the result that the accompanying statements do not reflect income earned but not collected or expenses incurred but not paid.

In our opinion, subject to the matters referred to in the preceding paragraph, the accompanying statement of private funds presents fairly the assets and funds principal of Smithsonian Institution at June 30, 1963; further, the accompanying statement of current general private funds receipts and disbursements and several statements of changes in funds, which have been prepared on a basis consistent with that of the preceding year, present fairly the cash transactions of the private funds for the year then ended.

PEAT, MARWICK, MITCHELL & CO.

WASHINGTON, D.C., *August 29, 1963.*

Respectfully submitted.

(S) ROBERT V. FLEMING,
(S) CARYL P. HASKINS,
(S) CLARENCE CANNON,
Executive Committee.

GENERAL APPENDIX

to the

SMITHSONIAN REPORT FOR 1963

720-018—64——19

ADVERTISEMENT

The object of the General Appendix to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by staff members and collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report of 1889, a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1963.

An "Author-Subject Index to Articles in Smithsonian Annual Reports, 1849–1961" (Smithsonian Publication 4503) was issued in 1963.

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, D.C., 20560.

The Solar System[1]

By Sir Bernard Lovell
Professor of Radioastronomy, University of Manchester, England

During the last few years there has been a renewal of interest in the problems of the solar system. This interest has been stimulated by the discoveries made by using space probes and by the results of research programs of the radio telescopes, which have revealed many new facts about our immediate environment in space, the explanations for which are not yet understood.

The basic astronomical data about the solar system are well known. The earth, moving in a nearly circular orbit 93 million miles from the sun, is a member of the sun's family of planets. Mercury, at a mean distance of 36 million miles from the sun, and Venus, at a mean distance of 67 million miles, are in orbits closer to the sun. The orbit of Mars lies outside that of the earth at a mean distance of 141 million miles. Then comes the outer planetary system of giants: Jupiter, 483 million miles from the sun, Saturn (886 million miles), Uranus (1,783 million miles), Neptune (2,793 million miles), and Pluto (3,666 million miles).

The inferior planets—Mercury, Venus, Earth, and Mars—are distinguishable from the giants by the fact that they have approximately the same size and density. Compared with the earth as unity, the densities range from 0.69 for Mars to 1.1 for Mercury, and the diameters from 0.37 for Mercury to 0.97 for Venus. The giant planets are in a different category, with densities much smaller than the earth (from 0.13 for Saturn to 0.25 for Jupiter), but they are of enormous size, ranging from Uranus which is 4 times the diameter of the earth, to Jupiter, over 11 times the earth's diameter. The outermost planet Pluto is exceptional: although its dimensions are not accurately known, it must be small, with the highest known density in the solar system. Between the inferior and giant planets, that is, between the orbits of Mars and Jupiter, there is a swarm of minor planets, or asteroids, the largest of which is Ceres with a diameter of 400–500 miles, but many are probably only a few miles in diameter. The

[1] This article appeared as Chapter II of "The Exploration of Outer Space," a collection of five lectures by Sir Bernard Lovell, published in 1962 by Harper and Row, 49 East 33d Street, New York, N.Y.

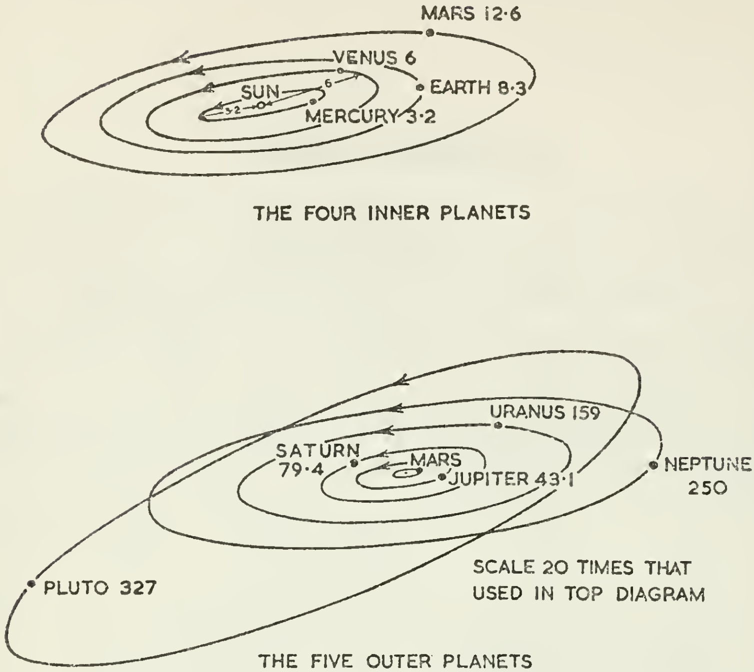

FIGURE 1.—The solar system. Numbers give the distance of the planet from the sun in light minutes.

number of asteroids is not known but there are probably between 50,000 and 100,000.

The dimensions of the solar system are determined by the extreme orbit of Pluto which is slightly elliptical. Although at its closest approach to the sun the orbit of Pluto lies inside that of Neptune, the most distant point of its orbit takes it 4,566 million miles away. At this point the light from the sun to Pluto takes about 6½ hours on its journey. And so the size of the earth's abode in space is epitomized by the 93 million miles or 8 light minutes which separate us from the sun and the 6½ light hours of the farthest point of Pluto's orbit from the sun. Although these distances are enormous by terrestrial standards it has to be remembered that once we move out from this system we have to travel for 4½ years at the speed of light before we get to the nearest star and then for 100,000 years to the extreme reaches of the galaxy.

The parent of the solar system—the sun—has a diameter of 865,000 miles (that is excluding the solar atmosphere) and is 332,000 times the mass of the earth. The weight of the sun is about 10^{27} tons; that is, a thousand billion billion [2] tons. The energy output of the sun

[2] The use of "billion" in this article refers to the English billion; that is, one million million (as distinct from the American billion, which is one thousand million).

is about 4×10^{23} or nearly a billion billion kilowatts. This energy is produced by thermonuclear processes which convert 4 million tons of the solar matter into energy every second. The conversion takes place in the center of the sun where the temperature is about 20 million degrees centigrade and the pressures amount to several thousand million atmospheres. Under these conditions the atoms may be stripped of electrons, in which case matter is said to be degenerate. These transmutations in the interior of the sun involve the conversion of 564 million tons of hydrogen to 560 million tons of helium every second. Although the solar material is being used at this rate the processes have already been operative for at least 4,000 million years. The sun's mass is so tremendous that this rate of use of its material represents only about one-tenth percent of its mass every 10,000 million years.

THE INTERPLANETARY SPACE

Until quite recently we have tended to think of the space between the sun and the earth and the planets as being empty—a near vacuum, not possessing many factors of interest to geophysics or astronomy. We were aware that the earth was surrounded by the ionosphere—a region of electrons of varying density extending to a few hundred kilometers above the earth's surface—and that the density of electrons in these regions appeared to be related to the condition of the solar surface and to be generally under solar control. Apart from this, the various bodies seemed to be rather disconnected except for the gravitational forces which controlled their motions. One of the most remarkable changes of opinion during the last few years is in respect of this situation in interplanetary space, because it now appears that this space is not empty. On the contrary, the interplanetary space must now be visualized as a medium where the conflict of a complex of radiation, ionized particles, and magnetic forces is determining the geophysical environment of the earth and the planets.

THE SOLAR ATMOSPHERE

The discovery of the ionized particles trapped in the Van Allen belts around the earth has led to a searching inquiry regarding their origin. The inner belt seems to be composed chiefly of protons which are believed to be the decay products of neutrons moving out from the atmosphere of the earth, where they have been produced by cosmic ray bombardment. The outer zone of electrons is unstable and the present theory of the origin of the electrons is that they are part of the stream of material which is being blown away from the sun. It is possible that in the region of about 10 earth radii we have the interfacial boundary, where the earth's own environment is coming to terms with these solar forces. The sun has an intensely hot central region where the thermonuclear energy-producing processes are taking place. However, its surface temperature as observed from earth through ordinary optical instruments is about 6,000°. Systematic observation of this solar surface reveals a number of variable features. The most striking is the apparition of sunspots, whose appearance on the disk varies in an 11-year cycle. Although sunspots were observed by Galileo—who was involved in a bitter dispute with Father Scheiner over the priority of discovery—their origin and nature are still not fully understood. Occasionally, when there is a rapidly changing group of sunspots, a solar flare occurs, accompanied by a violent ejection of hydrogenous material. The study of sunspots and solar flares with spectrohelioscopes and other optical instruments has in recent years been supplemented by radio astronomical studies. One of the earliest discoveries made during the rapid development of radio astronomy after the war was that sunspots, and particularly on the occasions when they associated to such an extent that a big flare occurred, generated powerful radio waves. Many types of intense and sporadic radio wave emissions from the sun are now recognized, in association with disturbances on the solar surface. The corona or atmosphere of the sun also generates radio waves which, although much weaker than the irregular outbursts, are present all the time. When the sun is eclipsed the vast gaseous layer of the corona can be seen streaming out to a few solar radii. This coronal gas is in a state of turbulent motion and the conditions are such that at half a solar radius above the visible disk there are about 30 million atoms per c.c. and the effective temperature is a few million degrees absolute. These conditions create a most interesting situation and recent calculations indicate that there is a resultant outward pressure which causes the material of the solar corona to expand outward continually with a speed of between 500 and 1,500 km./sec. This streaming material is known as the solar wind. The experimental evidence for the existence of this solar wind has, until recently, been rather scarce, but in the spring of 1961 the Americans launched a space probe equipped with instruments specifically designed to detect the existence and measure the constitution of this material streaming from the sun. Although the probe stayed up for only about 48 hours it succeeded in its task of recording and measuring the existence of the solar wind in the interplanetary space. The situation which occurs when sunspots and flares are seen on the solar disk is a violent modulation of this steady streaming away from the sun, because on these occasions the material of the corona and chromosphere is ejected at velocities several times that of the normal streaming velocity of the coronal material.

Another intriguing new concept concerns the behavior of magnetic fields. Hitherto we have tended to visualize magnetic fields as entities belonging to a magnet whose magnetic field moved with it. Astronomically it was believed that magnetic fields were localized in bodies like the earth, the sun, and some of the stars. Now it is realized that if there is a gas in a highly ionized condition, like the material of the solar wind, moving in interplanetary space where the free path is thousands of kilometers, then this material carries its own magnetic field. This concept of the trapped magnetic field—contained in a stream of gas, coming from the solar corona or from the shell of a star, moving away into space so that the ionized particles and the magnetic field move together, actually being transported through space to another part of the solar system or another part of the cosmos—has become of great importance in theoretical astrophysics. The possibility of magnetic fields moving in this way with the gas appears to be one of the controlling influences which may govern the organization of the interplanetary material and indeed of the interstellar gas in the cosmos as a whole. The fact that this gas streaming from the sun carries with it a magnetic field is a matter of great importance as far as the earth is concerned, because when this solar wind reaches the neighborhood of the earth then the earth's magnetic field is disturbed. The electrons which are streaming away from the sun can then be injected into the earth's own magnetic field; they become trapped in it and in this way the outer layer of the Van Allen belts is probably formed. These ideas provide a good explanation of the situation whereby this outer belt of electrons is so subject to solar control, why it disappears in a magnetic storm, and the processes by which it is repopulated after a matter of some days. In principle the earth's field should present a fairly solid barrier against the injection of particles of comparatively low energy from outside, but it is this distortion of the magnetic field by the traveling fields coming away from the sun which facilitates the injection.

The whole phenomenon of the earth's magnetic storms and the aurora borealis, or the northern lights, must be tied up with these particles which are trapped in the Van Allen belts. The aurorae were known to be associated with solar flares and it was believed that the phenomena were caused by the particles streaming out from the region of the flare on the sun and reaching the neighborhood of the earth after a period of 24 to 30 hours, when they entered the atmosphere and gave rise to ionization at a height of 100 kilometers or so. This explanation is now obviously incorrect because it is known that the particles from the sun are trapped in the outer Van Allen belt. The formation of the aurora seems to be associated with the draining of the particles from the outer belt during a magnetic storm. Apparently the primary aurora particles do orginate in this outer belt and the function of the magnetic storm in the aurora phenomenon is to produce the magnetically disturbed condition which allows the particles to escape from the belt and enter the atmosphere down the earth's own lines of force.

The phenomenon of the traveling solar magnetic field is of great interest in many other aspects of physics, particularly in cosmic ray physics. The primary cosmic ray particles are believed to be generated in the galaxy and it has been known for a long time that their intensity, incident on the earth's atmosphere, decreased when there was a severe magnetic disturbance. This effect was so closely linked with the modulation of the earth's field that it had been assumed to be a local terrestrial effect, in that the variation of the cosmic ray intensity was governed by the changes in the earth's field. During 1960 and 1961 Simpson of Chicago discovered, by cosmic ray-counting experiments in the American space probes Explorer VI and Pioneer V, that this decrease observed on earth was accompanied by a simultaneous decrease in the counting rate of the apparatus in the probes when they were many millions of kilometers away in interplanetary space. Clearly, it is the variation in the magnetic field in interplanetary space itself which is controlling this intensity variation and not the local field of the earth, and the variable interplanetary fields of this nature must arise through the magnetic field trapped in the material streaming away from the sun.

In addition to the material which streams away from the solar corona, and the high energy protons which are ejected at the time of solar flares, the sun frequently ejects large quantities of low energy protons. All these radiations present a serious hazard to the astronaut intending to travel in interplanetary space and considerable thought is already being given to possibilities of predicting the nature and timing of these solar outbursts.

Whereas the space probes have become avenues through which we are learning about the influence of the sun in interplanetary space, the observations of the solar radio emissions have revolutionized our picture of the sun itself. The powerful emissions of radio waves during sunspots and solar flares are the most obvious radio phenomena associated with the sun. But the observation of the less intense radio emissions from the solar corona has revealed an interesting situation. If we imagine ourselves looking at the sun with radio eyes instead of with ordinary eyes, then we would observe quite a different object in the sky. At a wavelength of 21 cm., instead of the uniform disk which we usually see, its appearance would be that of a disk that was brighter toward the edges and was flattened instead of circular. It would extend much farther into space than it does when visually observed. If our eyes were tuned to look at a rather longer wavelength in the meter waveband then we should begin to think that the sun was monopolizing the whole sky. On wavelengths of several meters the corona of the sun, or the radio sun, has been traced out to something like 20 or 30 solar radii. All this is compatible with the picture we have already formed of the influence of the solar atmosphere extending throughout great distances of interplanetary space.

METEORS OR SHOOTING STARS

In addition to the complex of radiation and ionized particles in space, there is a vast debris of small particles mainly composed of stone or iron. The most common manifestation of these is the appearance in the sky of a meteor or shooting star. Occasionally the particles are so big that they penetrate the atmosphere and fall to the earth as meteorites. The common shooting stars occur when the earth encounters this debris in its journey through space; the particles are heated by friction as they enter the outer layers of the atmosphere, and have generally evaporated completely at about 100 kilometers above the surface of the earth, leaving behind a transient trail of light. The occurrence of these meteors has been known for centuries and they may be seen in any clear dark sky with the naked eye at a rate of about 10 per hour. These are the sporadic meteors which appear to be distributed with a fair degree of uniformity in interplanetary space. On the other hand at particular times of the year, say in August or in December, the rate rises to 50 to 100 per hour for a few nights. These are the shower meteors which appear to radiate from a particular point in the sky and generally occur with considerable regularity from year to year.

The question of the origin of these meteors in the solar system is another problem of great contemporary interest. The earth moves in its orbit around the sun at a speed of about 29 km./sec.; as well as this motion of the earth around the sun, the sun itself and the entire solar system are moving through space with a velocity of about 20 km./sec., in the direction of the star Vega. To an observer outside the solar system the motion of the earth would appear to be like that of a giant corkscrew. In this journey the earth occasionally runs into the streams of debris which are concentrated in orbits around the sun. These enter the atmosphere of the earth and give rise to the showers of meteors.

These concentrations of debris are, in many cases, closely associated with comets. Although the origin of the comets is uncertain, we know that they are contained within the solar system moving under the gravitational control of the sun and are not visitors from interstellar space. The nucleus of the comet is an icy conglomerate of various carbon compounds, and most of the comets have a long tail which may stream behind the head for millions of kilometers. In this tail or in the orbit of the comet we have these very large numbers of small specks of dust which may have been evaporated from the nucleus as the comet approaches the sun. One comet which has been of considerable contemporary interest in the study of meteors during the last decade is the Giacobini-Zinner Comet. In October 1946 the earth crossed the orbit of the comet only a few days from the position of the nucleus. For a few hours between midnight and 6 a.m. on October 10 thousands of meteors could be seen in the sky, but before this and afterward the meteor rate was of the usual sporadic value of a few per hour. This was a clear and spectacular demonstration of the close relationship between meteors and comets.

The systematic study of meteors has been severely handicapped by the difficulty of making observations, as the sky is so frequently either obscured by cloud or made light by moonlight. Radio astronomy has given us new methods of investigating these meteors which overcome the difficulty of cloud, moonlight, or daylight. When the meteoric particle evaporates in the high atmosphere it leaves behind a trail of ionized particles as well as the luminous trail by which we see it. The electrons in this ionized trail are efficient scatterers of radio waves. A beam of radio waves transmitted from a radio telescope is scattered by the trail and the returned signal can be detected by the receiving part of the telescope equipment as a transient echo. If the recording equipment consists of a cathode ray tube with a suitable time base, it is possible to observe the diffraction pattern which is formed as the ionized trail crosses the perpendicular from the receiver to the trail. This is the radio analog of the diffraction of light at a straight edge—the rhythmic variations in brightness as the shadow merges into the light. In the radio case, since the range can be measured and the wavelength is known, the precise velocity of the meteor can be determined. If these observations are made from three spaced receiving stations using one transmitter, the exact orbit in space of a single meteoric particle can be obtained.

The relative infrequency of the meteors seen by a single observer gives a false impression of the vast numbers which the earth encounters in its journey through space. The number entering the earth's atmosphere which are big enough to produce a trail sufficiently bright to be seen in a small telescope is about 8,000 million every day. These are small grains of dust weighing only about a ten-thousandth of a gram. Using radio techniques one can detect particles of even smaller size, and the numbers increase by about 2½ times for every fainter magnitude. The particles detected by the most sensitive radio-meteor equipment available today are probably being swept up by the earth at the rate of about a million million per day. The numbers seem to increase endlessly as the size goes down, but when the radius of the particles is less than about a millimeter then these particles are too small to burn up. For these the ratio of the surface area to the mass is so large that the energy of interaction when the particles begin to enter the atmosphere is radiated away and the flight of the dust grain is stopped before evaporation occurs. These are the micrometeorites which eventually fall to earth as dust. From a study of the deposits on the ocean bed it has been estimated that the earth collects something like a million tons per annum in this way.

The micrometeorites are now the subject of investigations using satellites and space probes, and many space vehicles launched by the Americans and Russians have been equipped with some form of micrometeorite detector. In principle, the detection of these micrometeorites in space should be simple—by allowing them to collide with a diaphragm which is equipped with a microphone: when a dust grain hits the diaphragm it will make a sound in the microphone and be telemetered back to earth. In practice these impact methods have proved to be difficult because the microphones record noises other than the impact of the dust grains; the calibration, too, is uncertain. The techniques have now been refined and we have some idea of the amount of dust of this extraordinarily small size which exists in space. For particles which weigh a hundred-millionth of a gram the rate of impact is found to be equivalent to one particle per 1,000 second over a surface of area 1 square inch. For particles which weigh a thousand-millionth of a gram the rate is found to be 1 every 100 second. The quantity of this dust is 1,000 to 10,000 times greater than the particles which are big enough to burn up in the atmosphere.

From some of the recent analyses of the micrometeorite recordings in the American satellites, Whipple of the Smithsonian Astrophysical Observatory has concluded that a large quantity of this small dust appears to be traveling in an orbit around the earth. It appears that in some circumstances which are not yet understood some of this fine dust gets trapped in gravitational orbits around the earth. So we seem to have two new situations arising. We have the trapped radiation, the protons and electrons in the Van Allen belts (that is a magnetic trapping), and also a gravitational trapping of fine dust in the vicinity of the earth.

At the other end of the scale of size, as the particles become bigger their numbers decrease. Objects which we see in the sky as bright fireballs probably weigh about a gram, and there may be a million of these entering the earth's atmosphere every day. If the meteor is much larger than this it will not be completely evaporated in its journey through the atmosphere and some part of it will fall to earth as a solid body. Something like 500 kilograms of this material per year fall to earth in this way as meteorites. Occasionally these meteorites are extremely big and there are classic examples such as the meteor crater in Arizona and the Siberian meteorite which fell in 1908 and devastated 100 square miles of countryside. If ever a meteorite of this size fell on a populated area then there would indeed be a calamity, but oddly enough there seems to be no well attested case of anyone being killed by a meteorite fall. Some years ago a person in America was injured by a meteorite but even this was from the first bounce of a small fragment. There has been some discussion about the dangers of these meteors and meteorites to space travelers, but the chances of being hit by anything which could do serious damage to a space ship is so small that none of the experts really worry about it. Of course the astronauts who land on the moon will need protection, because there is no atmosphere to act as a shield even from the micrometeorites.

The refinement of the measurements made in space probes and satellites, coupled with further development in the ground-based photographic and radio-echo meteor work, will certainly lead to a much better understanding of the role of these particles in the formation and evolution of the solar system. At present it is believed that the large meteorites which fall to earth have a different origin from the meteors. Are the meteorites an extension of the size range of meteors, or are they a separate class? Does all this debris represent samples of the primeval material left over from the formation of the solar system or is it the consequence of some subsequent planetary catastrophe? It is clear that an extraordinarily complex situation exists in the solar system in the space between the earth and planets and the sun, not only of electromagnetic radiation but of corpuscular radiation, and of solid material particles in the form of dust and pieces of stone and iron.

THE MOON AND THE PLANETS

The techniques of radio astronomy and the space probe seem to be on the verge of increasing markedly our knowledge of the moon and the planets. For example, in the case of the moon, the radio astronomical work has already given some extremely interesting results. Ten years ago it was a difficult technological problem to transmit radio waves from earth and pick them up again 2½ seconds later after they had been reflected from the surface of the moon nearly a quarter of a million miles distant. Now, with the large radio telescopes, this is an easy technical task but, as so often happens with new scientific experiments, completely unexpected effects were encountered. The moon appears to be fairly uniformly bright to the eye, and it was assumed that if radio waves of uniform strength were transmitted to the moon, then they would be scattered uniformly from the lunar surface so that the signals collected by the radio telescope and recorded as echoes on a cathode ray tube would always be of the same strength. It was surprising to find that this was not the situation. The transmissions from the telescope were made in the form of short pulses which were expected to be recorded as pulses of uniform strength after scattering from the lunar surface. In fact, very marked irregularities in the strength of the returned echoes were found. The individual pulses, separated in time by a second or so, varied in strength and there was also a long-period variation in the average strength of the returned signals with periods of 15 or 30 minutes. It appears that these short-period and long-period effects are quite different phenomena. The long-period variation is the result of an influence on the radio waves of the earth's magnetic field as they traverse the space between the earth and the moon. Most of this influence occurs in the ionized regions of the earth at a height of about 200 to 400 kilometers, and the variation is caused by the rotation of the plane of polarization of the radio waves—the Faraday effect occurring in the earth's ionosphere. The exploitation of this effect in a systematic manner has provided a method of measuring the total number of electrons between the earth and the moon.

The short-period fading which takes place in periods of seconds has a different origin. This fading is an effect of the libration of the moon. Because of the irregularities of the slight ellipticity of the motion of the moon around the earth, it never presents exactly the same face but gives the effect of a slight oscillation known as libration. It seems that the nature of the lunar surface is such that even for radio wavelengths it does not reflect as a smooth body but has a number of plateaus which reflect the radio waves back to earth. The reflecting qualities of adjacent parts of the lunar surface differ so much that we get these very large variations in amplitude. An investigation of the statistics of this phenomenon leads to a surprising conclusion. In the case of the reflection of light, the moon behaves like a ball of chalk which appears almost uniformly bright in a beam of light. On the other hand, when radio waves are directed toward it the moon scatters similarly to a polished ball-bearing in a beam of light—the central region of the ball appearing much brighter than the remainder of the surface. When radio waves are reflected from the moon it seems that they are not returned uniformly from the whole forward hemisphere of the moon but predominantly from a small part of the forward hemisphere—a hemispherical cap only about a fifth of the radius of the lunar surface. This is a striking illustration of the overall smoothness of the moon as far as wavelengths of the order of a meter or so are concerned.

This discovery had an interesting practical result. The suitability of the moon had often been considered in relation to the problem of bouncing radio messages from one side of the earth to the other, using radio wavelengths so short that the earth's ionosphere was penetrated and, therefore, there could be no interference from sunspots. It had been decided that this was impossible because the moon, reflecting over such a large area, would introduce so much distortion that the signals would be unintelligible. However, the conclusion reached from the study of the short-period fluctuations, that only the central part of the lunar hemisphere was effective, entirely altered this situation, and it seemed at least possible that if one modulated the radio waves going out from the radio telescope with speech instead of with the pulses, then one might at least be able to get back intelligible speech reflected from the moon. This proved to be the case, and it is now possible to converse intelligibly between any two points of the world, from which it is mutually visible, by using the moon as a reflecting surface.

Radio telescopes have been used to measure the radio emissions from several of the planets in the region of centimeter wavelengths. This is the thermal emission appropriate to the temperature of the body, and useful comparisons with the temperatures derived by optical studies are being made. More surprising is the detection of large sporadic outbursts on long wavelengths from Jupiter. The energies involved in the generation of these radio waves must be enormous. There is some evidence that the events occur on the surface of the planet rather than in its atmosphere. Should this be the case, the forces at work must be equivalent to the energies involved in several hydrogen bombs, or in giant volcanic eruptions like the explosion of Krakatoa.

The extension of the lunar radar experiments to the nearer planets presented a major challenge. The moon is 240,000 miles distant and the return journey of the radio waves from earth takes 2½ seconds. At close approach Venus is nearly 30 million miles away and the radar signal would take over 5 minutes on the journey there and back to earth. In terms of sensitivity of apparatus it is 10 million times more difficult to achieve success here than with the lunar echo. However, a beginning has been made. An American team with a transmitter of very great power on an 80-foot radio telescope, and a team at Jodrell Bank using a smaller transmitter on the 250-foot radio telescope, have both achieved initial success in these Venus experiments. Even with these preliminary results a direct measurement of the distance of the planet has been made and the range of uncertainty about the value of the solar parallax has been significantly reduced. It is hoped that in the near future further extension of this work will enable the rate of rotation of the planet to be measured. It is likely, too, that the experiments will give some guidance on the nature of the surface of the planet.

At the moment no one can be sure whether the first determination of the rotation period of Venus will come from these radio-astronomical studies or from instruments carried in a space probe, which either orbits or make a close approach to the planet. There are, however, many aspects of these lunar and planetary studies which can be achieved only by the physical presence of instruments carried in space probes. Lunik II crashed its instruments onto the lunar surface. Soon we may expect control to be exercised in the final stages of flight. Then either a soft landing can be made and the instruments maintained in working order on the lunar surface, or the probe can be placed in close orbit around the moon. Then we shall have the potential for studying the lunar atmosphere and magnetic field (if any exists); and for making detailed measurements on the lunar surface, which may well have a decisive influence on many outstanding conflicts of opinion. The history of many eons of time is contained on the lunar surface, which must be almost untouched by erosion. Is there, for example, an identity of material between the meteorites which crash to earth and the surface of the moon? The analysis of certain meteorites made by Urey seems to indicate that at some stage in their history they must have gone through processes of heating which could occur only in the interior of a body of lunar size; and that these meteorites which we handle today are the result of a shattering of these moons in collision. If this is correct there must, at some stage in the evolution of the solar system, have been at least 10 objects the size of the present moon which eventually disintegrated in mutual collisions. It seems that these lunar investigations may well hold the key to a major problem in the evolution of the solar system.

THE ORIGIN OF THE SOLAR SYSTEM

Various forms of evidence indicate that the earth is about 4,500 million years old. In the first half of this century we believed that the earth and the planets were torn out of the sun in the form of great tongues of solar gas by the gravitational attraction of a passing star. The wandering star passed on its journey and eventually after eons of time the molten gas cooled down and formed the planets and the earth. One significant feature of this theory was that the close encounter of two stars in this way must be an extremely rare accident and in spite of the trillions of stars in the universe the solar system was probably unique. Today we are aware of reasons why the earth and the planets could not have been torn from the sun in this way. For example, 98 percent of the mass of the entire solar system is in the sun, but 98 percent of the angular momentum of the system resides in the planets. Since the division of angular momenta must have occurred at the time of formation of the solar system, this represents an impossible situation. Gaseous material torn out from the sun with that distribution of momenta would dissipate quickly and could not possibly have aggregated into planets.

Today we believe that the solar system was formed in quite a different way. Originally, the sun, which is an average star, was probably surrounded by a nebula of dust and gas. These particles of dust suffered collisions with one another and a certain degree of accretion or coagulation occurred. This process continued through a thousand million years or so, the coagulations all the time getting bigger and bigger, with fragmentation occurring as the larger particles collided. Eventually these became powerful accretors of material, and it is possible dynamically to explain with some degree of precision how the planets of various sizes and mass were formed in this manner.

One uncertainty in the argument concerns the process by which the sun collected the original nebula of gas and dust. There seem to be two possibilities. Interstellar space is full of clouds of dust, and it may be that the sun as it journeyed through space ran into one of these very dense clouds and carried with it this large nebula which must at that time have spread over billions of miles representing the extent of planetary orbits. Or it is possible that the event which gives rise to the birth of a star like the sun involves the simultaneous creation of thousands of stars from the primeval cloud of hydrogenous material, and that so much dust and gaseous material remains that the stars themselves are left with a nebula of gas and dust as part of this formation process.

There are important consequences of these new ideas. On the former ideas that the planets were torn out of the sun, the origin of the solar system was a rare accident; it must have been unique in the entire universe in spite of the vast numbers of stars which existed. In this theory the earth must originally have been extremely hot, and therefore all the biological processes which have since occurred must have been events which took place subsequent to the cooling down of the earth. On the accretion theory the situation is quite different. The formation of planetary systems from the nebulae around stars may be a frequent occurrence in the universe, and our own solar system can no longer be regarded as unique. Another important corollary is that this accretion of planetary systems occurs in a cold state and any prebiotic material which exists on the interstellar dust of the nebulae will be carried over to the planets.

Advances in Astronomical Technology[1]

By Aden B. Meinel

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[With 4 plates]

Astronomy is a branch of science that has contributed much to the rapid expansion of the frontiers of modern technology. The unique technical problem faced by the astronomer is the faintness of the stars and other objects with which he must work. Telescope mirrors measured in meters across are needed to gather enough flux of this faint light to permit its study. Celestial objects are also so far away that their apparent size is so small that the astronomer's telescope must, in addition, focus the faint light it gathers to a sharp focus.

Most celestial objects are in reality very hot and luminous but appear faint because of their great distances from us. The brightest star, Sirius, with an intrinsic luminosity 28 times that of our sun is approximately 10,000 million (1 followed by ten zeros) times apparently fainter than the sun, and it is one of the closest of the visible stars. The faintest galaxy of stars that can be detected with the 200-inch Palomar telescope is so remote that its light has taken over 1 billion years traveling at the velocity of light (300,000 km/sec) to reach us from the depths of space. These two problems, faintness and small angular size, set the unusual characteristics of astronomical instrumentation and research.

The eye is little used in astronomical work today except in the examination of the moon and planets. While the eye is exceedingly sensitive to light it does not have the property of integration. In other words, the eye will not detect any star fainter than one it can see in the first second of time. A photographic plate, on the other hand, will record the picture of stars 100 times fainter in 100 seconds than it will record in 1 second. In recent decades the astronomer has principally worked with the photographic process to determine the position, motion, and brightness of celestial objects. Photography still represents a method of information storing unrivaled for pictorial

[1] Reprinted by permission from *The Indian & Eastern Engineer,* 104th Anniversary Number, 1962.

display as is evidenced by the accompanying photographs. The fastest photographic emulsions, however, utilize only about 1 percent of the incident light. The best photoelectric devices available to the astronomer today can utilize approximately 30 percent of the light.

TELESCOPES

The principal auxiliary instruments currently used on a telescope are the photoelectric photometer and spectrophotometer, the photographic spectrograph, the photographic camera, and recently a new device, the image intensification tube. A spectrograph is a most powerful device in the hands of the astronomer. It can reveal many interesting properties of a star, such as temperature, mass, chemical composition, the extent of its atmosphere, whether the star is single, a binary system, etc., its motion toward or away from the observer and indirectly, but effectively, the absolute brightness, distance and even the age of the star. I cannot go into the many interesting details of how each of these things is learned, but I hope that the recitation of this list will give the reader a glimpse into the fascinating world open to the astronomer.

The astronomer has pushed the telescope close to its maximum useful size in the current century. At this time we have four telescopes that have been built with mirror diameters of 100 inches or more. In order of size these telescopes are the 200-inch Hale telescope on Mount Palomar, completed in 1947; the 120-inch on Mount Hamilton, in 1959; the 104-inch now being placed in operation in the U.S.S.R.; and the famed 100-inch on Mount Wilson, completed in 1919 and which did much to revolutionize observational astronomy in the hands of Hubble and Baade. A giant telescope of 240-inch aperture and of revolutionary design is reported under design by the Institute of Optics in Leningrad. A new telescope of 150-inch aperture has also reached the design stage at the Kitt Peak National Observatory in the U.S.A.

Since new and larger telescopes cost much in return for a relatively small gain in distance reached and in new knowledge, astronomers are now concentrating upon the use of new methods to make better use of the starlight that is collected by our terrestrial telescopes. They are also looking forward to the utilization of space telescopes, but before I speak of these new telescopes it is necessary to appreciate the handicaps with which the astronomer is faced with his telescopes located upon the surface of the earth.

The atmosphere limits the usefulness of a large telescope even on the clearest night atop a mountain. The small turbulences present in the atmosphere that are accompanied by thermal differences make it impossible to sharply focus a telescope. The air itself will not permit the far ultraviolet light or the infrared light to reach the highest mountain. In addition, the night sky background is not entirely dark. Far from the lights of the city and on a moonless night one can see with the dark-adapted eye well enough to read the large headline type of a newspaper. The stars are therefore seen by a telescope as upon this faintly luminous background. This diffuse "light of the night sky" and the lack of sharpness of focus from atmospheric turbulence combine to set the limit in faintness to which a telescope can reach.

The total brightness of the night sky background with a large telescope is approximately equal to that of one 20th magnitude star per square second of arc. It is obvious, therefore, that we cannot tolerate many square seconds of arc in a detector when we wish to observe a 23d magnitude star. Since the light of the night sky is a diffuse source, its brightness does not depend upon the mirror diameter of the telescope but only upon the ratio of the focal length divided by the aperture, called the f-ratio or f-number of the telescope.

INCREASING THE EFFICIENCY

Faced with the above limitations the astronomer has four means at his disposal where gains can be made as follows:

1. Increase the size of the telescope mirror,
2. Increase the efficiency of the detector,
3. Decrease the aperture, and thereby the night sky noise at the detector,
4. Place the telescope above the atmosphere, either on a high balloon or a satellite.

The first alternative, building a larger telescope, has been considered. While it is within the scope of present technology to build a 400-inch telescope, its cost would be in the vicinity of $40 million. Its ultimate benefits would be doubtful in terms of the great expense because of the limitations imposed by atmospheric seeing unless a site with unprecedentedly fine seeing could be found.

The term "seeing" is used by the astronomer to refer to two disturbances caused by the atmosphere. They are (a) time fluctuations in the intensity of the wavefront arriving at various points at the telescope aperture, and (b) time fluctuations in the direction of arrival of the wavefront. The first is called "scintillation" and is readily seen with the unaided eye as twinkling. The second effect is usually referred to as "seeing" since it affects the ability of the telescope, especially a large one, to focus sharply. Research into seeing has shown that these effects are most serious close to the land surface. To minimize these effects telescopes are now located, at no small inconvenience and expense, upon the summits of mountains in relatively smooth air. In the best sites the average seeing diameter for a large telescope is between 1 and 2 seconds of arc. Upon rare occasions the seeing may approach 0.2 to 0.3 second of arc, as has been noted at Pic du Midi in France; however, this size is still much larger than the theoretical resolving power of a large instrument. As a consequence a very large telescope can promise only a larger picture of the same blurred celestial object as would be obtained with one perhaps only one-half as big.

The second possibility for improvement is in the efficiency of the detection of the photons. The photographic process, widely used for many years, has the ability to record stars over a wide range of brightness, although the accuracy of the measure of brightness is relatively low. One photograph may record star images over a range of 20 magnitudes (10^8 in intensity) and also record a million information elements per square millimeter. Information densities up to 5 million elements per square millimeter are possible under laboratory conditions. The quantum efficiency of a photographic emulsion is low, ranging from 0.1 to 1.0 percent. There is little hope for a large improvement in the photographic process itself since individual silver grains in the emulsion are quite good detectors. The quantum efficiency for a single grain to be developable in terms of absorbed photons is 25 percent. One developed grain, however, does not provide a detectable quantity since every grain produced by chemical reaction called "fog" would be indistinguishable from a "star". Only when groups of 20 or more grains are developed does one recognize the clump as an entity on the background of fog grain clumpiness.

In recent years much effort has been devoted to the utilization of the high quantum efficiencies approaching 30 percent for the photoelectric detector. The photomultiplier is a commercially available device of high efficiency and built-in amplification which has been widely used in astronomy and nuclear physics. The internal amplification of such a device of 10^6 produces a measurable pulse each time a photoelectron is emitted from the cathode. The cathode will occasionally reject a "thermal" electron spontaneously as a consequence of the low work function of the caesium compound emitting surface. These thermal electrons produce what is called the "dark current," which adds a noise background to the signal. A good photomultiplier at room temperature will have a dark current of 10 to 20 electrons per second from a 1 cm.^{2} photocathode surface. Because the dark current emission is temperature dependent, the astronomical use of photomultipliers for use on faint objects is always with the device cooled to dry-ice temperature ($-80°C$). At this low temperature a good tube will have a dark current of about 0.2 electron per second per cm.^{2}

The photomultiplier is an excellent detector of a single object at a time. The output current is accurately linear over a wide range of intensities; hence, the brightness of a star can be measured very accurately. In practice, the photoelectric photometer isolates a single small region of the sky at the focus of the telescope. The size of the diaphragm of the photometer is kept small in order to reduce the noise signal from the background of the sky, but large enough to permit the blurred image of the star to pass completely through the hole and to allow for inaccuracies in the guiding of the telescope. The usual size of the diaphragm is 1 to 2 mm. diameter.

The high efficiency of the photoelectric surface has led to efforts to construct an imaging system where the astronomer could take a "picture" of many stars at a time rather than one by one. While the theory of an image tube is very simple—one needs only to electronically accelerate and focus the electrons emitted from the cathode upon a fluorescent screen or directly upon a photographic emulsion—the practical attainment of an image tube proved full of technical difficulties. The earliest use of an image tube in astronomy was by Krassovsky (U.S.S.R.) who adapted an infrared snooperscope tube to photograph the infrared airglow spectrum, a task not possible at all with the photographic emulsion since it is not sensitive to the infrared beyond 1 micron wavelength. The first image tubes to rival and exceed the direct photograph were made in France by Lallemande. While the use of these in astronomy has permitted unusual observation such as the rotational velocity of the nuclear regions of the Andromeda nebula by Walker (U.S.A.), each tube must be made minutes before use—hardly like taking a photographic plate out of a box purchased months beforehand.

The adaptation of the television tube method to astronomy has recently become possible by the development of tubes with high sensitivity to low levels of light and with integrating properties. Many astronomers in the U.S.A. are now experimenting with systems using commercial tubes with good success. The promise of this type of image tube is foreshadowed by the time in the near future when astronomers will want to have their "photograph" taken from a space telescope transmitted back to the earth.

A vast technology has developed for infrared detection in the region from 1 to 12 microns and which has only recently been applied to astronomy. The principal reasons for the lack of development of infrared astronomy are that the atmosphere transmission is highly variable in these wavelengths and detectors are still senstitive enough only to permit one to reach the brightest stars with a large telescope. To illustrate the problem of background noise in the case of an infrared telescope it is only necessary to remember that the maximum of the infrared emission from material at room temperature is at 10 microns. The detector therefore looks at the star through a telescope that is literally glowing with its own light even though it is night and completely dark to the eye. As a consequence, much remains to be explored of the heavens when infrared telescopes can be flown from balloons or space telescopes where the telescope can be made very cold.

BALLOON TECHNOLOGY

The third possibility for improvement in the operating efficiency and research potential of a telescope has now been opened through advances in balloon technology. As mentioned earlier, the efficiency of a telescope increases when the "seeing" image size is decreased. Much effort has been expended in the location of the Palomar and Kitt Peak observatories to find a site with the best seeing conditions. It does not appear that much can be gained in this direction for future telescope locations as long as the terrestrial atmosphere is involved. Only when one can place his telescope above the atmosphere does the theoretical resolving power of a telescope become obtainable. Balloon-borne telescopes offer this possibility.

At balloon altitudes of approximately 80,000 feet there is effectively no seeing disturbance even from direct sunlight on the telescope. While visual observations have been made from balloons, the first successful demonstration of high resolution photography was made with the 12-inch Stratoscope I by Schwarzschild (U.S.A.). This unmanned photographic telescope has taken superb direct photographs of the sun, achieving the full theoretical resolution of the telescope.

At the present time the 36-inch Stratoscope II system is nearing completion. This instrument is large enough to permit the observation of planets, stars, and nebulae, and it is designed to yield a guidance accuracy of 0.1 second of arc over extended periods. The achievement of this accuracy should, for instance, permit the solution of the existence or nonexistence of the "canals" on the planet Mars. Other balloon-borne telescopes are planned and several have failed. The launching and operation of as precise an instrument as a telescope from the tenuous platform provided from a balloon are complicated, and the probability for a malfunction of some portion of the system is a real threat to the success of the flight.

Rockets have been used for the last decade to obtain brief glimpses of the sun and stars from completely above the atmosphere. Even though a rocket-borne telescope has only 3 to 4 minutes of observing time, such a telescope is the only device that astronomers have had to observe the far ultraviolet beyond the atmospheric cutoff at a wavelength of 3000A. Beautiful far ultraviolet spectra and Lyman alpha photographs of the solar disk have been obtained by Tousey (U.S.A.). The recent flights by Stecher and Milligan (U.S.A.) have observed the spectrum of stars in the far ultraviolet. Since their observations showed that the theoretical predictions of the ultraviolet brightness of the hot O and B type stars was incorrect by a large factor much interest now exists in the pending operation of the first space telescopes. Telescopes as developed for use in the early rocket vehicles have been severely limited by the space available in the nose cone of the rocket. The accompanying photograph shows the instrument flown by Stecher and Milligan to illustrate this point. Their instrument was designed very compactly. A 10-inch telescope and diffraction grating was fitted into a space 14 inches in diameter and 12 inches in length.

The success of the rocket experiments and the great promise for the exploration of the universe in the far ultraviolet has led to the initiation by NASA (U.S.A.) of a spacecraft system capable of carrying a 36-inch telescope and all its related instrumentation. The program plans three such systems at an expected cost of $100 million. This is a large amount of money on any monetary scale and is justified by the fact that in no other way is it possible to learn what such an instrument will be able to tell us. The payload for the OAO telescope will be in excess of 4,000 pounds, the largest unmanned scientific payload to be launched to date by the U.S.A.

The most obvious gain to be had from a space telescope is, of course, the accessibility of the ultraviolet. This region of wavelengths is of great interest to the astrophysicist since the resonance absorption and emissions from atoms occur in this region. A less obvious advantage, and one that will require more technological development, is that an orbital telescope can work at the theoretical resolving power of the optical system, since no "seeing" disturbance is present. Given sufficient guiding accuracy, possible in free space, one could use diaphragms of very small angular size and increase the star-to-sky signal by 5 magnitudes over the same telescope on earth. If T.V. devices of sufficient information handling capability become available then high resolution studies on a fulltime basis will be possible. This possibility is of special interest for the observation of time-variable phenomena at a predetermined time or for long periods of time since neither weather nor daylight will interfere with the work of a space telescope.

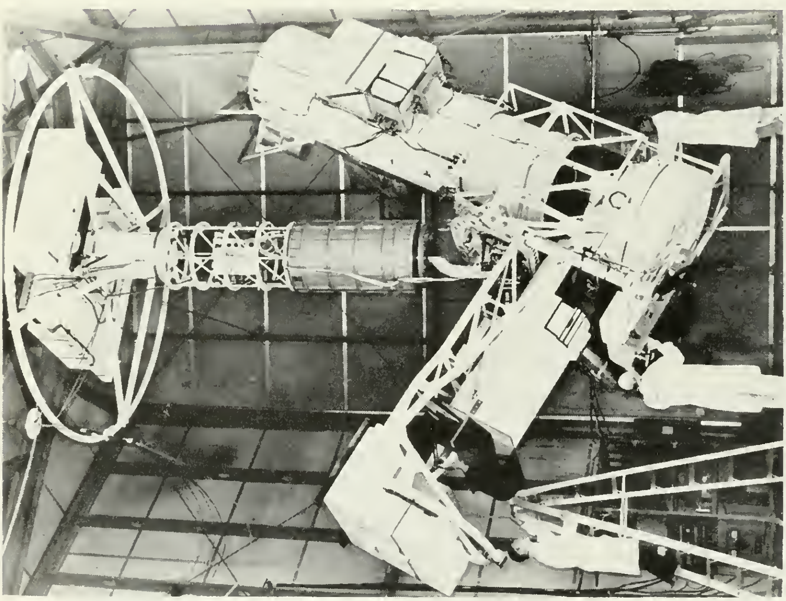
Space telescopes pose engineering problems that are not encountered in terrestrial telescopes and whose solution is required before successful missions can be made. The launching g-forces are an example. During the launching phase the telescope will be subject to thrust and vibration forces up to the order of 10 g's. As a consequence, either the engineer must find a structural design that will preserve optical collimation or the astronomer will have to have controls to permit him to realign his optical systems after the telescope arrives in orbit. The lack of proper collimation could seriously degrade the performance of a space telescope.

The second major problem in the design of the space telescope is that produced by its thermal environment while in orbit. Sunlight intermittently illuminates one side or the other of the space craft. This variable heating on one side coupled with the intense cold of outer space on the other produces a large and changing temperature gradient between the outer skin of the space craft and the telescope. It will be necessary to keep the thermal gradient small in the optical system if high resolution performance is to be obtained. The problem of computing what the thermal gradients will be before the space craft is in orbit is a difficult mathematical problem, and one that must be done with accuracy before the engineers can design a structure to meet the requirements.

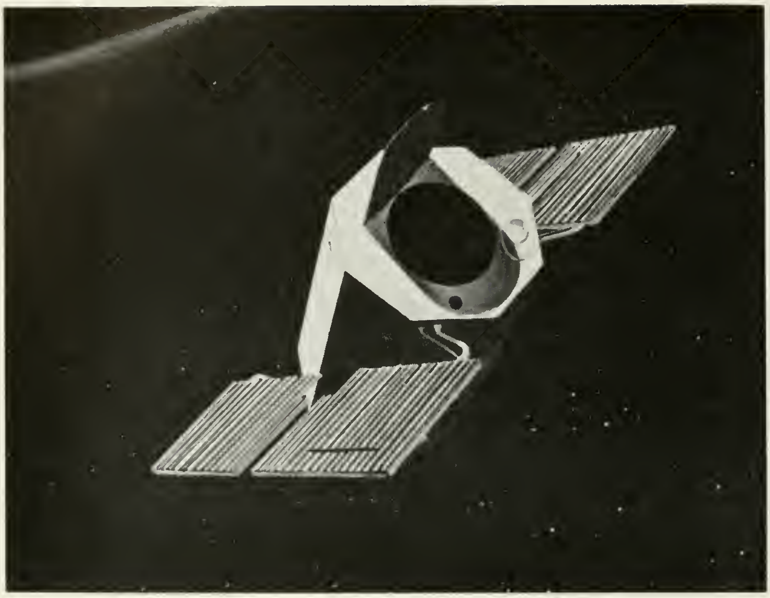
The third problem area, one common to all complicated mechanisms, is that of lifetime. Even when the probability of failure is very small for any one component of a system, when several hundred thousand components must function correctly the probability of failure of the system becomes large enough to present trouble. In the case of the orbiting astronomical observatories, the design lifetime is to be one year—an exceedingly difficult specification to design with confidence in the results. The environment of the hyper-vacuum of space causes many problems that we have no counterparts on earth. Lubricants evaporate, even gross metal, like magnesium, evaporates at such a high rate as to weaken structures. Moving parts tend to weld together since all the surface contaminants that contribute to low friction on earth evaporate. Primary cosmic rays can ruin the best high voltage insulation at a single impact, not to mention the gradual destruction of electronic components by the energetic particles in the Van Allen radiation belts. The list of problems rapidly extends as one looks closer into the actual design of a space telescope, yet the rewards of a new view of the universe draw astronomers onward.

1. The summer Milky Way photographed with an all-sky camera in infrared light. The brightness at the horizon is due to the upper atmosphere airglow of the earth.

2. Image orthicon telescope picture of the Whirlpool Nebula taken with an image orthicon tube attached to the 20-inch reflector at the Organ Pass observing station of the Dearborn Observatory. This picture would require a 100-inch telescope to photograph this object in the same exposure time with ordinary photographic plates.

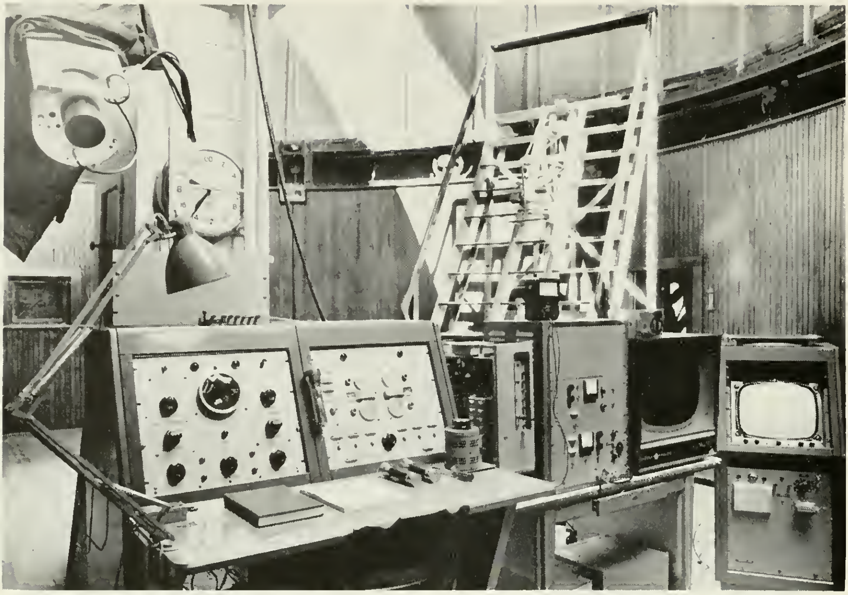


1. The 36-inch Stratoscope II balloon-borne telescope being readied for flight to 80,000 feet. The telescope and its balloon stand 562 feet high at launching. The telescope is shown at the right with the projection to the left containing the auxiliary cameras and instruments. The vertical column contains the pointing control system.



2. Drawing of the 36-inch orbiting telescope under construction by NASA. It is expected to be launched into a 500-mile-high orbit in 1965.

Photograph of the spiral nebula in Ursa Major (M 81) taken with the 200-inch Palomar telescope.



1. Dearborn Observatory telescope control console.

2. Inflation of the launch balloon. Stratoscope II is in the center of the photograph.

The Analysis of Starlight[1]

By Bernard Pagel

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[With 7 plates]

INTRODUCTION

Astronomy is a branch of science that enjoys a universal fascination. One of the reasons why it fascinates people is that the sheer romance of the night sky never palls even for the most hardbitten observer—at least in the warm and comparatively short nights of the summer. In winter it has to be admitted that observing is not quite so romantic after one has been at it for six hours or more, but there are always enough interesting things in the sky itself to compensate one for the effort. Another fascination exerted by astronomy is the literally unearthly appearance of the moon, the planets, star clusters, and nebulae seen through a small telescope or even a good pair of binoculars; then also there is the possibility of the existence of other worlds, some of which may for all we know be inhabited by intelligent beings, and all the exciting prospects of space exploration by automatic instruments or even by human astronauts, which are being brought a step further from science fiction and a step nearer to reality practically every day.

But astronomy also has a special appeal of its own on more strictly scientific grounds than these. The Ancients believed the heavenly bodies to be incorruptible and not subject to the laws governing our unhappy sublunary world, and our present belief that the same physical laws apply in the heavens as on the Earth is really a new and still staggering idea that goes no further back into history than the Newtonian revolution in science. The first applications of this idea were to the study of the motions of planets, comets, and, later on, double stars in the light of Newtonian mechanics; and it was not until the middle of the 19th century that the spectroscopists got to work, starting with the discoveries of Kirchhoff and Bunsen, and

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[1] Reprinted by permission from *The Advancement of Science* (London), vol. 19, No. 82, March 1963.

showed that the stars are made out of the same familiar elements of matter that we have here—hydrogen, sodium, calcium, iron, and even compounds such as cyanogen and titanium oxide. In the 20th century, modern atomic physics has provided us with two basic innovations in our thinking about the nature of stars both of which were first noted by Sir Arthur Eddington: the first of these is the fact that the material throughout a star, even at its center, is virtually a perfect gas although the material in the central regions of the Sun is 100 times as dense as water. This is because the temperature is so high—at about 15 million degrees—that the atoms lose almost all their electrons and become ionized; the stripped nuclei and free electrons that remain take up very much less space than do ordinary atoms, and so they can be compressed to very considerable densities without departing appreciably from the ordinary behavior of ideal gases as summarized in Boyle's and Charles' laws. A second important consequence of modern atomic physics has been the realization of the mechanism which enables the stars to shine: they derive most of their energy from thermonuclear reactions that are very similar to the controlled fusion processes that people are now trying to reproduce in the laboratory.

These nuclear fusion reactions most commonly involve hydrogen, which is the most abundant element in the universe, and the energy that comes out of the reaction is the nuclear binding energy that is released when four hydrogen nuclei, or protons, are fused together into one nucleus of helium, or α-particle. The weight of the helium nucleus is slightly less than four times the weight of the proton, and the difference is available as energy in accordance with the well-known equation of Einstein, $E=mc^2$. It is quite amusing to note that helium, which is the second most abundant element in the universe after hydrogen, was first discovered in the spectrum of the Sun by Sir Norman Lockyer at the total eclipse of 1868, a quarter of a century before the gas was isolated in the laboratory by Sir William Ramsay; and in a more general way we can say that the nuclear transformation of hydrogen into helium that is going on in the deep interiors of stars is just one example of the fact that astronomy can provide the physicist, and nowadays even the technologist, with an extension of his laboratory facilities to a vast range of temperatures, pressures, and, of course, sheer size, if only we have the wit to understand what is actually happening. In fact, one astronomer of my acquaintance recently remarked that the whole of physics and chemistry, as studied in laboratories, is just a special case of astrophysics.

Apart from the application of astronomy as an extension of our terrestrial laboratories, astrophysics provides us with an opportunity of investigating the answers to questions of a more or less historical character, such as: (*a*) How did the Sun, the planets, and in particular the Earth come into existence? and (*b*) Why do the chemical elements exist in the proportions in which we actually find them? The first question has proved to be a somewhat elusive one, but the second question—that is the one about the chemical elements—has made a great deal of progress in the last few years as a result of observational advances, and also very much as a result of the better understanding that we now think we have of the way in which stars change or "evolve" in the course of time, together with a coherent theory by Fred Hoyle and several collaborators on the synthesis of the elements by nuclear reactions in stars. We have seen that hydrogen is being transformed into helium in the interior of the Sun, and spectroscopic analysis reveals that helium is about half as abundant by weight in the universe as hydrogen. When we look for the common heavier elements such as carbon, nitrogen, and oxygen, we find that there is much less of them, just a few percent in comparison with hydrogen. Still heavier elements, which astronomers tend to lump together in cavalier fashion by referring to all of them as "metals", are even less common, at least among the stars and luminescent clouds of interstellar gas that can be investigated with the spectroscope: all of them *put together* on the average account for less than a tenth of 1 percent of the cosmic mixture of elements. The situation here on the Earth, which consists mostly of heavy elements, thus seems to be quite exceptional; presumably the hydrogen and helium, which are usually far and away the most abundant elements, escaped at an early stage in the Earth's history simply because they are so volatile.

The relative proportions of the commoner metals like calcium, sodium, and iron do not appear to differ very radically from one another in most stars; indeed they seem to be present in roughly similar proportions to one another in the Earth, in meteorites, in stars, and in clouds of interstellar gas. But the proportion of metals as a whole relative to hydrogen, while always small, varies quite widely from one star to another, ranging over a factor of maybe some hundreds. The variation in metal abundance appears to be related to the ages of stars, the stages that they have reached in the course of their evolution, and their distribution within the Galaxy; and I should like to say something in a very general way about these things and about our present ideas on the origin of the heavy elements, and then something in a little more detail about such related spectroscopic investigations concerning metal abundances and other characteristics among the relatively nearby stars as are now being carried out at the Royal Greenwich Observatory in Herstmonceux and elsewhere.

GALACTIC STRUCTURE AND STELLAR POPULATIONS

When we look up at the night sky we see a number of stars in all directions; these are relatively near to us in space, the stars visible to the naked eye being generally between 10 and 1,000 light-years away; that is to say they are at such distances that the light from them takes between 10 and 1,000 years to reach us. These distances are of course unimaginably vast by ordinary human standards, since light takes a mere 8 minutes to traverse the distance of 93 million miles between ourselves and the Sun. But they are quite small distances in comparison with the size of the Galaxy—which is the name that we give to the complete system of stars, or "island universe," that is defined by the Milky Way and to which we ourselves and all the visible stars belong. The Milky Way itself sweeps out a narrow belt in the sky, which is simply the projection of a large thin disk containing the Sun, many of the intrinsically bright stars (especially those that have a high surface temperature), and clouds of luminescent gas and dark obscuring dust.

A typical portion of the Milky Way, as seen through a telescope, is shown in plate 1, and you can see how the stars are mixed together with shining gas clouds and black clouds of dust that are generally referred to briefly as interstellar matter.

Recent work has shown that the Milky Way system is a typical spiral galaxy, somewhat similar to the great spiral nebula in Ursa Major that is shown in plate 2. This is a galaxy rather like our own viewed from an oblique angle so that we can see something of its structure. The brighest stars are concentrated in spiral arms, together with lanes of obscuring dust which appear as dark streaks over the central blob. The position of the Sun in our own Galaxy corresponds to a point in the outermost spiral arm but one, at a distance of about 30,000 light-years from the center, and the stars visible to the naked eye are confined within a sphere whose diameter is somewhat less than the thickness of one spiral arm.

Plate 3 shows another similar galaxy seen edge-on, which is known as the "Sombrero Hat" nebula. The spiral arms, defined by the horizontal streak of dark matter, are seen to be concentrated in a flat disk, which corresponds to what we see projected on the sky in our own Galaxy as the Milky Way. The particular interest of this picture is that it shows very clearly that we have at least two distinct populations of stars which interpenetrate: on one hand the disk and spiral arm population, concentrated toward a central plane which turns out to be exactly perpendicular to the axis of rotation of the whole system; and on the other hand a spherical or "halo" population which is densest around the center of the galaxy but shows very little flattening toward the plane. The disk and halo populations were christened by the late Walter Baade as Population I and Population II respectively; and the two populations differ from each other both in the physical characteristics of their component stars and also in the kinds of orbits in which the stars revolve round the center of the Galaxy, somewhat in the same way as the planets revolve round the Sun in the

Solar System. The disk stars of Population I revolve in circular orbits that are confined to the central plane, and the Sun, for example, is estimated to go right round a galactic circle in this plane in a period of 200 million years; whereas the stars of the halo population go round in elliptical orbits that are often steeply inclined to the plane.

The two stellar populations also differ from each other in their age. The key to the age difference is that stars are formed by condensation out of the diffuse clouds of interstellar matter which are concentrated in the flat spiral arms, and so any stars which are young must also be concentrated in spiral arms. The halo Population II, which is devoid of interstellar material, is in a kind of fossilized state because star formation must have stopped there at an early stage in the history of the Galaxy. We imagine that the whole Galaxy itself started off as a diffuse cloud of gas condensing under the effect of its own gravitational attraction and that while it was condensing groups of stars separated out of it at every stage, and indeed are still doing so at the present time. Owing to the rotation of the primeval gas cloud, it would have been gradually flattened out into a disk by centrifugal force, but the stars that had been formed before appreciable flattening had occurred would have been left behind in a spherical or spheroidal bulge; and this is more or less what we observe.

Many stars are concentrated in more or less compact physical groups known as star clusters; well-known clusters are the Pleiades and the Hyades, which are near to the Milky Way and are typical members of the spiral arm population or Population I; these are generally referred to as galactic or open clusters. One such cluster, the Double Cluster in Perseus, is shown in plate 4, figure 1.

The stars of the spherical population, or Population II, also are frequently (though by no means always) found in clusters. These tend to be richer in stars and more compact than the galactic clusters, and they are known from their shape as globular clusters. One example of a globular cluster is the system Messier 13 in Hercules shown in plate 4, figure 2.

THE COLOR-LUMINOSITY DIAGRAM AND STELLAR EVOLUTION

Star clusters of both kinds have proved particularly helpful in studying the evolution of stars in the course of time, because we can suppose that all the stars in any one cluster were formed at a single moment from one cloud of dust and gas, but that different clusters may have been formed at different times in the past. In order to understand how we interpret the observations of clusters, we shall now have to go into some details both about the nature of stars and about the kinds of observation that it is possible to make.

Suppose that a cloud of interstellar matter with a mass of the order of 10^{36} g. or about 1,000 times the mass of the Sun starts to condense under its own gravity and has reached a stage where it fragments into a number of smaller masses each of which then condenses further into an individual star. The individual clouds, or proto-stars, will go on contracting and in doing so they will convert their gravitational potential energy into heat which then escapes as radiation. In the last century this process was put forward by Helmholtz and Lord Kelvin as the main source of stellar energy, but it is easily shown that the Sun could not have lasted long enough on contraction alone to satisfy geological evidence as to the age of the Earth, which is now believed to be about 5,000 million years, and the discrepancy led to long and sometimes acrimonious debates in the British Association and elsewhere between Kelvin and the geologists, led by T. H. Huxley. However, as the contraction of the proto-stars goes on, their internal temperature and pressure will steadily increase until finally the conditions at the center have become sufficiently extreme for the hydrogen to undergo a nuclear transmutation into helium; the energy produced by the reaction will be carried outward by processes of radiative and convective transfer until it reaches the surface, from which it will then be radiated away into space. In order to reach a steady state, the whole star must adjust itself until two conditions are fulfilled: first, the energy radiated from the surface (or in other words the star's total luminosity) must exactly balance the energy liberated by nuclear reactions in the deep interior; and second, the pressure in every layer of the star must exactly balance the weight of the layers lying on top of it. When these conditions are worked out in detail, it turns out that the whole structure of the star, and notably its brightness and its size, are completely fixed by its mass. This is the basis of the famous mass-luminosity relation, which says that the light output of a star increases rapidly with the mass, about as the cube, so that a star with twice the mass of the Sun should have about eight times its intrinsic brightness.

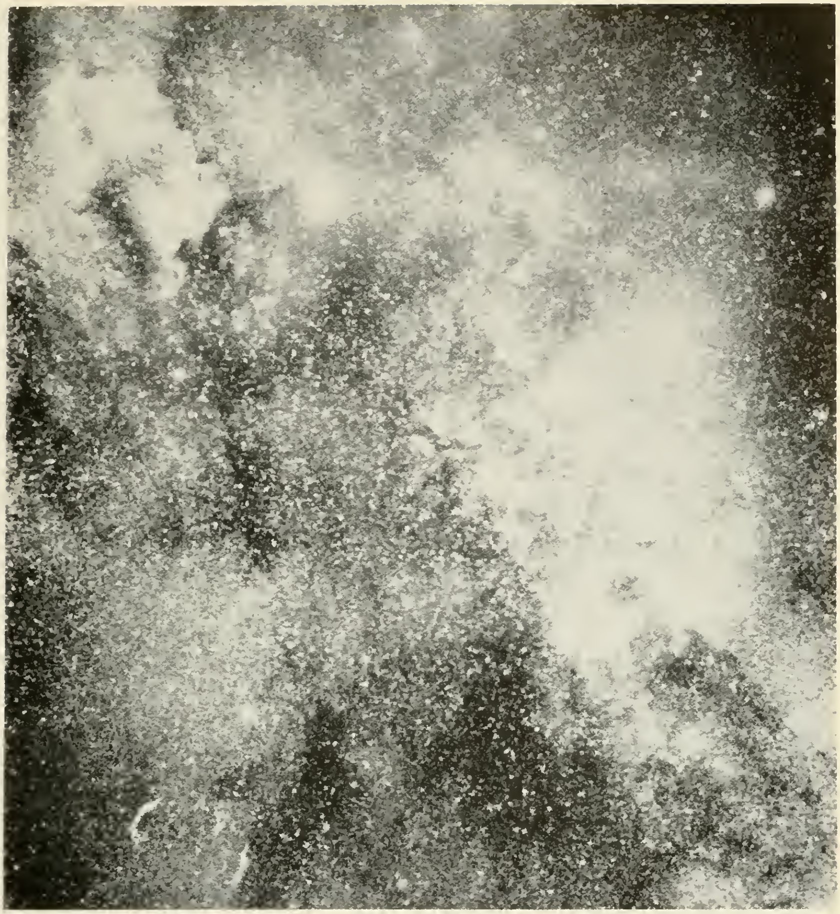
Unfortunately we can only measure the masses of a few stars in nearby double systems, and there is no general method of finding the masses of stars in clusters. However, there is another relationship that comes out of these considerations of a star's internal equilibrium: the brightness is related to the surface temperature, varying as about the 12th power of the latter, so that our star with twice the mass of the Sun and eight times its brightness should have a surface temperature of about 1.2 times that of the Sun or 7,000°, as compared with the Sun's surface temperature of about 6,000°.

Now we can estimate the surface temperatures of stars in two different ways. When you heat up a poker, then at fairly low temperatures the radiation from it is concentrated in the infrared part of the spectrum. As the temperature is raised, the energy distribution shifts its maximum from the red to the yellow and then to the blue and finally, at very high temperatures, to the ultraviolet. With a good telescope, or even in good weather with the naked eye, the differences in color between different stars are quite obvious when we look at them. Cool stars like Betelgeuse, at the top left corner of the constellation of Orion, are red, while hot stars like Rigel at the opposite corner of Orion are bluish white. To study these differences in color in a quantitative way, astronomers measure the brightnesses of stars with photomultiplier cells attached to the end of the telescope which are covered by optical filters of differently colored glass. Most commonly two such glass filters are used which let through mainly yellow light and mainly blue light respectively, and in this way one obtains a so-called color index which gives some indication of the distribution of light in the continuous spectrum and hence of the surface temperature.

A second method of estimating surface temperatures is provided by the spectroscope, which reveals the characteristic dark absorption lines of the different substances present in gaseous form in the visible surface layers of the stars. Most stellar spectra can be classified into a continuous series of "spectral types" ranging from spectra with dark lines of helium and hydrogen at one end of the scale to spectra with lines of metals and molecules like CH, CN, and titanium oxide at the other end. The different spectral classes do not, in general, represent different chemical compositions, although we saw earlier that such differences in composition do indeed exist; but the main cause of the different kinds of spectra that we see is the effect of thermal excitation of the atoms, molecules, and electrons, which prevents the molecules and metallic atoms from showing up in the spectrum unless the temperatures are comparatively low. At higher temperatures the molecules dissociate into their constituent atoms and the metallic atoms lose their electrons to become ionized, while hydrogen and helium atoms become excited to the rather high energy levels in which they need to be in order to absorb light in the visible part of the spectrum. The various spectral classes are arranged in order of diminishing surface temperature from about 30,000° at one end of the scale to about 3,000° at the other end, and for certain historical reasons the different classes have come to be designated by a series of letters of the alphabet: OBAFGKMRNS; these letters seem to be arranged in a completely arbitrary order, but in fact they can easily be remembered as the initial letters of the sentence "Oh, be a fine girl; kiss me right now, sweetie."

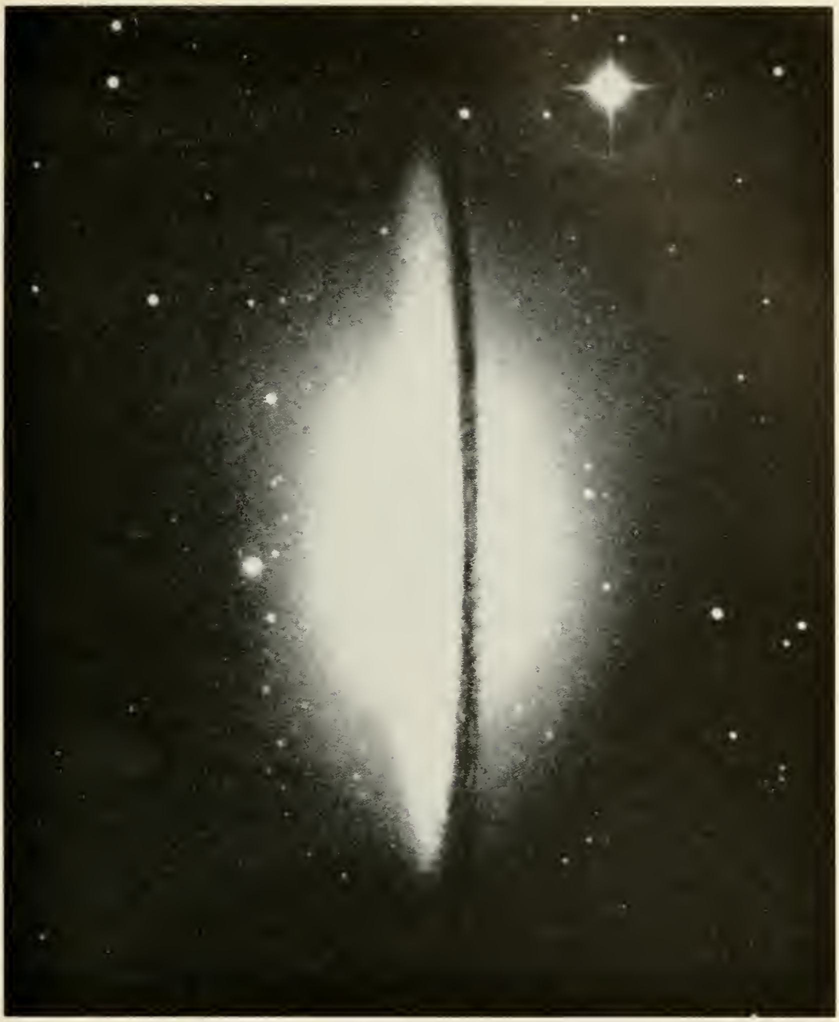
Plate 5 shows some typical spectra of the various different classes, with the hot, bluish white O-type stars at the top and cool, red M-type stars at the bottom. The gradations are perfectly continuous, and each class (corresponding to one of the letters) is subdivided further into decimal fractions so that A5, for example, is halfway between

A0 and F0. We see that the hottest stars, at the top of the diagram, have lines of ionized helium, He^+, and of ordinary helium; and when we go from class O to the slightly cooler class B, the ionized helium fades away but hydrogen becomes stronger. In class A, hydrogen reaches it maximum strength and completely dominates the spectrum, but this is not because hydrogen is any more abundant in these stars than in the others, since in fact a detailed analysis shows that the stars illustrated here have approximately the same chemical composition, with hydrogen much the most abundant element. The reason for the progression is simply that hydrogen is mostly ionized to H^+ in the O and B stars, and since H^+ is merely a proton with no electrons, it does not produce any line spectrum. When the temperature is reduced to about 10,000°, corresponding to type A0, the hydrogen is largely in its ordinary neutral state, but the temperature is still high enough to keep an appreciable proportion of the atoms excited to their second quantum level with a stored energy of about 10 electron volts for each excited atom; they have to be in this excited level to produce the lines of the Balmer series in the visible spectrum, whereas when they are in the ground state, with no stored energy, they only absorb in the far ultraviolet Lyman series that can be detected only from rockets and satellites above our atmosphere. When we go further along the sequence to F0, corresponding to a surface temperature of about 7,000°, there are correspondingly fewer hydrogen atoms excited to an energy of 10 electron volts and the hydrogen lines become weaker; but now two strong lines show up that arise from ionized calcium in its lowest energy state—the so-called H and K lines discovered by Fraunhofer in 1815. When we come to type G0, which represents stars that are just about as hot as the Sun, the lines of ionized calcium are the strongest ones in the whole spectrum and the hydrogen lines are still strong enough to be the next runners up. But now we see a number of additional lines arising from metals in the neutral state; that is, the atoms are being bombarded less energetically by photons and electrons, and therefore many of them are able to preserve their structure intact and show their characteristic absorption spectrum, exactly as they do in the ordinary electric arc. Most of the lines are due to iron, which is one of the most abundant metals: strong lines of iron can be seen around 4400 Å and around 4050 Å, and there is also a strong line of neutral calcium near 4200 Å. At 4300 Å, there is the first indication of an absorption band caused by a molecule; this is the simplest hydrocarbon, CH, and as we go on to still cooler stars of type K, with surface temperatures of about 4,000°, we see the molecular bands and the lines of iron and calcium growing steadily stronger, since the molecules become more abundant and the atoms settle down more and more

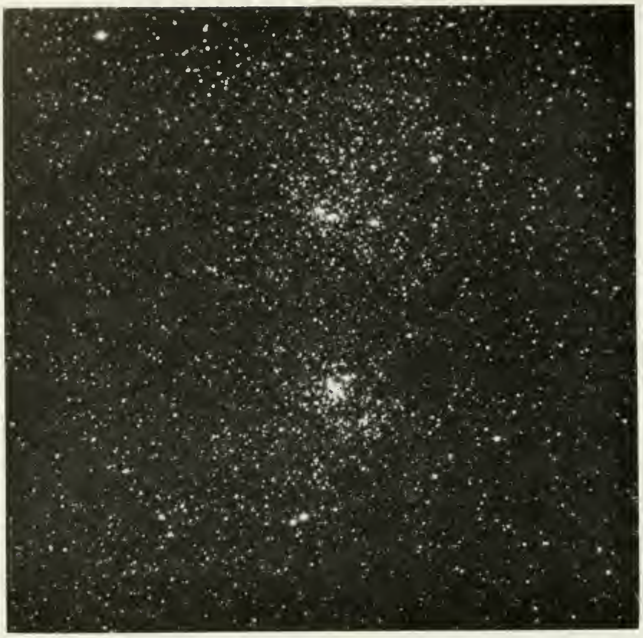


Field in Milky Way. (From *Atlas of the Universe*, Nelson, plate 47.)

Spiral galaxy M81 in Ursa Major. (From *Atlas of the Universe*, Nelson, plate 74.)

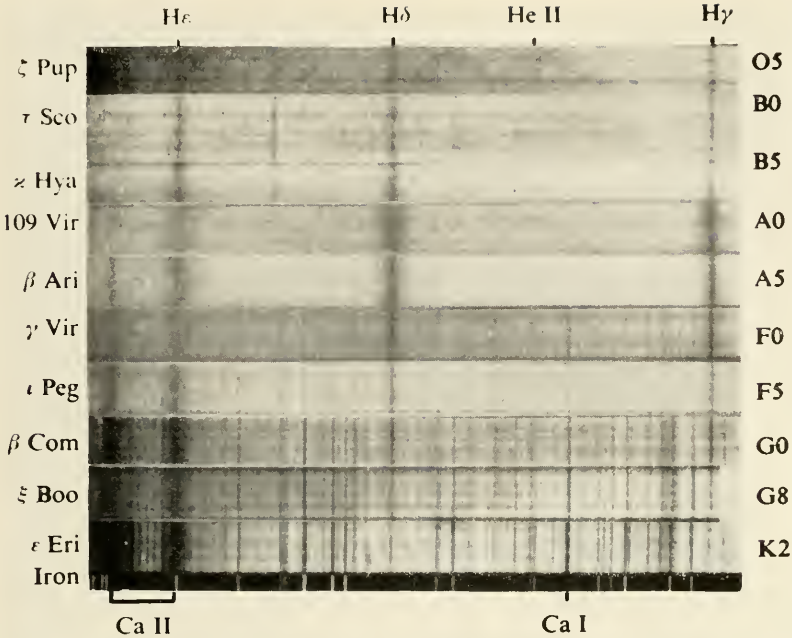


Spiral galaxy M 104 in Virgo—the "Sombrero Hat" galaxy. (From *Atlas of the Universe*, Nelson, plate 72.)

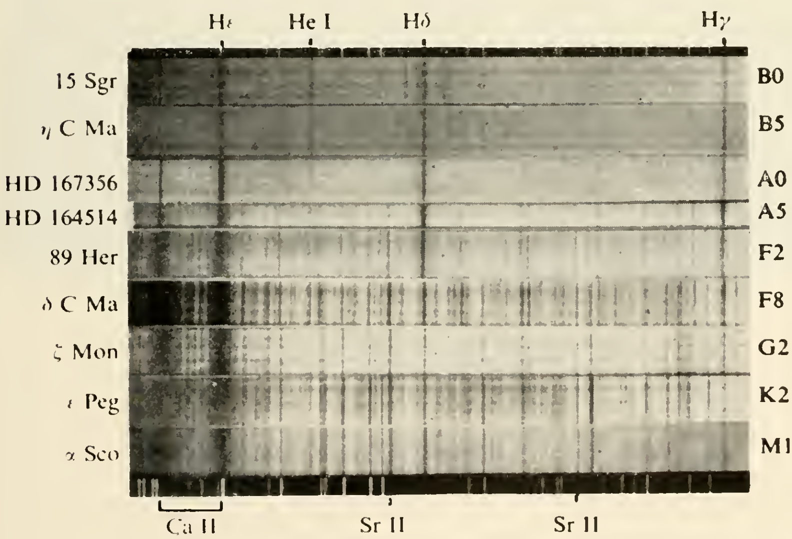


1. A galactic cluster—the double cluster of Perseus.

2. A globular cluster—M 13 in Hercules.

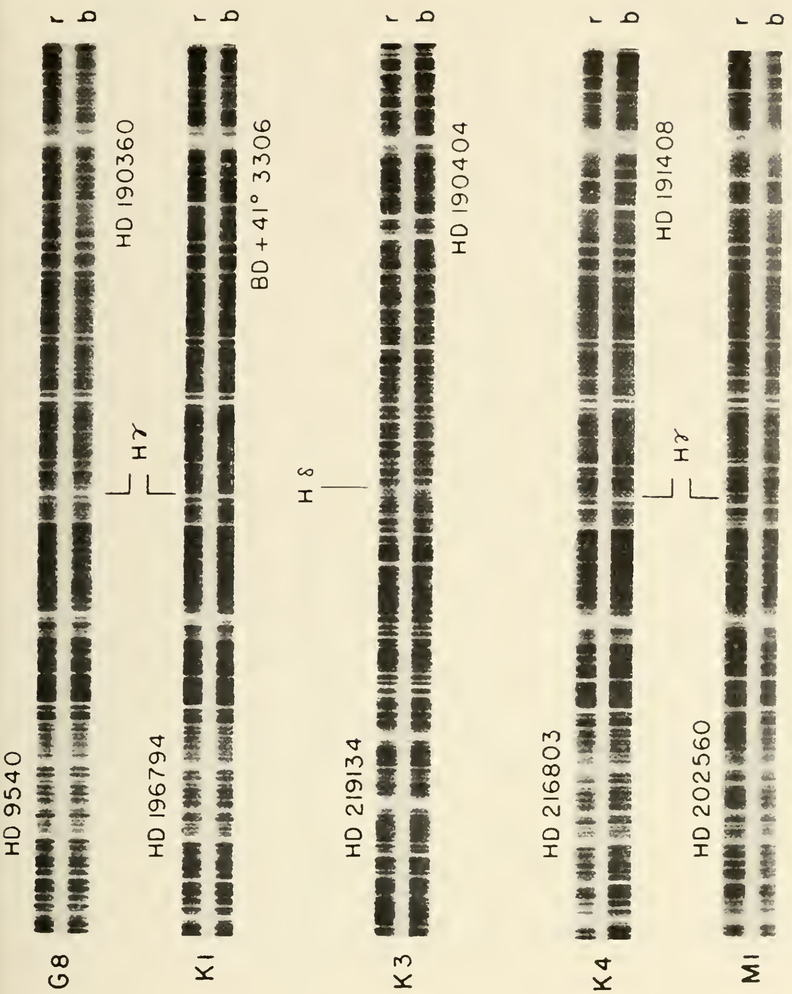


1. Spectra of main sequence stars (O5 to K2). The bright lines of iron in the comparison spectrum at the bottom can be matched with dark lines in the coolest stars.



2. Spectra of supergiant stars (B0 to M1). Note the sharpness of the hydrogen lines compared with figure 1, above. (Photographs on this page by Radcliffe Observatory X 10, from *Astronomical Spectroscopy*, by A. D. Thackeray.)

The Crab nebula.



Spectra of K stars by O. C. Wilson. (Courtesy, *Astrophysical Journal.*)

into their lowest energy levels. We shall come back to the cool type spectra later.

Having seen that there are two ways of estimating the surface temperatures of stars, either from the spectral type or from the color index, we now have to consider how we can derive their true brightnesses from photometric measurements. To do this, we have of course to allow for their distances away from us, since we would not otherwise know whether a certain star was very luminous and very far away or quite faint but very close to us in space. A typical example of the importance of the distance effect is provided by the well-known stars Vega and Rigel, which both have about the same apparent brightness; but Rigel is about 30 times as far away from us as Vega, and so its intrinsic brightness must be about 900 times as great. If the distance is less than about 100 light-years, we can measure it by a trigonometrical surveying method using the diameter of the Earth's orbit around the Sun as a baseline; this is referred to by astronomers as measuring the parallax. If they are farther away but in a cluster, we can estimate the distance of the whole cluster, sometimes rather roughly, by identifying stars in it whose brightnesses we think we know on the grounds that they are the same breed of animal as some nearby star that has been done by the trigonometric method.

In this way we can take a group of stars and plot the luminosities against the surface temperatures, as estimated from the color distributions or spectral types; generally the color indices are preferred as being more accurate. Figure 1 shows such a color-luminosity

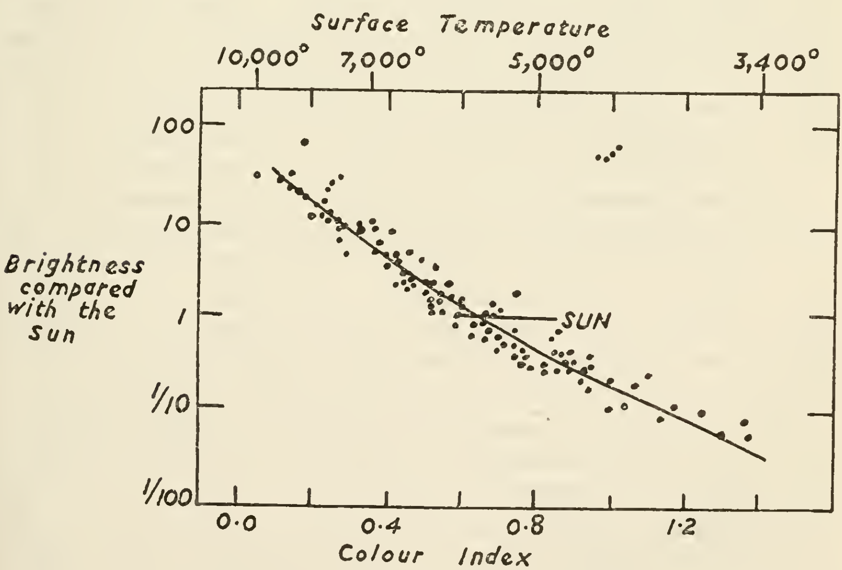


FIGURE 1.—Color-luminosity diagram for the Hyades.

diagram for the nearest galactic cluster, the Hyades, which are exceptional in that we can estimate their distance rather accurately by a trigonometrical method based on their group motion.

We have seen that if the stars are in equilibrium and uniform throughout, the hot stars should be much brighter than the cool ones. Astronomers have a peculiar habit of plotting the temperature scale backward, with the hot stars of spectral types O and B on the left and cool stars of spectral types K and M on the right, and we see that most of the stars do indeed lie on a line going from top left to bottom right in the diagram, which is known as the "main sequence" or "dwarf sequence."

There are however, a few stars definitely not on the main sequence. These stars are bright, about 100 times as bright as the Sun, and cool (that is, as hot as the Sun or cooler), and it follows from this that they must be very much larger, having something like 10 times the solar radius of 700,000 km. These stars, of which there are many well-known examples like Arcturus and Capella, are therefore called "giants," in contrast to "dwarfs" like the Sun which lie on the main sequence. According to current theories of stellar evolution developed in the last 10 years by Allan Sandage, Martin Schwarzchild, Fred Hoyle, and others, a star is believed to remain on the main sequence for a long period of time in the earlier part of its life history, and the length of its lifetime on the main sequence depends on how bright it is. A hot star will last only for a few million years, while a relatively modest star like the Sun, which is much more sparing in using up its nuclear fuel resources, is estimated to be able to last for over 10,000 million years. When a certain proportion of the hydrogen in its central regions has been transmuted into helium, the star is no longer able to remain in a steady state on the main sequence, but swells up to form a red giant; and this state of affairs is reached much sooner by a bright, hot star than by a faint cool one. In a young cluster, therefore, the main sequence will stretch upward to include stars of considerable brightness, and the upper limit where the main sequence terminates will gradually travel downward in the diagram in the course, of time; that is, with increasing age, the stars that have just left the main sequence will gradually become fainter and so the age of a cluster can be judged from observation of its color-luminosity diagram. The age of the Hyades is estimated in this way to be a few hundred million years.

When we look at the corresponding diagram for a typical globular cluster, like the one shown in figure 2, we see the main sequence terminating much lower down, at about three or four times the Sun's brightness. Most of the bright stars in globular clusters, and in the halo Population II generally, are red giants, and the bright blue stars are completely absent. It is concluded from this that

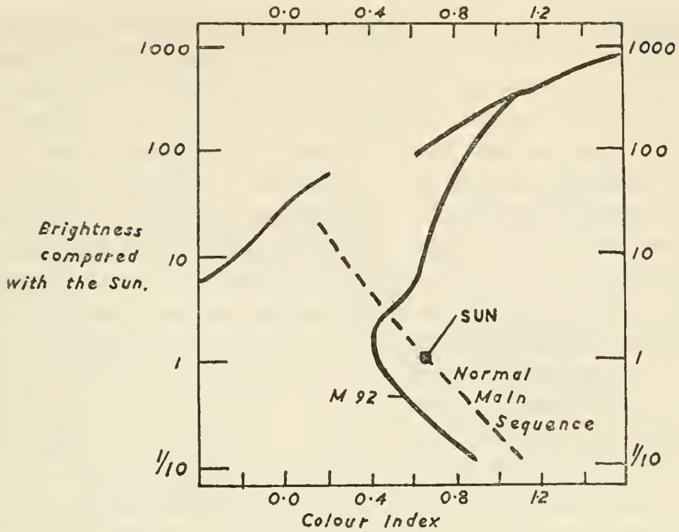


FIGURE 2.—Color-luminosity diagram for a globular cluster, M92.

here we have a very old stellar population with an age of about 10,000 million years—almost as old as the Galaxy itself. We also notice that the main sequence is somewhat lower in the diagram than the main sequence of the Hyades; these stars are referred to as "subdwarfs," and the existence of subdwarfs is closely related to the evidence that we have that there is a big difference in chemical composition between the two stellar populations in the sense that the old stars of Population II seem to have a much lower abundance of metals mixed in with their hydrogen than have the younger stars of Population I. The difference between the two degrees of metal abundance is considerable, generally a factor of about 100.

To account for the difference in metal abundance between the stars of different ages, Hoyle suggested some time ago that when a star has gone through the giant phase of evolution, it runs out of hydrogen to an ever-increasing extent and further nuclear reactions have to occur involving heavier elements, particularly helium. When the interior of the star has contracted and heated up sufficiently, helium nuclei can fuse together with one another or with hydrogen to produce a number of chemical elements up to atomic weight 56, corresponding to iron. Still heavier elements, going all the way up to uranium and beyond, can then be built up by capturing neutrons, and in this way Hoyle, Geoffrey and Margaret Burbidge, and William A. Fowler of California Institute of Technology have put forward a detailed theory which is in tolerably good agreement with the relative abundances of the heavy elements found in nature. A further idea is that, at a late stage of evolution, many stars explode; this is the so-called supernova outburst in which a star suddenly becomes about a million times brighter and then gradually fades away over a period of a few months; this is observed to happen quite frequently in external galaxies, although the last outburst seen in our Galaxy was in 1604. When the star explodes as a supernova, it forms a vast expanding cloud of gas like the famous Crab nebula shown in plate 6. This nebula is the relic of a supernova outburst in the constellation of Taurus witnessed by Chinese and Japanese astronomers in A.D. 1054 and it has been steadily expanding since then. It is supposed that such a cloud will eventually diffuse into the interstellar medium together with the heavy elements that were manufactured in the star just before the outburst, and in this way more and more heavy elements become mixed with the original interstellar hydrogen clouds as time goes on; these clouds in turn will eventually condense into a new generation of stars, which will therefore contain a larger admixture of metals than previous generations. In other words, young stars will have a bigger proportion of heavy elements than old stars; and this prediction is partially borne out by observations of the spectra of stars in globular clusters.

SPECTROSCOPIC OBSERVATIONS OF NEARBY STARS

These general ideas have brought us up to a point where I should like to say something about the very nearby stars, those within a mere 60 light-years or so from the Sun, which have recently been studied from various points of view at the Royal Greenwich Observatory. These stars are near enough for us to be able to distinguish between dwarfs and giants by the trigonometric surveying method of finding their distances, and we can also see dwarfs that are comparatively cool and faint because they are not too far away. We can also determine at what speed and in what direction they are traveling through space, and thus judge whether they are going round the center of the Galaxy in circular orbits, like the stars of Population I, or in elliptical orbits like the older stars of Population II. On the other hand, these stars do not belong to clusters, and so they form a confusing jumble of different ages and chemical compositions, and the purpose of this work is to sort out exactly what kind of star we are dealing with in each case: that is, to determine its physical and chemical properties and its genetic relationship, if any, with the stars in the galactic and globular clusters.

Figure 3 shows the color-luminosity diagram for these nearby stars determined by Olin J. Eggen. We see that most of the stars are rather cool and faint as compared with the stars in young clusters, but there is a group of rather faintish giants (known as "subgiants") which must have been around for long enough to have evolved away from the main sequence. In addition to stars like the Sun, on the normal main sequence, a number of stars are below,

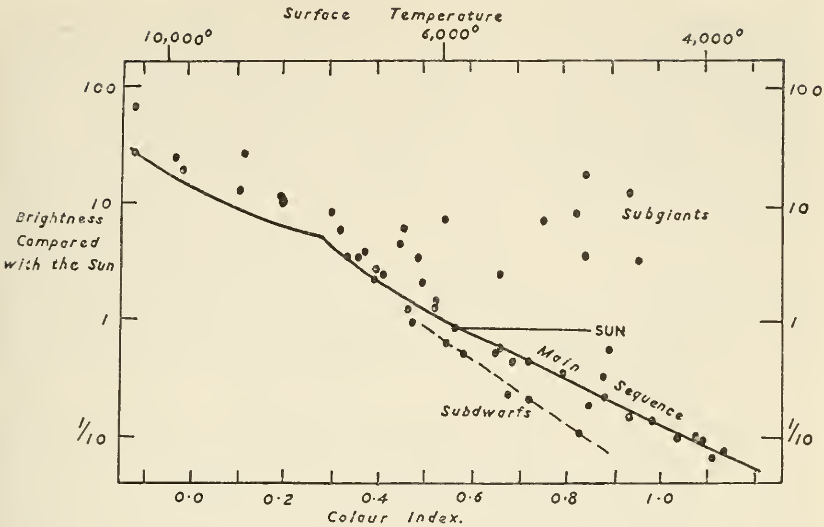


FIGURE 3.—Color-luminosity diagram for stars within 64 light-years.

or perhaps I should rather say to the left of, the main sequence, and these are further examples of the stars that are known as subdwarfs; these stars are of considerable interest because they appear to be related to the dwarfs in the globular clusters. For one thing, they appear to be going round the center of the Galaxy in elliptical orbits, sometimes with quite high eccentricities and inclinations to the galactic plane. Furthermore, when their spectra are examined, they tend to show a deficiency in metals, which is another resemblance to the stars in globular clusters. They seem to be interloping members of the halo-type Population II, or possibly an intermediate class between the extreme population types.

The fact that subdwarfs are shown lying below the main sequence does not necessarily mean that they are peculiarly faint for their surface temperature (that is to say, peculiarly small in size), because the measured color that is plotted along the horizontal axis is itself affected by the presence of dark absorption lines superimposed on the continuous spectrum. It was noticed about 60 years ago by Sir Arthur Schuster that the absorption lines are not uniformly distributed throughout the spectrum of a star, but that they become systematically stronger and more numerous as one goes from the red end to the blue and on to the ultraviolet. Since the absorption lines remove some of the energy that would otherwise be detected when we make our measurements through yellow and blue glass filters, a star having faint lines due to low abundance of the metals will seem to be relatively brighter in the blue, as compared with the yellow, than another star of the same surface temperature, but having higher metal content and stronger absorption lines. Therefore the first problem that arises in interpreting the position of subdwarfs in the color-luminosity diagram is to sort out the effect of temperature on the color from the effect of metal abundance, that is to say we have to decide whether star A is more blue than star B because it is hotter, or because it has a lower abundance of the metals. For stars that are about as hot as the Sun, this problem has been solved by making photometric observations through a third glass filter that lets through the ultraviolet, making use of the fact that comparison of the three different values of the brightness obtained by measuring through the three different glass filters gives an indication of the strength of the absorption lines and hence of the metal content.

When we come to somewhat cooler dwarfs, with surface temperatures of the order of 4,000° and corresponding to spectral type K, the whole effect becomes more subtle and complicated, and it is this section of the main sequence that we have recently been considering from the viewpoint of the theory of stellar atmospheres. As the stars become cooler, a high proportion of the metal atoms settle down into their lowest energy states and produce numerous very strong absorption lines which overlap, so that in the blue part of the spectrum it is no longer meaningful to speak of a continuous background at all. Another difficulty is that there is little obvious difference between the spectra of dwarfs and subdwarfs when they are as cool as this.

One factor having an important influence on the intensities of absorption lines is the degree of transparency, or of opacity, of the stellar atmosphere. So far, we have dealt only with the dark absorption lines in the spectra of stars and said nothing about the continuous background light on which they are superposed, except to compare the latter to the black-body type of radiation emitted by a heated poker. In the 19th century, stars like the Sun were believed to be essentially solid or liquid bodies, owing to their high density, and the continuous radiation from them was believed to be quite analogous to the light radiated from an ordinary solid or liquid heated to incandescence. The dark absorption lines are, of course, characteristic of matter in the gaseous state, and so it was supposed that they were produced by a gaseous atmosphere very similar to the atmosphere of the Earth, only hotter of course. Nowadays we know that the Sun is a gaseous body throughout, and when we talk about the solar atmosphere or stellar atmospheres in general, we merely mean the layers of the star which we can see because they are close to the surface, making no distinction between the layers where the continuous radiation comes from and the layers producing the dark lines, since both are essentially the same surface regions. This introduces some extra complication into the problem of predicting how intense we should expect a given absorption line in the spectrum to be, since there will now be a competition between the selective absorption at the line wavelength of our atoms of hydrogen, calcium, or iron on the one hand, and the continuous absorption of the atmosphere, at all wavelengths, on the other hand. If the atmosphere is transparent, then we can see a large number of atoms of calcium or hydrogen and the absorption lines will be correspondingly strong; whereas if the surface layers are more opaque, we shall see weaker lines even if the number of hydrogen and calcium atoms per gram is the same.

Now the continuous absorption of light in cool stellar atmospheres is due to a negative ion of hydrogen, H^-, which consists of a proton surrounded by two electrons and absorbs light by losing the extra electron to form ordinary atomic hydrogen. The number of H^- ions in the atmosphere itself depends on the rate at which neutral hydrogen atoms can capture free electrons, and these electrons are supplied in turn by ionization of the metals; the degree of ionization of the metals is here about a half, so that there is one electron for every two metallic atoms. If we now compare a dwarf and a subdwarf, the subdwarf having fewer metal atoms by a factor of a hundred or so, we see that the subdwarf has not only fewer metal atoms capable of producing a dark absorption line, but also fewer electrons to provide general opacity in the atmosphere, so that the subdwarf atmosphere is considerably more transparent. Consequently the metallic absorption lines do not become fainter to the same degree as one might normally have expected, certainly nothing like the factor of some hundreds shown by the abundances, and even the weakening that does occur in the metallic lines can be more or less got rid of by choosing your subdwarf at a lower surface temperature; you will recall from the picture of the spectral sequence how rapidly the intensities of the dark lines increase with diminishing surface temperature toward the end of the sequence.

These points are strikingly displayed by a series of spectra of K-type dwarfs taken by Olin C. Wilson at Mount Wilson and Palomar Observatories (pl. 7).

The interpretation that I have placed upon these spectra, which is not necessarily accepted by other people, is along the lines of what I have just said. In each pair, the lower spectrum represents a subdwarf with fewer metal atoms in its atmosphere than are present in the normal dwarf shown above, though not by the large factor of 100 that I have been quoting up to now. The difference is probably by a factor of 5 or 10. The subdwarf, however, which is marked "b," has a more transparent atmosphere than the normal dwarf marked "r," so that the absorption lines due to metals look about equally strong in the two spectra. However, the lines due to hydrogen—H gamma and H delta—are quite different as can be seen; they are stronger in the spectrum of the subdwarf because its atmosphere is more transparent

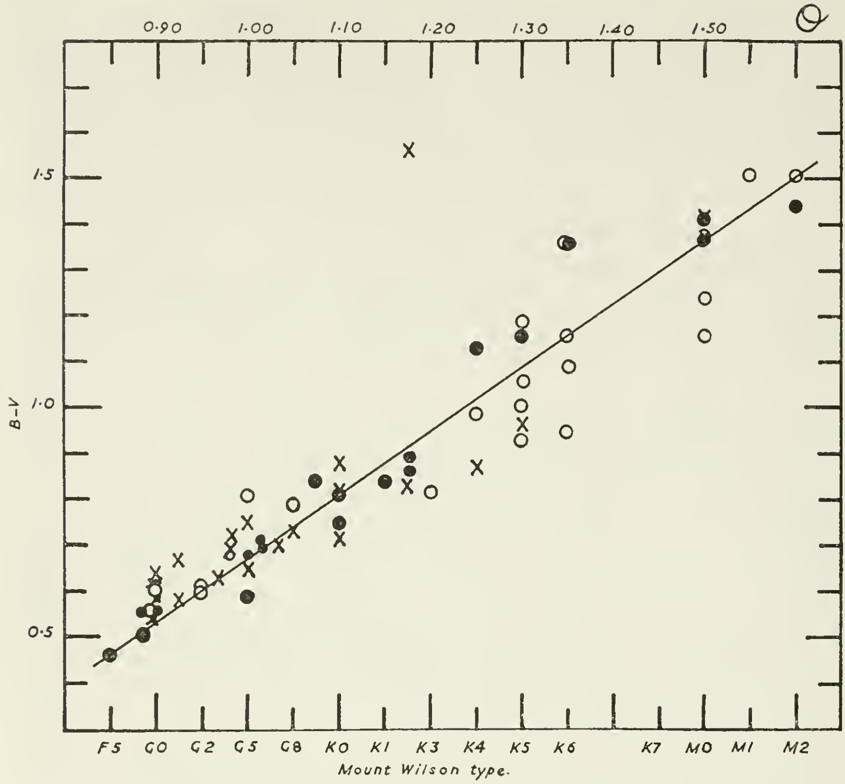


FIGURE 4.—Color index plotted against Mount Wilson spectral type for dwarfs. (Courtesy Royal Observatory Bulletins, 1962.)

owing to the shortage of electrons, and so more hydrogen atoms appear in the line of sight. But it should be borne in mind that the hydrogen lines are also sensitive to temperature, and it has not been established that the stars in each pair actually have the same surface temperature; so that this conclusion may not turn out to be right in all cases.

There is another curious effect which has been pointed out by Wilson, which is that the stars whose spectra have been shown display a big difference in color at one spectral type. The interesting thing here is that it seems to be the subdwarf, which was marked "b" for blue, that is relatively brighter in the blue band of the spectrum although its temperature is about the same as that of the normal dwarf marked "r" for red; in spite of the appearance of the spectra, on which the lines seemed to be equally strong within the very limited degree of accuracy afforded by mere visual examination, the lines must really be a little weaker in the subdwarf and cause the color distribution to go in this direction although the subdwarf is no hotter, and perhaps even a little cooler, than the normal dwarf.

Figure 4 illustrates how the effect shows up in the color index, which has been plotted here on the y-axis against spectral type on the x-axis. The straight line represents the effect of variation in temperature alone for stars having the chemical composition of the Sun, or Population I; such stars are tentatively identified here as stars traveling in a circular orbit around the center of the Galaxy, and they are shown as black dots. Known subdwarfs are represented by crosses, and the open circles represent stars that are moving in elliptical orbits round the center of the Galaxy, and it is suspected that some of these would actually turn out to be subdwarfs as well, if their distances were better known. For the stars of spectral types F and G, about as hot as the Sun, the dots, circles, and crosses are distributed anyhow, but when we come to type K, there is a definite tendency for the subdwarfs and other elliptical-orbit stars to lie below the others in the diagram, that is to say their blue light is too strong for their spectral types because of general faintness of the lines. The general effect is in accord with theory and provides a possible method of judging the chemical composition of a star from comparatively simple observations and with only a fairly rough knowledge of its distance.

Unfortunately the spectral types of stars can only be assessed rather roughly, but we can confirm these conclusions for a limited number of stars by appealing to photometric measurements in a relatively unpopular region of the spectrum, the red and infrared, where absorption lines are weak and so we have a better chance of judging the surface temperatures of stars from observations of the color distribution.

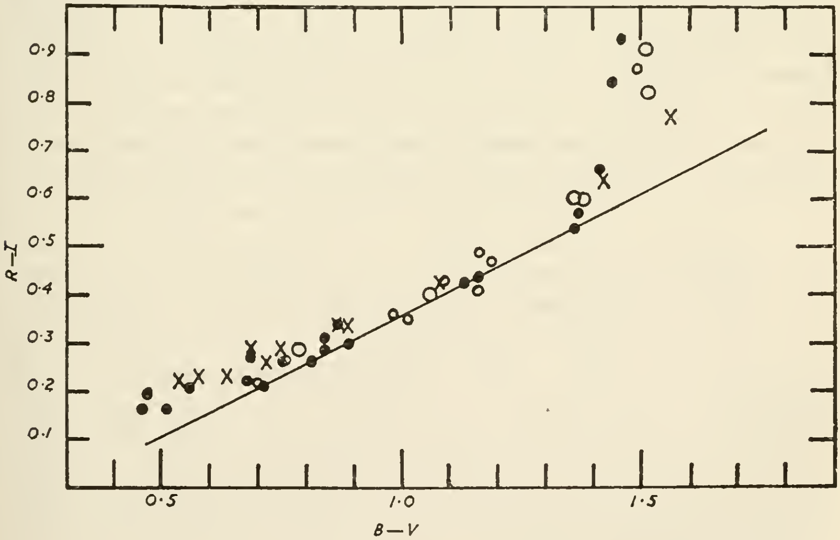


FIGURE 5.—R–I color index plotted against B–V color index. (Courtesy Royal Observatory Bulletins, 1962.)

This is shown in figure 5, where a red and infrared color index measured at the Lick Observatory, Calif., and at Mount Stromlo Observatory in Australia is plotted on the vertical axis against the ordinary blue-yellow color index on the horizontal axis. The vertical axis is now essentially a measure of surface temperature, with cooler stars toward the top and right of the diagram, and the tendency of the subdwarfs and elliptic-orbit stars is to lie to the left of the line defined by the normal dwarfs of Population I, just as we would expect from the relative weakness of their dark absorption lines in the blue part of the spectrum. These results are now being extended by Gerald E. Kron, of the Lick Observatory, who is observing the brightnesses of the stars in six colors—infrared, red, green, blue, violet, and ultraviolet, and his work should soon enable a clear and quite reliable distinction to be made between the effects of surface temperature and metal abundance on the measurements.

CONCLUSION

Probably more than enough has been said now about the somewhat technical details of the interpretation of the brightnesses, colors, and spectra of the stars, and it may be worth while to try to recapitulate a little and especially to repeat some of the reasons why we consider this work to be of general interest. We have seen some—I think—very pleasing pictures of external galaxies that are believed to bear close similarity to our own Milky Way system, and some of the inferences that can be drawn from them as to the two main stellar populations existing in the Galaxy at large and also in our own neighborhood. At one extreme we have Population II distributed in a spherical halo around the center of the Galaxy, consisting of old stars and devoid of interstellar matter. At the other extreme we have Population I concentrated in the central plane of the Galaxy and especially in spiral arms, in which new stars are still being formed by condensation out of the interstellar medium. The examination of the color-luminosity diagrams of the clusters that are characteristic of the two stellar populations, aided by a great deal of theory developed mainly over the last 10 years, has led to a picture of the way in which stars evolve in time which perhaps does not quite explain everything, but does at least provide a framework into which a wide variety of observations can be fitted. This theory has been accompanied by the suggestion of Fred Hoyle and his collaborators that the chemical elements in the universe, and in particular on the Earth, were formed by nuclear synthesis from hydrogen, helium, and neutrons in the interiors of hot stars which then exploded as supernovae; this mechanism scatters the newly formed heavy elements into the interstellar medium, where they mix with the hydrogen already there and form an enriched or contaminated medium—whichever way you prefer to look at it—from which new generations of stars will condense. This picture is in general agreement with spectroscopic observations which show that stars believed to be old, like the ones in globular clusters, have a much lower admixture of metals in their atmospheres than stars thought to be young, like the ones in the Hyades, although there is surprisingly little difference in metal abundance between the oldest and youngest clusters of Population I. Most stars in clusters, however, whether of the globular or the galactic variety, are a very long way off and their distances and real brightnesses can only be estimated by indirect methods that are often little better than guesses. Furthermore, the clusters undoubtedly contain stars that are intrinsically faint and so cannot be observed at all.

For these reasons, our ideas as to the nature of stars and the course of stellar evolution need to be completed by examining the stars that are near to us in space, especially those which are so near that we can measure their distances directly. Except in the case of the Hyades, such stars do not usually belong to clusters, but they may have escaped from clusters in the past; furthermore, we can try to relate them to the stars that are in clusters by observing their motions in space—or in other words their orbits round the center of the Galaxy—and their physical and chemical properties, and it is with this last question that I have been primarily concerned.

The problem of sorting out the true nature of a star from the physical and chemical point of view is quite a complicated one, which has to be tackled from various different angles. First there is the theory of stellar structure, whose task it is to calculate the relationship between the luminosities and surface temperatures of stars and to predict how these quantities will change in the course of time, that is to develop a picture of stellar evolution. Then there is the theory of stellar surfaces, which says what happens to the atoms and electrons in the atmosphere and tries to predict the distribution of energy in the continuous spectrum and the intensities of the various absorption lines, when the luminosity, surface temperature and chemical composition of the atmosphere are given.

When we try to verify these theories by making observations, we come up against a number of difficulties. Ideally, we should like to make direct physical measurements of the quantities discussed in the theory, that is we should like to measure the total brightnesses and surface temperatures of stars and then make a quantitative chemical analysis of the line spectrum to determine the relative abundances of the elements. But the amount of light reaching us from a star is very small, and so we cannot usually examine either the continuous spectrum or the line spectrum in the amount of detail that we should like; the only star that is really satisfactory in this respect is the Sun.

To make what use they can of the minute amounts of light that we get from most stars, astronomers have developed their primitive-sounding methods of photometry through colored glass filters and spectral classification from spectra taken with low resolving power; nowadays spectral classification is often done in a more quantitative way by isolating a narrow band of the spectrum containing the absorption line one is interested in with the aid of an interference filter or a spectrometer, but the principle is still not so very different from the older and cruder method of looking at the spectrum under a microscope and saying that line A is stronger than line B but weaker than line C. All these methods can be broadly described as methods of stellar classification, and they have two great advantages. The first advantage is that relatively little light is required and so one can examine stars, clusters of stars, and even galaxies at very great distances; and methods have been developed of estimating the age of a galaxy from the color distribution or spectrum of the galaxy as a whole, without even looking at the individual stars belonging to it. The other advantage of such methods is their rapidity. Naturally if the measurements are comparatively simple, one can observe a large number of stars in a reasonably short time and so by now extensive lists are available giving spectral types and color indices for thousands of stars. On the other hand, the experience of the last few years has shown that one can quite easily be fooled by the results of these classification methods, because a given result can come about from different causes. An example of this is that the color and the spectral type of a star depend on its chemical composition as well as on its surface temperature; and another example which complicates the issue further is the fact that, if the distance of the star is not known at all, we still have the problem of deciding just how bright it is.

The moral of this is that the extensive lists of comparatively simple observations on many stars have to be supplemented by an intensive attack on a relatively small number of cases by using the more powerful but laborious approach of taking spectra with as high a resolving power as possible and examining the weak lines as well as the strong ones. This has been done so far for no more than about 100 stars, which is far too few, and of course there are difficulties, in particular the fact that it requires huge telescopes to collect enough light for the purpose, even for the study of most of the comparatively nearby stars. A very hopeful technical development in this direction is that of image converter or image intensifier tubes, which have already been brought to a considerable degree of perfection by Professor André Lallemand of Paris Observatory, and which promise to be about 100 times as sensitive as ordinary photography. Even this development, however, does not mean that we shall be able to do without large telescopes, and I hope very much that by about 1966 we shall have a 98-inch telescope operating in this country, at Herstmonceux, which we shall be able to use in extending these investigations; and if this can be supplemented by an even larger telescope in the Southern Hemisphere, then that will be even better.

Astronomical Photography from the Stratosphere[1]

By Martin Schwarzchild

Eugene Higgins Professor of Astronomy, Princeton University

[With 2 plates]

Throughout the centuries astronomers have labored under one enormous handicap that has set harsh limits to all their observational work. Between celestial objects which are the subject of the astronomer's research and his telescope lies the earth's atmosphere, a murky restless layer which forever garbles our only source of information on the universe around our earth. This handicap imposed by the earth's atmosphere has made itself felt most strongly in three broad areas: First, no ultraviolet light with wavelengths shorter than 3,000 angstroms can penetrate the earth's atmosphere at all; this loss of the ultraviolet prohibits us from studying the bulk of the light emitted from the hottest and most energetic stars and prevents us from making accurate measurements regarding many of the astronomically most important chemical elements which have their main absorption lines in this spectral region. Second, large blocks of the infrared spectrum are completely blocked out by the earth's atmosphere and thus we have been unable to study the cooler stars in detail and to measure the absorption bands of many of the key chemical compounds. Third, even the ordinary visible light, though not absorbed by the earth's atmosphere—or at least absorbed only to a minor degree—does not reach our telescopes ungarbled; the turbulence of the atmosphere bends the light rays from the stars slightly and thus prevents us from getting as sharp pictures of the celestial bodies as our instruments otherwise would permit. Even at the best mountain observatories on those rare occasions when the atmosphere above behaved relatively quiescently only a very small number of astronomical photographs have been obtained which show details as small as half a second of arc; this angle corresponds to half a mile on the moon,

[1] The 28th annual James Arthur lecture on the sun, given under the auspices of the Smithsonian Institution on May 8, 1962.

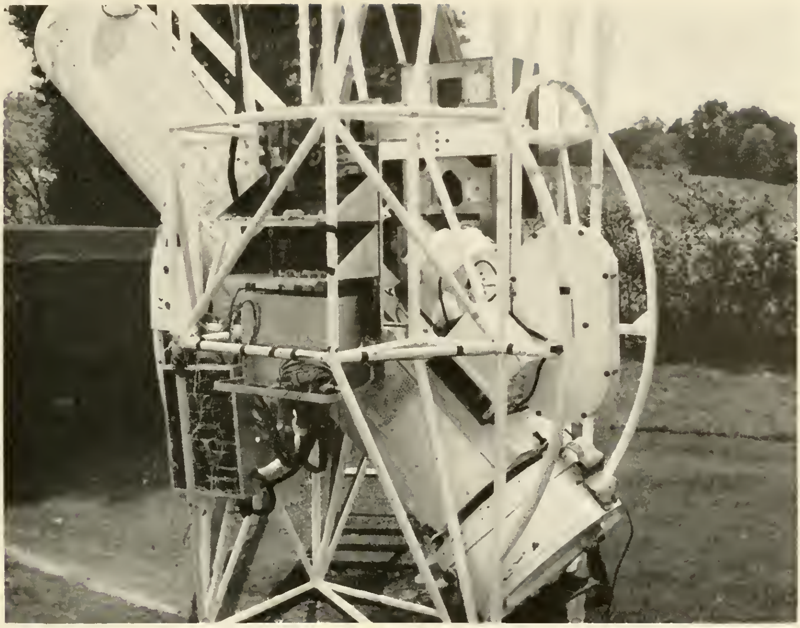
200 miles on the sun, and several light years in the nearest stellar systems such as the spiral Andromeda Nebula. Clearly, even our best photographs have been coarse indeed.

The astronomical profession had adjusted itself through the centuries to labor under this all-prevailing handicap. Then, about a decade ago new technical tools appeared which promised to remove this handicap for good: Rockets began to lift above the earth's atmosphere small telescopes with which for a few short minutes the ultraviolet light of the sun and the stars could be studied; balloons carried astronomical cameras above 95 percent of the atmosphere and brought down for the first time sharper photographs of astronomical objects; now satellites are being developed which will carry major astronomical instruments far above the earth's atmosphere and may permit effective research there for long time intervals.

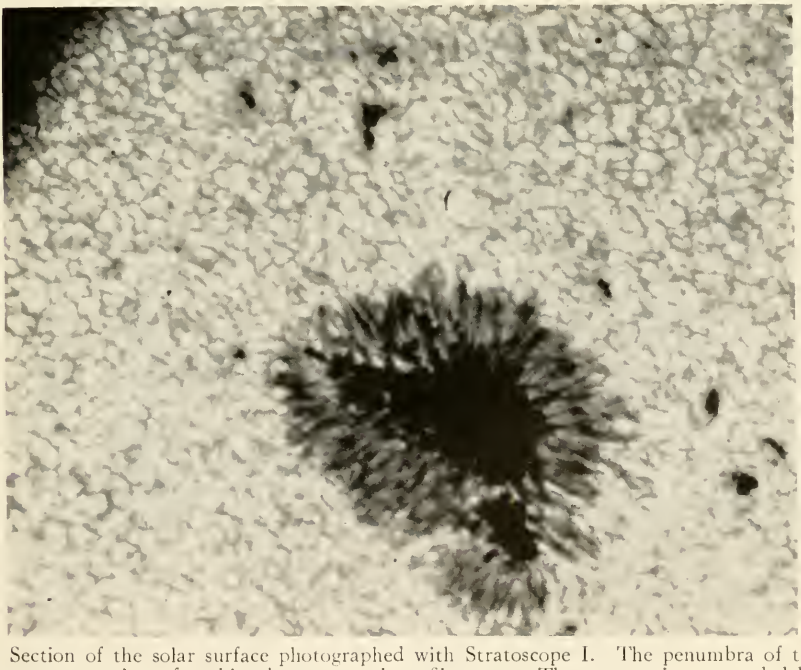
It is hard to describe the force of the impact that this development has had on astronomy as a science and on astronomers as persons. Even now astronomers are far from having reached a balanced adjustment to the new circumstances; we are still swaying back and forth between elation and bewilderment. Nevertheless, I think it is by now obvious that the new tools of rockets, balloons, and satellites open up an immense area for astronomical research, though it would be clearly a grave mistake to consider these new tools actually as replacements for the old ground-based instruments and techniques, rather than as decisive and stimulating additions.

If, from here on, I concentrate entirely on one specific astronomical balloon project—Project Stratoscope—my sole reason is that I am very closely acquainted with this activity. Project Stratoscope is only a minute facet in the entire program of off-the-ground astronomical and geophysical research. However small in the overall research picture, for those of us involved it has been and continues to be an absorbing and immensely exciting activity.

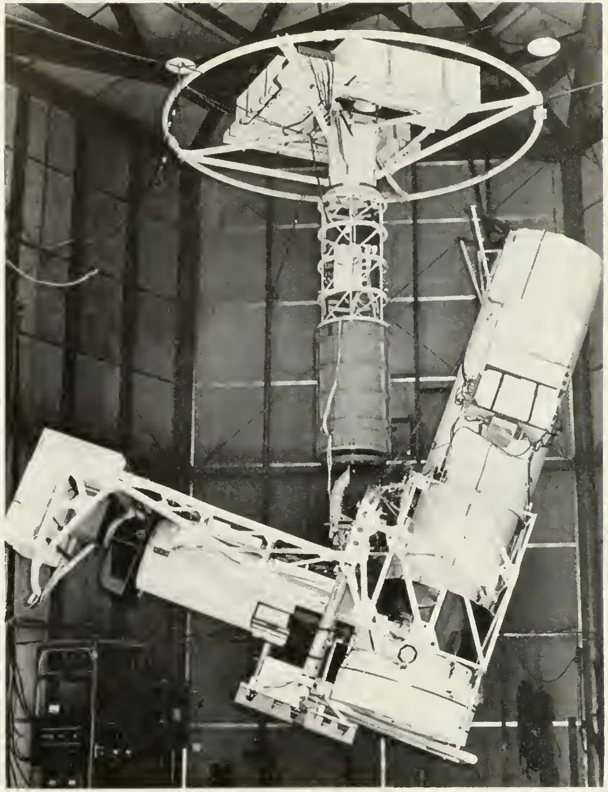
Project Stratoscope arose from a specific scientific problem. The tremendous energies produced by hydrogen burning in the interior of the sun are carried out to the surface by enormous convective movements of the gases in the outer layers of the sun. These convective movements can actually be seen on the surface of the sun in the form of the granulation, the fine mottled structure covering the entire solar surface at all times. It became clear that to understand the detailed mechanism by which this convective motion of the gases transports the heat energies outward is an unavoidable prerequisite to following the evolutionary changes of any star such as the sun. On the other hand, it became desperately clear that, though the detailed observational study of the solar granulation would help much toward this understanding, such detailed observations on the ground were made essentially impossible because of the image deterioration caused by the



1. Stratoscope I. The cylindrical cell at the bottom of the main tube contains the 12-inch primary mirror. The flat elliptical container is the 35-mm. film magazine. Beside it, the rectangular box houses the TV camera which transmits the same picture just being photographed down to the ground station.



2. Section of the solar surface photographed with Stratoscope I. The penumbra of the sunspot consists of nothing but narrow long filaments. The sunspot is surrounded by the granulation which covers the entire solar surface; the bright patches of the granulation are hot convective gas masses rising from the interior.



1. Stratoscope II suspended in its test housing. The tipped L-structure contains the telescope proper, with the 36-inch primary mirror in the bottom of the main tube and the spectrometer at the left end of the side arm.

2. Stratoscope II seconds after its first launch. On top is the "launch balloon" which contains all the necessary helium. During ascent the helium will expand and fill the "main balloon" (here still stretched into a thin cylinder) until it forms a sphere 240 feet in diameter. The telescope at the bottom is attached to the main balloon via a suspension containing the antennae for the radio links and two parachutes.

earth's atmosphere. For this reason we decided to study the possibility of sending a telescope up on a balloon with the specific purpose of obtaining high-definition photographs of sample areas on the solar surface. When these studies indicated that such an undertaking appeared technically feasible we decided to go ahead with it—elated and filled with awe at the same time.

The instrument built for this specific research, Stratoscope I, had to fulfill two central conditions: First, it had to contain optics capable of producing a highly enlarged image of the solar surface on the photographic emulsion; for this purpose a parabolic mirror 12 inches in diameter was used as the primary optical element followed by an enlarging lens which produced an image of part of the solar surface with a scale equivalent to a telescope with a 200-foot focal length. Second, this telescope had to be pointed toward the sun by electrical motors steered by electronic devices so steadily that the telescope would not turn by more than about a fifth of a second of arc in the required exposure time of about two-thousandths of a second of time, an extremely exacting condition on pointing steadiness indeed.

We flew this instrument for the first time in the summer of 1957. After a preliminary test flight with a dummy telescope to determine whether the balloons and launching techniques then employed were capable of safely carrying a delicate optical instrument into the stratosphere and whether the return of the instrument by parachute was practicable, two flights were carried out with Stratoscope I, itself. These two flights brought down 16,000 photographs of parts of the solar surface. Nearly all of these photographs were of poor quality because of a number of instrumental inadequacies disclosed by subsequent analysis. Among this vast number of photographs, however, we found about half a dozen superb ones, which for the first time showed the detailed structure of the convective elements in the solar granulation well. We returned home from that first flight season jubilant—and still filled with a sense of awe.

The next 2 years we were strenuously occupied by measuring and analyzing the fundamental characteristics of the solar convection shown on our best photographs and deducing from these data tentative conclusions regarding convective energy transport in stars relevant for the theory of stellar evolution. At the same time we concentrated hard to eliminate the instrumental faults shown up in the first flights of Stratoscope I. Also, we made one major modification of the instrument which increased greatly the effectiveness of this telescope as a research tool. This was the addition of a radio-command link from a ground station to the unmanned balloon telescope by which the focus of the telescope could be regulated and by which the telescope could be pointed at will to any portion of the solar disk. To make this command link effective we also added a small television link

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which permitted us to see in the ground station exactly the picture being photographed at the telescope.

In the summer of 1959 we were ready for another sequence of flights. The character of these flights was entirely different from those in 1957 in one decisive respect. In 1957 after launch the entire balloon and telescope system operated completely automatically, according to its built-in program of operations without any possibility of human influence during the flight. In 1959, when the balloon had reached its stable altitude of 80,000 feet in the stratosphere, a small group of engineers and astronomers in the ground station took over the actual operation of the telescope through the newly added command and television links. It is hard to describe the excitement we felt as for the first time we saw on the television screen the picture of a piece of the solar surface and as this picture moved about over the surface of the sun in perfect accordance to the radio commands we gave. We thus could select during the flight particularly favorable areas for our research, such as areas on the solar disk far removed from any apparent disturbance like sun spots or prominences. Or, in contrast, we could move to an area occupied by an active sunspot group to study the effects of the magnetic fields in the sunspots on the convective gas motions.

If human control during the flight so greatly increased the effectiveness of this research undertaking, one might ask whether it would not have been better if one of us had gone up in a sealed capsule with the telescope. I believe that such a manned flight would not have been a good choice; the effort required to safeguard the life of the person going up would seem far larger than the effort required in developing the necessary radio links to permit human control from the ground. Furthermore, the person in his capsule, attached to the same suspension from the balloon to which the telescope itself must be attached, would have had to avoid any motion whatsoever to preserve perfect quietness for the telescope pointing. This strong conviction that unmanned balloon flights are preferable for this type of astronomical experiment in no way implies the opinion that manned high-altitude balloon flights have not been of decisive value. Indeed, I believe that without the vital and energetic enthusiasm for manned stratospheric balloon flights balloon technology would never have developed to the state that permitted us to lift Stratoscope I into the stratosphere. I strongly suspect that much the same situation will hold in the satellite field. It seems entirely plausible that most of the research results from the space program will come from unmanned space vehicles. It appears equally true, however, that the natural human urge for manned flight into space is the essential driving force behind the technological developments necessary for any space flights.

But back to Project Stratoscope. After a series of four flights we returned home in the fall of 1959 with a couple of hundred high-definition solar photographs. These contained not only detailed pictures of the granulation, both in undisturbed and in highly disturbed magnetic regions, but also full-time sequences of both types of areas. Thus it became possible in the subsequent analysis to determine not only the distribution of sizes of convective elements in the solar atmosphere but also the average period of time a typical convective element exists. These observational data have greatly strengthened our theoretical picture of convective heat transport in stars. As a matter of fact we at Princeton as well as astronomers at other institutions are continuing with the theoretical developments helped and stimulated by these measurements.

The sun is by no means the only celestial object of which higher definition photographs are needed for the solution of fundamental astronomical research problems. The sky is full of objects the essential details of which are blurred on photographs taken with telescopes on the ground. There is Venus with its cloud cover, the structure of which has hardly been glimpsed. There is the great Orion gas nebula in which we are sure from indirect evidence stars are now being formed; but whether this giant gas mass is smooth or knotty or filamentary we still cannot judge from our present photographs though we need to know before we can securely develop a theory of the origin of stars. There is the Andromeda spiral nebula with its incredibly dense stellar nucleus defying photographic resolution. Many items can be added to this list, all referring to objects that are typical examples of the celestial phenomena filling the universe around us. Of all these it is only for the sun that the modest aperture of 12 inches of Stratoscope I would suffice to obtain substantially sharper photographs than those already available from the ground. The other objects would require a telescope with at least a 36-inch aperture. After the first successful flights of Stratoscope I it was tempting to start studying the feasibility of a larger balloon-borne telescope and in due course we did begin the design and construction of such an instrument—now called Stratoscope II.

The requirements regarding optical perfection and pointing accuracy are, of course, much higher for the larger Stratoscope II than they were for Stratoscope I. For example, the pointing accuracy will have to be better than a thirtieth of a second of arc over exposure times as long as 1 hour to make Stratoscope II fully effective. The requirements on optical perfection and on guidance are much less stringent if Stratoscope II initially is used not for high-definition photography but for spectrophotometric investigations in the infrared. The latter presents another effective astronomical use of a balloon-borne telescope since the few percent of the atmosphere above 80,000 feet are practically transparent in the infrared (though they are still entirely opaque in the ultraviolet). We decided therefore to take a more cautious approach and first use Stratoscope II for a study of the infrared spectrum of Mars during its opposition early in 1963. Stratoscope II was ready for infrared spectrophotometric research in February of this year and was launched on its first flight on the evening of March 1. The events of that night could not have been more exciting for any of us involved.

The late afternoon launching went entirely smoothly; the specially designed balloon, capable of flying a gross load of 13,000 pounds, lifted the 3-ton telescope off the ground by a newly developed static launching method with accelerations not exceeding 0.2 g. In the meantime the ground station had been set up about 200 miles downwind along the predicted flight path for the night. This ground station provided a link between the engineers and scientists in it and the telescope high above it that was far more extensive and versatile than that used in Stratoscope I. In total more than 70 different commands could be transmitted to the instrument and a similar number of data relative to the telescope could be read in the ground station via a telemetry channel. Even a full-scale television channel was available to make possible the acquisition of any object in the sky. Through these radio links Stratoscope II is perhaps at the moment the most versatile scientific robot operated from a far distance by man.

However, as might not be so unexpected, this robot misbehaved in a variety of ways during his first flight. A series of inadequacies and direct failures occurred throughout most of the night. The versatility of the command system made it possible, however, to analyze the difficulties sufficiently well to make possible their correction prior to the next flight, and even to overcome to a certain extent their negative consequences during that first flight. This series of technical difficulties greatly reduced in quality and quantity the scientific material acquired during the night. Nevertheless, it was possible in the last observing hour to obtain a number of tracings of the infrared spectrum of Mars which in combination with the recent observations from the ground in other wavelength regions have already contributed to our knowledge about the chemical composition of the Martian atmosphere.

At the end of the night, when the observational work had been concluded, one more hair-raising complication occurred. The descent of the balloon was initiated by a radio command which opened the helium valve at the top of the balloon. After the valve had opened and enough helium had escaped to give the balloon the appropriate moderate descent rate, another command was given to close the helium valve to avoid any further acceleration. This command failed and in spite of a variety of experiments the helium valve could not be persuaded to close again. In consequence the balloon with the telescope descended more and more rapidly. Finally it became necessary to cut (by another radio command) the balloon from the parachutes and let the telescope come down to earth on the parachutes which are always carried as a safety device. This type of landing is very much rougher than direct landing by balloon. Nevertheless, by miraculous luck the damage suffered by the whole instrument at landing was quite modest and its repair less than a tenth of the total cost of the instrument.

It is obviously always a bit of a disappointment when a first flight of a new instrument does not right away provide all the new exciting scientific data of which theoretically it is capable. But this dims little the pleasure that the new data, however limited, have given us, and much increases our eagerness to correct the inadequacies of the instrument and to get it ready for its next flight.

I have sketched the story of Project Stratoscope up to its present status. May I once more emphasize that Project Stratoscope is only a small facet of the total space activity in this country. But even this small facet clearly requires funds beyond the means of an individual university. Project Stratoscope has been sponsored by three Government agencies, Office of Naval Research, National Science Foundation, and National Aeronautics and Space Administration. These three agencies have in Project Stratoscope a remarkable record not only in continuous effective cooperation with each other but also in their persistence of giving us astronomers in Princeton the freedom to make the scientific and technical decisions.

Even with this strong financial and moral support from the Government, however, we astronomers in Princeton would still be incapable of carrying out the Stratoscope experiments if it were not for the existence of daring engineers and the commercial firms to which they belong who are ready to cast their lot for a good while into a risky pioneering undertaking like Project Stratoscope. We astronomers may know the scientific problems which need attacking and may understand what basic type of instrumentation is needed, but it is the ingenious engineers who—in close and continuous contact with us—design, build, and operate the entire equipment and thus make this type of experiment possible.

Of all the factors, however, which have to be favorable to make an undertaking like Project Stratoscope possible, historically the most remarkable seems to me the spirit prevalent at this time in this country that gives us with enthusiasm the opportunity to proceed with an endeavor that basically has an abstract scientific character and aim. For an astronomer it is an incredibly wonderful time and place to be alive.

The Smithsonian's Satellite-tracking Program: Its History and Organization

PART 2[1]

By E. Nelson Hayes

Chief, Editorial and Publications Division, Smithsonian Astrophysical Observatory

That evening of October 4, 1957, the Observatory Philharmonic Orchestra, which drew its performers from both Harvard and Smithsonian, held its first rehearsal for the tenth annual concert to be given the following spring. As the rehearsal proceeded, the players were one by one quietly called from the room. There was business at hand. The Russians had launched an artificial earth satellite, and these men and women were needed to attempt preliminary estimates of the orbit, to answer inquisitive and often anxious telephone calls from the public, to meet with newsmen, and otherwise to do the thousand and one tasks that marked the beginning of a new era of astronomy.

It would not be too much to say that the rather abrupt ending of that night's rehearsal was the end also of a time when astrophysical research was the private and what seemed to be the impractical pursuit of scientists isolated from the main stream of public life. Since that evening, and perhaps for the first time since the Renaissance, the astronomer has helped to guide the destinies of nations.

THE FIRST DAYS

Word of the launching of Sputnik I had first reached the Observatory at 6:15 of that Friday evening of October 4, 1957. Everyone had left for the weekend except Dr. J. Allen Hynek, associate director in charge of the tracking program, and Kenneth Drummond, his assistant. They were leisurely discussing plans for the following week when the telephone rang. Hynek casually lifted the phone and gave his name.

"Do you have any comments on the Russian satellite?" It was a reporter from a Boston newspaper. Although not taking him quite

[1] Part 1 was published in the Annual Report of the Smithsonian Institution for 1961, pp. 275–322. The present article takes the development of the satellite-tracking program up to early 1958. Other parts are to follow.

seriously, Hynek asked him to read the full dispatch. Only then did he realize that the months of planning and work had suddenly and unexpectedly culminated in the launching of a satellite that now had to be tracked by whatever facilities were operational.

After a few moments of dazed unbelief, Hynek and Drummond began telephoning staff members and some Moonwatch team leaders. A few of both had to be convinced that this was not a joke, that this was indeed the zero hour, not one that they had planned for, but here nevertheless.

As staff members arrived at Kittredge Hall, where most of the satellite-tracking offices were, so also did dozens of people from press, radio, and television. The building was soon a blaze of lights, to which were added the brightness of television and movie lamps and the blinding glare of flashbulbs. It must have been a spectacular display, for a woman living several blocks away reported that the building was on fire, and soon confusion was compounded by a pumper and a hook-and-ladder dispatched to the scene.

Dr. Fred L. Whipple, director of the Smithsonian Astrophysical Observatory, and Leon Campbell, chief of the Moonwatch program, were attending a meeting of the U.S. Committee for the IGY in Washington, D.C. At the end of the afternoon session of October 4, Dr. Whipple boarded a plane to return to Cambridge, and Mr. Campbell went with Dr. Afshar of Iran to Springfield, Va., about 15 miles out of Washington, where as guests of Moonwatch team-leader Robert Dellar they were to attend a practice observing session. At about quarter to seven, Mrs. Dellar called Leon Campbell into the house saying "The Observatory is on the telephone. Mr. Drummond says Russia has launched a satellite!"

In a three-way conversation, Campbell told Drummond and Hynek that the Moonwatch network was sufficiently well organized to enable some teams to observe the satellite. He also suggested that, since he would be on his way the following afternoon to a meeting of the International Astronautical Federation in Barcelona, Spain, Armand Spitz be asked to come to Cambridge to take over temporary direction of Moonwatch operations. Reached later that evening, Spitz promptly agreed and set out for Cambridge.

What had been planned as a mock observing session now became an actual search for a satellite, the first such attempt in the Western world. The telescopes formed the fence pattern that had earlier been determined as the most efficient technique for a Moonwatch team, and soon the observers were at the eyepieces. It was, however, a frustrating and frustrated effort. They did not have the parameters of the orbit; and in any case they were attempting to see what no man had ever seen before by a method that had never previously been employed.

That team was not to make its first observation of Sputnik I until October 15.

Campbell then went to the IGY headquarters in Washington, where for a few hours he served as liaison officer between the Observatory and the scientists in Washington who were attempting to determine the orbit of Sputnik I from the little information available. Early the following morning he flew to Boston.

Meanwhile, Dr. Whipple had arrived at Logan Airport in Boston at about 6:30 p.m. Since evidently no effort had been made to contact him while he was on the plane, he took a taxi directly to his home in Belmont. His wife told him the news, and he immediately went to the Observatory, where he stayed until four in the morning, organizing the activities of dozens of people, meeting with the press, and otherwise dealing with the initial problems of the program.

INITIAL PROBLEMS

The satellite-tracking program faced a number of pressing problems. The first of these was communications. On October 4 there was not a single TWX (teletypewriter exchange) machine installed in the communications room; in fact, because extensive alterations were being made to the offices at Kittredge Hall, there was not even a communications room. Charles M. Peterson pulled every string in his bow, and late that night the first teletype machine was in operation, supplemented, of course, by telephone communications.

The next need was to track the satellite. The first Baker-Nunn camera to be assembled at the Boller and Chivens plant in South Pasadena, Calif., was not operational on the night of October 4. It had been disassembled and was scattered all over the plant; some of the gears and other intricate parts had been sent back to contractors for remachining or refinishing. When Dr. Hynek reported to the staff members in South Pasadena that the Russians had launched a satellite, work had progressed so far that they discussed the possibility of readying the camera for a Saturday night observation of the satellite. Only word from Dr. Whipple that the orbit was definitely poorly situated for observations in Pasadena led to their canceling this plan. Two days later, Boller and Chivens set Wednesday afternoon of October 9 as the deadline for the completion of an operational camera.

Meanwhile, the Observatory received observations of a sort on the evening of October 4, and early the next morning fairly good observations from the Geophysical Institute in College, Alaska. From these data the Observatory was able to advise Moonwatch teams when and where they might be able to sight the satellite. Within a few days a number of Moonwatch teams sent good observations, although actually not of the payload but of its rocket carrier.

Third, the Observatory had to develop as quickly as possible a means for determining accurate predictions of transits of the satellite. This required that in the agonizing weeks to follow the staff work out a successful empirical program, as opposed to the more theoretical methods that Drs. Leland Cunningham and Donald A. Lautman had been preparing.

Finally, the Observatory found itself with many responsibilities for which there was no adequate executive direction from the higher echelons of the Government. The Observatory became the one reliable American source of information about Sputnik I. Thousands of inquiries poured into Kittredge Hall and extra staff had to be hired for whom there was no budget allowance. In addition, a reasonable public information program had to be set up for the press, radio, and television people who, almost literally, besieged the Observatory during the weeks that followed.

SPUTNIKS I AND II

(Satellites 1957 Alpha and Beta)

The launching of the first satellite by the U.S.S.R. came as an overwhelming surprise not only to the American public but also to most officials of the United States Government, including those responsible for the IGY program. Fortunately, however, Dr. Whipple had given considerable thought to this possibility. In a memorandum to Dr. Schilling dated June 18, 1957, he stated that as a matter of policy the Observatory should be on the alert to make orbital calculations and to issue predictions for use not only in the United States but also throughout the world. He conceived this to be an undeniable aspect of the Observatory's responsibility to the IGY. He added that in case of an unexpectedly early satellite or other space effort the announcement card system of the Harvard College Observatory could easily be expanded to provide rapid publication of such data, to be followed by scientific results issued in the journals. He concluded that all members of the Smithsonian satellite-tracking program should consider themselves to be on a general alert beginning July 1. He ended the memorandum—"Exciting thoughts, aren't they?"

Later that month a group of Soviet scientists participated in the third symposium on cosmical gas dynamics at the Smithsonian Astrophysical Observatory in Cambridge. During their visit the Russian delegates showed considerable interest in the IGY program for optical tracking of satellites and suggested close cooperation between Moonwatch and a comparable group then being organized in the U.S.S.R. This interest even extended to the possibility of direct communication between Cambridge and Moscow, in addition to the regular CSAGI world-warning system.

Late in July, Dr. Whipple wrote to Dr. Joseph Kaplan, chairman for the U.S. National Committee for the IGY, a letter concerning the acquisition, optical tracking, and data analysis of U.S.S.R. satellites that might be launched during the IGY. Dr. Whipple felt that serious consideration should be given to the establishment of additional Moonwatch teams at higher latitudes, possibly to 65° north and south, and ultimately to the possibility of expanding the Baker-Nunn camera to 20 network stations. He made clear that these prospects had been in the minds of the Smithsonian staff for some months and involved such further matters as additional computational requirements, public relations problems, the obtaining of preliminary orbital data, and above all the question of how the Observatory should fund the tracking of satellites not launched by the United States. There was clear agreement on the part of the Observatory staff that the nature of the Smithsonian charter involved an obligation that it track any and all satellites and issue the results of such efforts to the public and to the scientific community.

Meanwhile, the Russians had made it perfectly evident that they hoped and planned to launch a satellite before the United States did. The IGY satellites were supposed to broadcast on a frequency of 108 megacycles. The Russians announced, however, through the pages of their journal *Radio* that their satellites would broadcast on 20 and 40 mc. in order to permit the flight of certain basic experiments and the telemetering of data to ground stations. Most U.S. agencies paid no attention whatsoever to these announcements, so that when Sputnik I was launched there was not a single radio-tracking system in the United States able to monitor the satellite. In the words of one rather bitter critic, the United States was "caught with its antennas down."

The only optical tracking facilities available in the United States on October 4, 1957, were those of the Smithsonian Astrophysical Observatory. As a consequence, the Observatory had to undertake immediately an optical tracking program that involved locating and following the satellite, issuing predictions, and similar activities not fully provided for under the IGY grants to the Observatory. This necessity put a heavy strain on the budget, particularly for personnel. The scientists who promptly and willingly undertook to process the data that resulted from the early Moonwatch tracking had to carry on for a number of weeks without positive assurance of additional funding and without precise assignment of responsibilities.

On October 9 the U.S. National Committee for the IGY did issue a memorandum on Sputnik I. Under the heading of Tracking Data, it stated that "visual and optical data should be sent to the Smithsonian Astrophysical Observatory in Cambridge," and radio data to the Vanguard Control Center at Naval Research in Washington, D.C. The memorandum went on to say that "in general, the above institutions should be allowed to make statements on the data and the analysis, for these institutions have been assigned respectively the optical and radio-tracking tasks. Statements by others in these technical areas should be discussed with this office. Statements by the above two institutions should also, if at all possible, be phoned in prior to release." This gave the Observatory an IGY mandate to issue tracking data and other information about the satellite.

Sputnik I (1957 α 2) was a sphere approximately 22 inches in diameter and weighing 184 pounds, made of aluminum alloys, with 4 spring-loaded whip antennas. The power supply for telemetering information to ground stations was a chemical battery. The perigee of the initial orbit was 142 miles, the apogee 158 miles, and the period 96.17 minutes; the inclination to the equator was 64.3°; speed at perigee was 18,000 miles per hour, and at apogee, 16,200 miles per hour.

Little information was immediately forthcoming from the Russians, who showed considerable reluctance to release data concerning the satellite itself. The payload was probably painted black and therefore not visible. The Baker-Nunn cameras never did acquire it, although the Harvard super-Schmidt meteor cameras photographed it on Thanksgiving Day at both Organ Pass and Sacramento Peak, N. Mex.

What was, then, being tracked was the rocket (1957 α 1). On the basis of the first sightings made at College, Alaska, by Dr. Gordon Little and his group, Dr. Whipple called Dr. McCrosky of the Harvard Meteor Program and asked whether it could possibly be a meteor. He replied that he did not think so but rather believed that it was the rocket of Sputnik I. This actually was the first time that anyone had thought about the rocket stage, since all were primarily concerned with the payload.

There followed a policy discussion as to whether Dr. McCrosky's speculation should be issued to the press before it was proved. The decision was that he should be allowed to speak as an individual scientist giving his personal view. This he did, and shortly thereafter the Russians made the same announcement. In an ironic sequel, the Russians later claimed that one of their rocket bodies had fallen in Alaska and that the Americans had it and would not give it to them. A committee of three, consisting of Dr. Schilling, Dr. Whitney, and Stuart Fergusson, determined from computations and all other possible sources of information that the rocket had indeed not landed in U.S. territory.

A year later, when Dr. Whipple was in Russia, he and a few other American scientists visited the exposition of agriculture and mechanical arts to inspect the model of the satellite that was there on display. He confirmed certain physical measurements and other features of the satellite. Up to that time the Russian scientists still had not provided such fundamental data as the mean cross-sectional area of the satellite.

On November 3 the Russians launched their second satellite, 1957 Beta, carrying instruments to detect cosmic-ray, ultraviolet, and X-ray radiation, and an 11-pound dog that died after approximately 100 hours at zero gravity. Transmitters and power supply were similar to those on board Sputnik I. Its perigee was 140 miles, apogee 104 miles, inclination to the equator 65.4°, and its speed 18,000 miles per hour at perigee, and 15,000 miles per hour at apogee. The satellite re-entered the atmosphere and decayed on April 13, 1958.

PRESS AND PUBLIC

The public reaction to Sputnik I was, in the words of Dr. Hynek, "a strange mixture of awe, admiration, and fear, the last enhanced, of course, because there had been no warning." In those early days people wrote thousands of letters, made hundreds of telephone calls, to the Observatory. A few were frankly incredulous; they simply refused to believe that the Russians had the technical capability to launch an artificial satellite when the United States had not yet done so. Others were openly fearful; they believed that Sputnik I carried either atom bombs to destroy the United States or television cameras to spy on her. Not a few felt that the scientist was once again meddling in cosmic affairs that were not his business; their arguments overlooked the fact that man had already profoundly modified his natural environment and would inevitably continue to do so. Then there were the angry ones, who were ready and willing to blame everyone in the Federal Government from President Eisenhower to the obscurest technician in a laboratory for the failure of the United States to beat the Russians into space. Finally, and these were the most numerous, there were those who simply wanted to know; they offered hundreds of questions for answer: What exactly was the orbit of Sputnik I? How had it been launched? What instruments did it carry? How long could it be expected to stay up? Many of these inquiries were from children eager to learn, reflecting a youthful concern for things scientific that was in itself a credit to American education and would provide the materials for the quickening of the American school system in response to the challenge of Sputnik I.

Both Whipple and Hynek had a profound conviction that the people were entitled to know everything. It was their policy from the beginning that no question would go unanswered if the answer could be found. There was never "no comment!" Their thesis was based on the charter of the Smithsonian Institution, which refers to "the increase and diffusion of knowledge." They leaned heavily on that word "diffusion," in the argument that the Smithsonian was a public institution engaged in nonclassified work. Others outside the Observatory wanted the information given out differently; especially there was pressure from IGY headquarters in Washington to have all news statements and releases channeled through that office. Both Whipple and Hynek resisted manfully and successfully.

The Observatory became quite literally the information center for the entire Western world on this new and frightening object in the sky. It was in many ways a terrible responsibility. The slightest word of Whipple or Hynek to the press carried enormous weight. To this was added the complicating factor that Sputnik I was launched into an orbit that made it invisible over the United States for some days. Consequently, in the first few press interviews Whipple and Hynek had to make judicious guesses on the basis of Russian announcements. Their guesses turned out to be correct, and this fact helped to establish in the minds of both the press and the general public that the word of Observatory officials was reliable.

Much of the success of the Observatory in its public relations during those days was the result of the hard work and tactful understanding of Dr. John White, the Observatory's press officer. He helped to "interpret" questions from and replies to the press and served as a kind of watchdog over the remarks made by the Observatory scientists. There were inevitably, of course, a few slips. Perhaps the most glaring of these was a Boston headline reading "Mysterious Force Grips Sputnik," which some imaginative news reporter wrote after Dr. Hynek released a statement to the effect that the orbit of Sputnik I could not be explained solely by the laws of Newton, since other factors such as atmospheric drag were involved.

Of the many reporters who descended on the Observatory that night and stayed through the exciting days and weeks that followed, only a few had any special training or background in science. Most of them were pulled off other assignments. For example, one reporter to the Massachusetts Legislature was sent over to Kittredge Hall because at that time the legislature was not in session. He became an expert in satellites almost overnight.

The newsmen were quick, intelligent, and earnest and showed a remarkable facility for moving into a complicated area of scientific research and development for which they had no suitable background. Most of them, incidentally, went back to their own fields later after the newspapers had been able to find or train science reporters and editors.

The confidence of these reporters was urgently needed. First, the Observatory wanted to see in print stories that were accurate in fact and reassuring in tone. This was a particularly difficult task both for the scientists and for the reporters because the latter, with little background information, had to write intelligent and intelligible stories in a matter of minutes. Second, the Observatory wanted to keep to a minimum stories that would arouse further fear and anxiety among the public. When someone telephoned a newspaper—as frequently happened—and said that he had seen a gigantic flying saucer over his house, the paper had the choice of printing the story or of calling the Observatory for its opinion. More and more the newspapers did the latter. Then the Observatory would say that the report was extremely exaggerated and that probably the man had seen a weather balloon or something of that sort. Inquiries made directly to the Observatory were handled in a similar manner.

How hysterical was some of the response, and how necessary the calm reassuring word of the Observatory, can be judged from events in November. One evening a spectacular red aurora—one of the most startling ever recorded by astronomers—frightened thousands of people. The Observatory received hundreds of telephone calls, as did also the newspapers. People thought that the Russians were painting the sky red or that they were sending a rocket toward the moon, or that a hydrogen bomb had been exploded—there seemed to be no end to the menaces that were seen in this quite natural phenomenon. Through replies to the individuals and statements to the press, the Observatory was able to calm the public by telling them what was actually happening.

A similar incident occurred later that winter when the planet Mars seemed to be close to the moon. The Russians made one of their periodic announcements that they were going to send a probe to the moon, and suddenly people saw this little dot of light and became worried. Many had never even seen the planet before Sputnik I went up. Again, the Observatory sent out reassuring statements. Both these incidents served to dramatize one of the major results of Russian Sputnik I. Millions of people who literally had never before bothered to observe the night skies became increasingly knowledgeable of astronomical matters.

From the first, the Observatory held press conferences daily, at 9 a.m. and at 3 p.m., and these went on for several months. Some newspaper reporters deliberately asked odd questions designed to trap Whipple and Hynek into foolish or melodramatic answers. The conferences were an attempt to establish some kind of order and to give the principals an opportunity to speak under organized conditions and without improper competition among the papers.

At each conference a member of the scientific staff of the Observatory would release the news that had occurred since the preceding one and give reporters a chance to ask questions. All the papers received this material on an equal basis and handled it as they wished. There also was established the standard practice of permitting a reporter to see anybody working on a special project; by this means he could obtain not a news scoop but a color or angle story. If another reporter asked for the same story, he would be told that someone else was on it but that if he still wished to pursue it he could.

Over the months the confidence of press, radio, and television gradually grew. In time they cut down their "death watch" to one man, and each wire service took a turn at night, usually sleeping on the table in what had once been the ladies' lounge in Kittredge Hall. Here, "Chief" Peterson had set up a battery of telephones as another step to preserve fair competition among the newsmen. The final result of these policies was that the reporters left the staff pretty much alone except when the Observatory really had some news to release.

Sputnik I was certainly the best and most widely publicized achievement of modern science. Leafing through the thousands of newspaper clippings on file at the Observatory, one is again and again impressed with the accuracy and the thoroughness of the reportage. And in view of the scarcity of solid information in those first weeks after October 4 it can be said that never was so much known by so many about so little.

THE FIRST TRACKERS

MOONWATCH

Although the Observatory had planned to have Moonwatch fully operational by March 1958, the program was in fact sufficiently ready when Sputnik I was launched to begin supplying observations almost immediately. On October 6 a dubious observation was reported by the team in Terre Haute, Ind. The first confirmed Moonwatch observations were made on October 8 by groups in Sydney and Woomera, Australia; the first in the United States on October 10 by the team in New Haven, Conn.

During those first weeks, essentially all the observational data from visual sightings were furnished by Moonwatch, and from these the Observatory derived such orbital elements and predictions as were then possible.

Here again, Dr. Whipple's conviction, founded upon a profound knowledge of astronomy and a no less profound understanding of human nature, proved to be correct. He had earlier insisted that the Moonwatch program be an effort of amateur astronomers and science enthusiasts, at a time when the military services and other Government agencies felt that amateurs could not be trusted to carry on such a complex and vital program. The unique success of Moonwatch demonstrated what amateurs could do when properly inspired and led. And it should not be overlooked that it was certainly the least expensive effort of the entire IGY program of the United States.

Toward the end of 1957, two significant steps were taken to improve the Moonwatch observations. On November 1 a satellite simulator built under contract by Jack A. Wegener of Gloucester, N.J., was delivered, with arrangements being made for the completion of two more by early 1958. The instrument was intended for training Moonwatch teams in observing satellites. Through an eyepiece the observer could watch an image similar to that which would appear through a Moonwatch telescope sighted on a satellite. The first simulator was sent to a team in the southwest United States, and the Observatory then planned to send it from station to station for training purposes.

As an aid to the many Moonwatch teams scattered around the earth and distributed through a considerable range of latitude, the National Geographic Society in cooperation with the Observatory had by the end of 1957 designed a map and overlay kit that could be used for making estimates of the times at which observation of Sputnik I or II should begin and the altitude and azimuth of the probable passage. These aided considerably in providing the teams with the means of making their own satellite predictions.

By the end of 1957 there were 115 Moonwatch teams registered in the United States, and another 90 in foreign countries—71 of them in Japan. Teams in the United States, Australia, Chile, Japan, and Curaçao had made a total of approximately 700 observations of satellites 1957 Alpha and 1957 Beta. The program had successfully developed into a tracking project not only for the acquisition of satellites but also for observations of them during their "dying" stages.

COMMUNICATIONS AND PUBLICATIONS

Meanwhile, an efficient communications network had been built up by "Chief" Peterson. Messages were being handled through teletype machine models 28 and 19 linked with the commercial network of American Telephone and Telegraph. The first was used primarily for two-way conference calls, the second for the transmission of data to domestic sources and for contacts with overseas networks via American Cable and Radio, Western Union, and R.C.A. A Navy teletype machine (NTX) model 19 provided noncommercial contact with all Government and military installations through the military communications network. Operations were conducted on an around-the-clock basis.

Peterson had an extraordinary ability to conjure up the communications facilities needed and to get word to anyone anywhere. He

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could by means that were not always quite clear locate people for Whipple or Hynek, relying occasionally, one suspects, not only on telephone and telegraph companies but also on any other sources of information. The network he developed was the means by which the very life blood of the tracking program was circulated.

Dr. Whipple felt that the results of the optical satellite-tracking program should be distributed to the scientific community as promptly as possible. He therefore conceived a series of special reports that would publish observations, orbital elements, and scientific results in a matter of days after they had been processed at the Observatory. On October 14, ten days after Sputnik I was launched, the first of these was issued, *The Preliminary Orbit Information for Satellites $\alpha 1$ and $\alpha 2$* by Schilling and Sterne, which listed Moonwatch and other observations. The special reports have continued to be published in ever-increasing numbers.

THE BAKER-NUNN CAMERA

At the end of September, tests of the first Baker-Nunn camera in South Pasadena showed that: (1) The best focus with as yet unfinished optics was within 1 mm. of the value predicted by the manufacturers; (2) the image produced by the optics was composed of three parts—an outer halo, an intermediate core, and a sharp inner core; (3) the initial collimation of the mirror was satisfactory; (4) operation of the camera in several of its modes of mechanical movement indicated that the triaxial mount was highly successful; and (5) some mechanical vibration was observed at high operating speeds although this apparently had little effect on the film exposure. Dr. Whipple then knew for certain that the camera was capable of tracking and photographing the IGY artificial earth satellites.

By September 30, several electronic time standards had been received from the Norrman Laboratories and were being tested. Also Shapiro & Edwards had completed the design of the slave-clock electronic circuit and delivered a prototype to Boller and Chivens, where it was installed in the first camera. The first photographs taken by the complete assembly were rushed to Washington by Stefan Sydor and there displayed to the press and to scientists and administrators attending the IGY meeting. No longer could anyone say that Vanguard was being deliberately delayed because the Baker-Nunn camera was not ready.

After the camera had been torn down, minor adjustments made, and the instrument then reassembled, it was set to photograph the first transit of 1957 α 1 over South Pasadena. On the evening of October 17, everything and everyone were ready. The camera was in good operating condition. Dr. Henize, Sam Whidden, Gerry Barton, and Aubrey Stinnett had received the appropriate predictions from headquarters in Cambridge.

When the satellite appeared in the sky it looked like a large airplane light. In this transit it was orbiting so low and was so large that one probably could have photographed it with a Brownie camera.

Although the observers had no difficulty in acquiring the satellite visually, they did have problems in pointing and training the camera in the right direction. No one had ever used a satellite-tracking camera before, and the orbital information was rather inexact except for the time of the satellite's appearance over the horizon. The predictions called for it to be in an area 29° SSW, although in fact it appeared at approximately 41°.

By might and main the observers swung the camera around until it was sighted along the correct altitude and then moved it by its power drive to the proper elevation. They then started the film mechanism. The satellite took approximately a minute and a half to move from horizon to horizon.

When they developed the film, the observers found that the image of Sputnik I appeared on only four or five frames. Had they been more expert they would have been able during such a transit to photograph the satellite on every frame.

They now had the first satellite film ever made by a tracking camera of the Western world. Prints were made of the best frames and distributed to the press. The wide publicity that resulted properly convinced millions of Americans that if the Russians had put up a satellite, United States scientists had been going through an orderly process of research and development and were now actually able to track the object.

In the nights that followed, the observers reviewed their tracking techniques and within a short time were able to photograph the satellite without difficulty. The camera remained in operation in South Pasadena for about 3 weeks, until Sputnik I was no longer visible in that part of the United States. It was then disassembled and loaded on a van that had been especially provided and equipped by Bekins, a large moving and storage company in southern California. Gerry Barton rode aboard the van from South Pasadena to Las Cruces, a trip of a little more than 24 hours.

INTERIM OBSERVING PROGRAM

In November only one Baker-Nunn camera was in operation to photograph Sputnik I, and no one in this country knew what and when the Russians would launch in the next month or two.

The staff of the New Mexico station of the Harvard Meteor Project demonstrated that the super-Schmidt camera was capable, without any adaptation, of photographing so bright an object as Sputnik I.

Whipple and Hynek then decided upon an interim program for satellite observations, making use of the super-Schmidt camera. One was shipped to the site of the station in Hawaii where, under the direction of Dr. McCrosky, it was operational early in January 1958 and by March had taken a number of satellite films.

A second super-Schmidt camera of the Harvard Meteor Project was sent to Argentina under the supervision of Kenneth Morrison. The observing station there had not yet been completed, the power supply was not working, generators for auxiliary power had proved unreliable, and a small fire had done some damage. The situation was quite unmanageable, and Morrison was never able to use the super-Schmidt to photograph either Sputnik I or Sputnik II.

The Observatory also borrowed two Small Missile Telecameras from the Army Bureau of Ordnance and shipped these to West Palm Beach and to Curaçao. By March these telecameras were tracking satellites. Cinetheodolites were shipped to the stations in Peru, India, and Iran as a possible backup system for the launching of an American satellite. And, of course, the super-Schmidt at the New Mexico station continued to photograph Sputniks I and II until the Baker-Nunn camera was installed there.

In mid-1958 this backup program was discontinued.

FIRST OBSERVER-TRAINING PROGRAM

In September 1957 the men who were to be the first observers at the Baker-Nunn camera stations went to South Pasadena, Calif., where they had an opportunity to become acquainted with the camera, even though not a single one had yet been completed. They could at least see the interior details and could discuss some of the operating problems that might arise. They were also of some help in looking after the construction of the camera-house test facilities that were being built next to the Boller and Chivens plant.

These first observers had little in common except an intense interest in satellite tracking and a romantic desire to visit foreign places. They had all been inspired by the vision and enthusiasm of Whipple and Hynek, and they felt themselves to be pioneers in a new and splendid enterprise.

The group was led by Dr. Karl Henize, Observatory astronomer for the satellite-tracking program. A man of unusual knowledge, he taught as much by doing as by preaching. His deputy was James Knight, welding engineer and lover of telescopes, whose ability to organize men and equipment was invaluable to the program. He later became senior observer at the station in Spain, and then station chief in South Africa. Working closely with them in training the first observers was Aubrey Stinnett, whose knack with machinery had already been a major factor in the development of the Baker-Nunn camera. He was to become the first station chief at Hawaii.

Among the observers was Morgan Thomas, an extremely keen amateur astronomer who by profession had been a technical photographer for Boeing Aircraft; a side activity was the production of documentary films on natural history. The group drew heavily on his mature experience in organizing and running things. He later became the first station chief at Iran.

Sam Whidden, who had earlier been on the Harvard Meteor Project, was actually the first observer to be signed by Smithsonian. He had already become something of an expert in the processing of the film to be used in the Baker-Nunn cameras. He married Marty Holt of the Cambridge staff and together they went to the station in India, where he was the sole American representative. Later, upon their return to this country, he served as a technical liaison officer between the Baker-Nunn network and the Moonwatch program.

Walt Lang, a bearded giant, a graduate of Texas A. and M., and a former pilot of the United States Air Force and later a mathematics instructor, brought to the program an expert knowledge of building design and construction. A man of unusual energy, he went on to supervise the construction of the other stations in North and South America, and later was chief of the station in Hawaii.

Also from Texas A. and M. was Martin Burkhead, the youngest of the group. An enthusiastic electronics engineer, he became chief of the station in Peru and with characteristic devotion and dedication developed there a number of valuable techniques for observing satellites.

An astronomer and mathematician, Robert Cameron made his most significant contribution to the program in developing techniques for precise setting of the Baker-Nunn camera from often inaccurate predictions. He later became the first chief of the station in South Africa.

From Australia came John Grady, who had been working at the Woomera rocket range in the development of missile-tracking techniques. After serving as station chief in Australia through its formative months, he went to Cambridge as specialist in photographic and tracking systems.

Responsibility for the Norrman clock was in the hands of Gerald Barton, an expert in electronics and foreign languages, who instructed the observers in the intricacies of the timing system. Working closely with him was Bud Ledwith, who taught the tricks of computing and allowing for the speed of radio time signals.

Two others who were not observers but were at the New Mexico station at that time should also be mentioned. George Bandemer, a cartographic engineer, was assigned to the project from the Aeronautical Chart and Information Center of the United States Air Force. He brought with him an invaluable knowledge of the working problems of those who map the world from imperfect angular observations. His own interest in satellite tracking grew as he worked with the group, and eventually he became station chief in Argentina. Jed Durrenberger, a senior photomechanical engineer, served as a consultant on the assembly, adjustment, and inspection of the Baker-Nunn camera, and in addition, led the Moonwatch team in Las Cruces.

In the early days of the satellite tracking, at Organ Pass, N. Mex., the Smithsonian Astrophysical Observatory shared quarters with the Harvard Meteor Project, which was also directed by Dr. Whipple. At one end of the building Smithsonian personnel were preparing for the arrival of the Baker-Nunn camera and its auxiliary equipment; at the other end Charles Tougas, Edward Horine, Gunther Schwartz, and Kenneth Morrison were working on the meteor program and at the same time taking photographs of Sputnik I with their super-Schmidt camera. These four knew the night sky with a thoroughness that comes only after many months of intensive observation. Their knowledge became singularly significant in the early development of tracking techniques with the Baker-Nunn camera. Later, Tougas, Morrison, and Horine joined the Smithsonian staff, and each became a station chief.

In October Martin Burkhead and Walter Lang arrived at Organ Pass to prepare for the shipment of the Baker-Nunn camera and to uncrate and store the supplies of chemicals, films, and other materials that would be needed. When the Norrman clock came, they set it up. They erected a prefab powerhouse and put in a 110-volt amplifier, a 5-kilowatt generator, and the wiring to the camera house.

About 2 weeks before the Baker-Nunn arrived at Organ Pass a bad storm took away the roof and one wall of the camera house. With the help of the Harvard Meteor staff, Lang and Burkhead rebuilt the walls and contracted for a new roof, which was installed on November 2. The next day they painted the floor. On November 4 the camera and the observers arrived from South Pasadena, Calif. With them came Dr. Henize, who was in charge of the group, and Aubrey Stinnett and James Knight. The training session, which began on November 12 after the camera had been installed, was to last until December 6.

The men lived at a motel, some 20 miles from the station, owned and operated by George and Irma Duchenki, who were not only host to the group but also father and mother and, when the per diem allowance of the observers did not come through from Cambridge or Washington, friendly bankers.

Those weeks were not without dramatic moments quite unrelated to the satellite-tracking program. Nearby St. Augustine Mountain, some 8,000 feet high, became a challenge to those who were not fully taxed by the demands of setting up the first station. On one climb, Stinnett fractured an ankle and had to be carried down the mountain by Whidden, Grady, and Henize. He was promptly appointed safety officer for the group. One evening Bandemer, in the excitement of pointing out to the Duchenkis a transit of Sputnik I, fell into the grease pit of the gasoline station next door and had to be hospitalized for cuts and bruises.

The training program itself was, of course, wholly without precedent. There had been some talk about preparing an observer's manual, but this proved to be impossible since there was not even a prototype camera to work with at that time. The observers were eager to learn the necessary techniques for the full operation of a tracking station. This involved considerably more than the camera itself. They had to learn how to maintain the Norrman clock, to develop the film, to carry through a field-reduction program of measuring the position of the satellite image on the film, and to maintain efficient communications with headquarters in Cambridge.

The first films taken with the camera in New Mexico were out of focus because the primary corrector cell had unfinished optics. This cell remained in use until March 1958, when it was replaced. Thereafter, the camera was able to acquire the faint image of Explorer I.

Time reduction was very primitive. None of them knew much about the corrections that had to be applied to WWV time in order to calibrate the Norrman clock. At the Harvard Meteor Project, timing was needed to an accuracy of only one-half second, in no way comparable to the millisecond that was the goal of the satellite-tracking system.

The film of the Baker-Nunn camera was somewhat difficult to work with when compared with the concave molded frames used in the Harvard Meteor Project. And there was no microscope available for finding the star field in which the satellite image appeared.

Moonwatch was of major assistance in pinpointing predictions for the first camera. Observatory predictions sent from Cambridge were off by 5 or 10 minutes in Alamogordo, Las Cruces, Albuquerque, and Phoenix. A small group in El Paso—actually not a registered Moonwatch team—called in observations at the last minute to Las Cruces. The Observatory even arranged a conference with five local Moonwatch teams so that they would, when they saw a satellite passage, telephone the position and their location to the Organ Pass station. Finding the satellite image itself was then no particular problem, especially as 1957 α 1 was a very bright object. The observers could run the film through a projector and look among the streaks with five breaks representing the star images to find the point that was the satellite image; at that time the camera was simply matching the apparent motion of the satellite across the sky. Later, the oscillating technique was used experimentally, but then abandoned as unnecessary.

This was, then, a simultaneous process of developing rather involved technical methods and of teaching them to one another. By the end of the first training session, profiting from the experience and knowledge gained in those 6 weeks, the Observatory was able to plan a more efficient and more thorough program for the next group of observers who came through Cambridge and New Mexico early in 1958.

THE BAKER-NUNN CAMERA STATIONS

As each Baker-Nunn camera was completed and tested at the Boller and Chivens plant in South Pasadena, it was couriered by a member of the Observatory staff, usually on a MATS plane, to the station for which it was intended. Table 1 indicates the schedule of shipment, the dates of first successful observations, and the object photographed. By mid-1958 the Observatory could announce that all 12 Baker-Nunn camera stations were operational.

TABLE 1.—*Shipping schedule of Baker-Nunn cameras and first successful observations*

Station	Date camera shipped	Date of first observation	Object photographed [1]
New Mexico	November 2, 1957	November 26, 1957	1957 α1
	1958		
South Africa	February 3	March 18, 1958	1958 Alpha
Australia	February 22	March 11, 1958	1957 Beta
Spain	March 2	March 18, 1958	1957 Beta
Japan	March 20	April 15, 1958	1958 Alpha
India	March 30	August 29, 1958	1958 δ1
Peru	April 8	July 4, 1958	1958 Alpha
Iran	May 1	May 20, 1958	1958 δ1
Curacao	May 5	June 22, 1958	1958 Alpha
Florida	May 8	June 10, 1958	1958 δ2
Argentina	May 15	July 10, 1958	1958 δ2
Hawaii	May 28	July 4, 1958	1958 Alpha

[1] The designation for the first satellites was decided by Dr. Whipple, as later explained in the *Smithsonian Contributions to Astrophysics*, vol. 2, No. 10, p. 189 (1958): "Notation system for satellites. The tentative system of notation, suggested by Whipple, identifies each artificial earth satellite in the following manner: the year of launching is followed by a letter of the Greek alphabet to indicate the order of the satellite's launching within the year, and, when more than one object is observed from one launching, a number is added to indicate relative brightness. When the orbiting rocket assembly or assemblies from one launching are referred to as a whole, or when the components are not distinguished nor considered separately, the Greek letter is spelled out and the succeeding number is omitted."

The first Baker-Nunn films of Satellite 1957 α 1 were taken at South Pasadena on October 17 and at the Organ Pass station in New Mexico on November 26; of 1957 Beta, New Mexico, December 13; of 1958 Alpha, South Africa, March 18, 1958; and of 1958 Beta, New Mexico, March 19, 1958.

Of the 12 Baker-Nunn camera stations, the two in Australia and Japan were staffed entirely by nationals, and equipped by them except for the camera, clock, and electronic accessories. In some of the other countries, at least one national was on the staff of the station, and usually several others provided practical support for station operations.

There were three types of stations. First, there were those wholly operated by fully professional astronomers or their equivalents; these were the stations in Tokyo, India, and Australia, where all or most of the staff were nationals. Second, there were the wholly American groups in Florida, Hawaii, and New Mexico. The remaining six were a "mixed" operation, which proved to be eminently successful. At these stations the Observatory had to develop a working relationship between its own high-speed, fairly well integrated organization and the local people working at and with the station; and because this was essentially an American-oriented scientific program and because in most of the countries there was a lack of personnel trained to do the technical work at the station, the chief of the group was an American.

The Observatory program had been based on the assumption that at most each station would have to observe not more than three or four satellites during a single night's operation. Actually the demands became much heavier as more and more satellites were launched in 1958 and in the years to follow. It is a remarkable tribute to designers and builders of the Baker-Nunn camera and the associated equipment that the stations have proved capable of meeting this ever increasing responsibility.

Again, a historical accident as far as the Americans were concerned offered the time necessary for the stations to develop into a smooth, efficient network. If after Sputnik I the Russians had immediately launched Sputnik II, III, IV, V, and VI—all of them designed for long life—and if Vanguard had been initially successful the Observatory would have had to reorganize its program. Fortunately, with only two or three objects to track during those first few months opportunity was provided for slower but better development of techniques. The stations' basic problem in the early days was making the equipment work and getting reliable results. It was necessarily a program of trial and error. At each station the staff would develop their own particular means and methods of tracking satellites. Some were good, some were mediocre, some were down-right bad. And no matter what the methods, considerable difficulty resulted in correlating the observations from all of the stations. Again, the independence of the first observers proved to be both a boon and a bane, and many of the problems that arose were not to be settled until the first station chiefs' conference in June 1959.

Certain operational hazards plagued the stations for many months. Brief interruptions in tracking occurred in Iran because of cold weather and mechanical troubles with the camera; in Florida, Curaçao, and Japan, because the slave clock had to be overhauled; in India, because of maladjustments of the film transport system.

Each station had its unique problems. In a letter from South Africa to Ken Drummond, Jim Knight neatly summed up several of the pressures experienced in South Africa: "You should know that the job here entails certain things beyond normal situations at normal stations. In addition to running the station, one must act as Moonwatch coordinator for three teams in the Union of South Africa, and now one in Rhodesia. On top of this, there is Dr. Hynek's observing program at Radcliffe, probably a continuing one, and the additional task of spending hours working on time propagation studies."

And at every station there was the necessity for dealing tactfully, constructively, and intelligently with the local people. In a sense, the nine Baker-Nunn camera stations overseas might be thought of as harbingers of the Peace Corps, and like that group they had both their successes and their failures.

The first months of the stations were all the more exciting and all the more frustrating because the initial predictions from Cambridge were not of the desired accuracy. The perturbations of a satellite with a significantly low perigee are such that if it is not observed on a regular schedule or if bad weather or poor twilight conditions interfere for a few weeks, predictions of time may become uncertain by a matter of minutes, and of the position of the orbital plane by a matter of tens of miles. In this situation, the observer had to develop search techniques, which might require a half hour of preparation, a half hour of observing, and many hours of scanning the films.

For 1957 α 1, the observers tried all the observing techniques that could be used with the Baker-Nunn camera. They kept the camera motionless, so that the satellite image would appear as a trail; they tracked the satellite so that the stars would form trails and the object would be a pinpoint; and they used the oscillating technique that allowed both modes. The last method was not used very much after the first few months because the observers soon realized that they were devoting a good deal of time and energy to obtaining results that really were not needed, particularly for satellites of the brightness of 1957 Alpha and Beta.

Insofar as possible the Observatory wanted long-arc observations; in other words, photographs that showed the satellite as it appeared over the horizon, at culmination, and through to the other horizon. While the camera could track at variable speeds in order to match the apparent motion of the satellite, it could not follow the same pattern without changes in altitude of the line of sight. There were two aspects to this problem: one, to predict the path; the other, to have the camera follow it. The observers improvised various means of achieving these ends.

When the camera followed the motion of the satellite, the satellite image on the film would appear as a pinpoint and therefore might be very difficult to find. The observer soon discovered that elongated images could be obtained just by holding the shutter open and jiggling the mechanism a little bit. By this means they had their first real opportunity to detect faint satellite images.

Since some of the predictions were not accurate, the observer often had to pattern the sky for the satellite; that is, he would scan the sky with a camera, making changes of altitude and other corrections, hopping by this means to catch the satellite.

After the film was developed, the observer had to identify the position of the satellite image among the stars. The staff of the Harvard Meteor Project in New Mexico had literally memorized the night sky. When, using the super-Schmidt, they photographed a satellite passage, they made a mental note that it went 2° south of the star Fomalhaut. They then took out the CD star chart and fitted the field against that of the film.

The new observers of the Smithsonian program had no such knowledge and experience, so they had to find other means of identifying the star field quickly. Tables were prepared for rapidly converting azimuth and altitude, known sidereal time, and even the right ascension and declination, on a star chart. Also mechanical means such as a navigation globe were developed.

At first observers would spend as much as 9 or 10 hours identifying the star field. As the satellite load increased, this became an impossible procedure. Each station developed its own particular technique for identifying the star field, and only much later would these be standardized to a common procedure.

Finally, most of the stations had some problems with the power supply to the Norrman clock and the slave clock. At the New Mexico, Florida, Hawaii, and South Africa stations there were only small and infrequent fluctuations of power in the commercial line, and few power failures. At the other oversea stations, however, the voltage fluctuations were often quite considerable so that the time presentation of the slave clock would vary considerably. When the field-reduced satellite position and time were sent to Cambridge, the errors in timing became, of course, a source of errors in new predictions generated from them.

COMPUTATIONS

The Soviet Union told the outside world little concerning the orbits of Sputniks I and II. In fact, much of the data they distributed to the Western press and to the IGY consisted merely of the times of transit over major cities in both hemispheres. Nevertheless, scientists of the Smithsonian Astrophysical Observatory and those of other agencies and organizations were able in a very short time to issue relatively accurate information and even, later, to predict the demise of Sputnik II so precisely that the Russians claimed they must be fabricating rather than forecasting.

The problems that confronted the computations staff on the night of October 4 seemed overwhelming. The orbital programs that had been worked out by Drs. Cunningham and Lautman could not be used in tracking Sputnik I. The initial orbit determination program that Slowey and Briggs had written was still being debugged and would not be ready for a day or two for practical computations.

None of these programs included air drag; scientists everywhere had believed that it would have only a small effect on the orbit of an artificial earth satellite because they greatly underestimated the atmospheric density between 100 and 200 km. above the surface of the earth.

Then too, the United States had planned to launch its first satellite—which it assumed would be the first satellite—at a height at which air drag would not have been a very important factor. Sputnik I, however, was moving low in the atmosphere.

Furthermore, the errors of the first observations received by the Observatory were much larger than those that astronomers were accustomed to in the study of celestial mechanics. The computation methods at hand were necessarily sensitive to errors of observations, so that when the observations were poor, the orbit derived from them, if one could be derived at all, was necessarily poor.

Finally, the practical philosophy of the Smithsonian Astrophysical Observatory was to accumulate as many observations as possible, rather than to work with a minimum number from the field. Ultimately, the effort to combine dozens of observations into the determination of an orbit proved highly successful. At first, however, provisional techniques had to be developed to use whatever data were at hand.

The Observatory was not, of course, alone in this dilemma. The satellite-orbit programs of other observatories failed initially for much the same reasons. In all fairness, it should be noted that no one could have realized all the intricacies of atmospheric density determined by seasonal, diurnal, and solar variations. Indeed, had it been possible to predict these intricacies, there would have been considerably less purpose to any passive tracking system.

In the months that followed the launching of Sputnik I the computations staff of the Observatory had a very difficult and very busy time. They rapidly gained the experience that they all had lacked, experience that had been impossible before a satellite was actually launched. They realized early the magnitude of the job before them, and were particularly conscious of the importance of air drag in the computing of satellite predictions. All of them were under constant and heavy pressure, not only to organize an efficient means of generating predictions but also to help establish and maintain good relations with a now somewhat doubting public. Most of them during those first weeks worked as much as 18 hours a day. Cots were set up at Kittredge Hall, so that many of the computers simply did not go home at all until they had achieved a basic and necessary success.

Their diligence and devotion were matched by those of other members of the Observatory staff, and especially of the wives of all of them. Headed by Mrs. Whipple and Mrs. Hynek, these good women maintained a constant supply of coffee, sandwiches, clean shirts, and other necessities.

The first observations were, to say the least, rather inconsistent; that is, the format and the data were not the same from one to the next. In addition, some of these observations came from places that had not been adequately "located"; for example, if someone informed the Observatory that he had witnessed a transit of the satellite, the computers had to find out as exactly as possible the coordinates of his position. There was, then, a complex job of the bookkeeping, as well as an equally complex task of reducing the data to a consistent format.

In addition to its own scientists and technicians the Observatory called on mathematicians and astronomers of the Harvard staff, particularly Drs. Frances Wright and Richard McCrosky, to help during these first stages.

Jack Slowey, Robert Briggs, and Dr. John Rossoni of IBM soon had the initial orbit program in operation. Through the traditional Harvard Announcement Card (No. 1375) a preliminary estimate of the orbit of Sputnik I was published on October 15.

In theory, an orbit can be predicted from a set of any three observations. In their urgency to derive the orbit of Sputnik I, mathematicians of the Observatory took such a set of three observations and fed it through the initial orbit program. When the results did not seem to match their estimate of the orbit, they rejected it and tried another set. Eventually, one orbit determined by this means fairly well matched their estimate, and it was this that was distributed to the scientific community and to the press.

Thereafter, the staff processed individually each of the observations, most of which were naked-eye or Moonwatch sightings made in the United States; no photographic observations were available during the first 2 weeks. The Observatory was primarily interested, at this point, in making predictions of transits over the United States. Many data were required to eliminate errors.

On a large map of the United States the computers marked for each sighting a spot to indicate where the observer was. Ideally, his observation would have: (1) The time at which he made it; (2) the azimuth, or the direction along the horizon; and (3) the elevation above the horizon. Observations in a different form, in which data were given with respect to the star background, had to be reduced to readings of azimuth and elevation.

From the position of the observer, the staff would draw a line in the direction in which he saw the satellite, which was the azimuth that he observed. They computed from the orbital period the height of the satellite above the surface of the earth.

If the orbit is perfectly circular, then its height above the earth is essentially independent of its position in the orbit. One takes the elevation above the horizon at which the satellite was observed, and combines this datum with the height estimated from the orbital period. One can then calculate by simple trigonometry the distance of the satellite from the observer, and on this azimuth line, mark a point for the estimated position of the satellite.

This was done for one evening's observations. Say the satellite passed over New England. There would be perhaps half a dozen observations. From each of these one derived a point representing the position of the satellite projected onto the surface of the earth at the time of the observation. There resulted half a dozen points, more or less on a line. A straight line was drawn among these points as well as possible. By noticing how the points fell in relation to the line, one could go back and correct the estimate of the height of the satellite and obtain a more consistant analysis of these particular observations. The line on the surface of the earth represented a trajectory of the satellite for that evening's pass. Then, from a similar set of data for the following evening, one plotted another line on the surface of the earth, representing the passage of the satellite for that evening. At this point, there was enough information to compute with fair accuracy the period of the satellite—essentially its velocity—and find the position of the line on the surface of the earth for the following evening just by extrapolating the data. The Observatory staff did this partly by using a theory that predicted the motion of this line produced by the flattening of the earth, but since they did not know with sufficient accuracy what the flattening was, they did not trust the extrapolation they obtained this way.

After the first week or so the staff became a little more sophisticated. Instead of going to the map, they would start with a desk computer. The problem was again one of trigonometry, of finding the position of the satetille, plotting the positions of the satellite corresponding to the observations, and then trying to fit lines through them so that they could predict ahead. The major difficulty was that the orbital period was shortening fairly drastically, so they needed a good way of determining how the period changed with time to allow them to extrapolate ahead.

When Dr. Luigi Jacchia of the Harvard Meteor program returned from Italy late in October, Dr. Whipple asked him to take a hand in the computations work. He immediately considered what stop-gap measure might best utilize Moonwatch and other observations to derive more accurate and more automated predictions. He devised the so-called subsatellite program that could be fed into an electronic computer to reduce each observation. From a fairly accurate orbit—and by this time the Observatory had such orbits—the program would compute for each observation the position of the node and the time of the crossing of the equator. Then, from a diagram based on these two quantities, the program would allow one to follow the object and to make predictions for a fairly long period of time. After some preliminary experiments with the program by hand computation, Dr. Jacchia asked Robert Briggs to set it up for the IBM–650, an electronic computer with which he was familiar. By late November, the Observatory was able to reduce an observation in something less than one minute of machine time and to prepare reasonably precise predictions of transit of Satellites 1957 Alpha and 1957 Beta.

The program developed by Jacchia could not be used by itself to derive orbital elements. There were five other orbital elements that still had to be determined (see part 1 of this history). The program could derive discrepancies between the observations and the assumed orbital elements, in much the same way that Lautman's program was later to operate. It was now a question of taking these discrepancies and plotting them in order to decide which orbital element most needed correction, improve that one, and then continue this analysis of the observations again to find a new set of discrepancies; and so on. Although, in a sense, the program was, as Dr. Hynek described it, a "quick and dirty approach," for the next year and a half it was the work horse of the Computations and Analysis Division.

Jacchia found that he had unofficially taken on the task of predicting the positions of the first two Russian satellites, which he continued to do until April 1958, and which resulted in his writing the historically memorable Special Report No. 15 on the demise of Sputnik II.

By the end of 1957, the initial orbit determination program of Slowey and Briggs had been completed, debugged, and was being used to generate orbits. A loading routine had been written to permit observations to be read directly into the computer in the form in which they were received, with reduction being done internally and automatically. Another addition to the program was the inclusion of a routine to find suitable starting values for the topocentric distances that the program used to obtain correct orbits. On December 28 Mr. Slowey presented a general description of the method and program to a meeting of the American Astronomical Society in Indianapolis, Ind. It was estimated that the program was at least 90 percent effective in producing orbits from sets of observations chosen at random.

By the end of the year, 1,956 observations of Satellite 1957 α 1, 43 dubious observations of 1957 α 2, and 494 observations of 1957 Beta had been processed.

A master list of station coordinates, including the identification number and the height of the station above sea level, had been compiled in a form that could be used as input for the IBM–704 computer. Included in this list were all registered Moonwatch teams, selected American and foreign observatories, and a number of miscellaneous observers.

Predictions were by this time essentially of two types; the first consisted of an ephemeris giving the time and longitude of all crossings of the 40th parallel; these were distributed to the press, to observation teams throughout the world, and to interested individuals and agencies. The second consisted of an ephemeris giving more detailed and specific information for special observation teams such as Moonwatch. Both ephemerides were programed for the IBM–704 computer.

PROJECT VANGUARD

Meanwhile the American public had been clamoring for a U.S. satellite, to challenge the dramatic successes of the Soviet space program. Seemingly the only possibility for a launching lay with Project Vanguard, since it was the one official satellite program for the IGY; no alternative was being developed.

While the public was impatient, the directors of Vanguard were proceeding with necessary and commendable caution. They had defined the project as "a complete system for space exploration," for it included not only the design, manufacture, test, and launch of the rocket and its payload but also the development of launch, tracking computation, and other operational facilities.

As a pioneer undertaking, Project Vanguard was confronted with delays and frustrations toward which the public showed singularly little sympathy and understanding. In addition, the project was plagued by lack of adequate funding. The program had been specifically designated as nonmilitary, in keeping with the spirit of the IGY, yet the monies for it came out of the budget for the Department of Defense. To further complicate matters, first plans for Vanguard grossly underestimated the funding that would be necessary.

On December 6, 1957, what had originally been planned as a test became in fact the first American attempt to orbit a small sphere carrying a radio transmitter. The effort failed, to worldwide publicity that was reinforced by a second miss on February 5, 1958. One result has been that in the minds of many Americans, Project Vanguard was a failure, when in fact the program "produced a basic concept of launch vehicles . . . (and) pioneered the use of advanced state-of-the-art techniques." [2]

On November 8, 1957, the newly appointed Secretary of Defense, Neil H. McElroy, ordered the Army to undertake its own satellite launching. By coincidence or contrivance, Von Braun and his group had almost ready an assembly of Redstone and Sergeant rockets to send a satellite into orbit. The payload that had been planned for the Vanguard satellite was modified for the Army assembly, and a target date of January 31, 1958, set for the launching.

[2] "The Early Years: Goddard Space Flight Center," National Aeronautics and Space Administration, 1964, p. 16.

The Neutrinos[1]

By Melvin Schwartz
Professor of Physics, Columbia University

[With one plate]

In recent months, the attention of physics has centered upon the most elusive of all elementary particles—the neutrino. A recent experiment at Brookhaven National Laboratory and Columbia University has shown that there exists in nature two independent types of neutrinos—one associated with electrons and the other associated with mu mesons. This experiment has also opened a new chapter in high energy physics—namely, the study of energetic neutrino interactions.

To understand the neutrino and the history of its discovery, we must go back some 30 or 40 years. At that time, much less was known about nuclear physics than is known today but, on the other hand, the triumphs of quantum mechanics were fresh and exciting and many of the conservation laws of physics were on a very firm footing. In particular, conservation of energy was a cornerstone of the edifice which had been built up in the three centuries since Newton's time.

While investigating the behavior of nuclei, physicists had noted the phenomenon called beta decay. They observed that occasionally a nucleus would spontaneously emit an electron (or its antiparticle, a positron) and change into another nucleus (fig. 1). Now if this were all that were happening, we would expect the electron and the residual nucleus to travel off in opposite directions, with the electron having a unique energy. We would expect that the total energy of the electron and the residual nucleus should add up to the total energy of the initial nucleus (including the energy equivalent of the masses involved by means of the relation $E = mc^2$).

Now in these early experiments it was not possible to observe the residual nucleus, but measurements of the electron energy alone indicated a difficulty. Its energy was not unique; indeed, it showed a continuous spectrum of energies up to a certain maximum value.

[1] Reprinted by permission from *Discovery* (London), vol. 23, No. 11, November 1962.

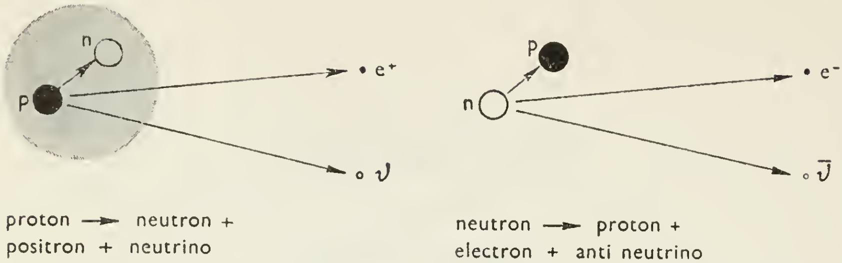


FIGURE 1.—Two examples of beta-decay, that on the left occurring only within the nu cleus. It was to carry away excess energy in beta-decay that the neutrino was first postulated in the 1930's. Decay is governed by the weak interaction.

This maximum value corresponded to the energy that might have been expected for all of the electrons. The lack of uniqueness of the electron energy appeared to be prima-facie evidence of a lack of energy conservation in beta decay.

Now, with the level of sophistication which prevails in today's physics, the answer would have been obvious. As it was, it took the enormous insight of Wolfgang Pauli to see it. To solve the dilemma, he suggested that another particle had to be emitted—a particle carrying no charge and having a mass less than that of the electron. This particle would serve to carry away the energy that was clearly missing. The only known particle with mass less than the electron was the photon—the quantum of light. That was easily ruled out in the case of beta decay and so the particle which was sought was one whose presence was completely unknown until then.

A very short time later, Enrico Fermi struck the crucial blow in favor of the Pauli hypothesis. He developed a theory which explained, in large measure, the detailed shape of the electron spectrum from the beta decay. That is to say, he was able to predict, with accuracy, the probability of observing particular electron energies. The key ingredient of his theory was a new particle which he labeled the neutrino—"the little neutral one." To agree with experiment, the mass of the neutrino had to be very small compared to that of the electron. At present, it is assumed to be zero.

PARTICLES AND ANTIPARTICLES

Before proceeding, let us make a slight digression based on work which has taken place since that time. For every particle which can exist in nature there is an antiparticle whose existence is also allowed. In the case of a particle which carries an electrical charge, the antiparticle carries an equal and opposite charge. The positron, for example, is the antiparticle of the electron. In the case of an electrically neutral particle, the antiparticle is, of course, also neutral. Now in the latter case the antiparticle and particle may be completely indistinguishable, in which case they are assumed to be the same particle. Experiments done in the last 10 years have shown that the neutrino and the antineutrino are in fact distinguishable in some of their physical properties. Insofar as beta decay is concerned, the appearance of an electron seems to be accompanied by the production of an antineutrino while the appearance of a positron seems to be accompanied by the production of a neutrino (fig. 1). The decision as to which shall be called neutrino and which antineutrino is made by convention.

THE FOUR INTERACTIONS

To return to our story, beta decay is an example of a class of interactions which have acquired the label "weak." In nature there appear to be four quite distinct types of interactions, each with its characteristic strength. Listed in order of decreasing strength they are: Strong, electromagnetic, weak, and gravitational. The first three are the only ones which concern us when we discuss nuclear phenomena. Their respective strengths are roughly in the ratio of 10^{13} to 10^{11} to 1. The strong interactions are responsible for holding a nucleus together against the repulsive electromagnetic interactions among the various protons. The weak interactions are responsible for beta decay. Among the above three types of interactions the neutrinos participate only in the weak. Were it not for this class of interactions, neutrinos would not exist at all (or, at best, they would be *completely* undetectable and irrelevant to the rest of nature). It is the weakness of its interaction with matter that makes the neutrino so elusive. Just how difficult it has been to detect will shortly become apparent.

THE NEUTRINO IS NEEDED AGAIN

As we have said, the neutrino was born out of the theoretical need to preserve one of the fundamental laws of physics. Since it was first proposed, more detailed experiments have shown that its presence was also necessary to preserve other conservation laws. For example, measurements of the direction in which the residual nucleus went showed an apparent violation of momentum conservation. The same neutrino also resolved the difficulty here. Furthermore, it was necessary for the neutrino to carry away angular momentum—indeed, precise measurement showed that the neutrino carries the same intrinsic angular momentum as the electron. All of these experiments served to endow the neutrino with practically all of its properties before it was ever observed directly.

But now we turn back the clock again some 20 years for the beginning of another major chapter in the neutrino story—the discovery of the pi meson (or pion, as it is often called). Hideki Yukawa had calculated that the forces which bind a nucleus together should

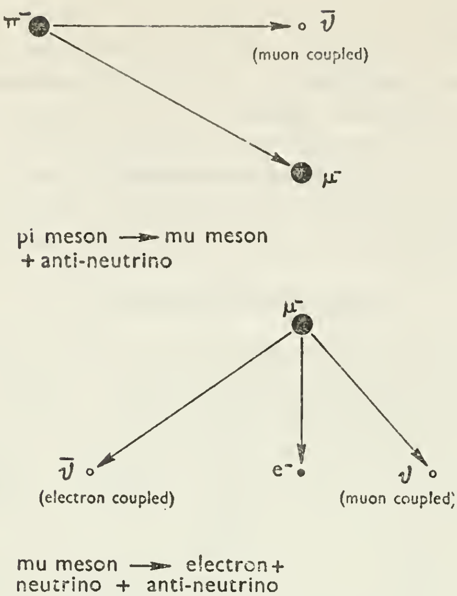


FIGURE 2.—Decays of pion and muon both involve neutrinos (or antineutrinos). It is now known that two kinds of neutrino are involved, as indicated in the diagram.

be the result of a particle with a mass equal to several hundred electron masses. A search for the pi meson in cosmic rays led to the discovery of a particle with a mass not too different from the predicted one. However, detailed experiments showed that this new particle did not participate in the strong interactions and hence could not be the pion. It was subsequently called the mu meson (or muon). Its origin was a complete mystery until sometime later when the pion was finally found and observed to decay spontaneously into the muon.

But now the picture was again not quite complete. During this decay of a pion into a muon there was also an apparent failure to conserve energy and momentum. Another particle had to be formed as well. Careful measurement indicated that the neutrino fitted perfectly, and so for many years the same neutrino which participated in beta decay was presumed to participate in pion decay (fig. 2). Furthermore, a study of the muon itself showed that it apparently decayed in several millionths of a second into an electron, a neutrino, and an antineutrino.

PARITY VIOLATED

Historically, this brings us to the mid-fifties and the beginning of a new era in the understanding of the weak interaction. One of the fundamental "principles" in the development of quantum mechanics until that time was the law of parity conservation. It states that the laws of physics which one would deduce from observing nature directly must be identical to the laws of physics one would deduce from observing nature through a mirror. About that time, however, physicists observed what appeared to be a violation of the parity law in the decay of the K meson—which also took place by way of the weak interactions.

As is always the case, physicists tried to preserve the rule by inventing all sorts of other schemes. However, T. D. Lee and C. N. Yang, surveying all of the experimental evidence existing until that time, pointed out (in a now famous paper which won the Nobel Prize for physics in 1957) that the only evidence for parity conservation existed in the realm of the strong and electromagnetic interactions. They proposed a series of experiments to investigate the validity of this rule in the realm of the weak interaction. The first crucial experiment was performed by E. Ambler and C. S. Wu at the U.S. National Bureau of Standards in 1956 and showed conclusively that parity was not conserved in beta decay. They thus resolved the problem at hand and opened the way for a large series of additional experiments on beta decay, pion decay, and muon decay.

In each of these reactions, the violation of the parity rule became apparent. Insofar as the neutrinos were concerned, the parity violation gave rise to a most fascinating aspect of their behavior. A neutrino always travels as though it were a left-handed screw. An antineutrino, on the other hand, travels like a right-handed screw. The verification of these and other properties of the weak interaction encompassed one of the most productive periods in modern physics. Further progress was made shortly afterwards when R. Feynman and M. Gell-Mann, in a brilliant paper, showed that all the features of both beta decay and muon decay can be explained by one relatively simple theory which seemed to be quite universal in its aspects. Indeed, almost *too* universal, for it predicted that there was no difference in the basic interaction of the electron and muon with other particles. In a sense, this was quite puzzling because the two particles differ in mass by a factor of 200, and physicists tend to think of mass as largely the result of interaction properties. This puzzle is, as yet, unresolved. And, as we will shortly see, it has become even sharper in recent months.

THE NEUTRINO IS DETECTED

The mid-fifties also saw another great achievement in neutrino physics—the first direct observation of neutrino-induced reactions. C. Cowan and F. Reines, working at a large nuclear reactor, observed antineutrinos which were emitted by beta decays within the reactor. On the average, these particles could spend a full year traveling in a straight line through solid lead before being absorbed. It was only by passing a phenomenal number of them through a detector that they could be detected at all. Those few which did interact in the detector initiated the reaction:

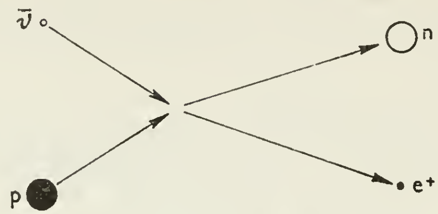


FIGURE 3

It was the simultaneous appearance of the reaction products which indicated to the experimenters that an antineutrino had been stopped. The completion of this experiment yielded the final proof that the neutrino really existed—anticlimatic in a sense but, nevertheless, essential.

As we have said before, the theory was, in some sense, in good shape. It was possible to calculate low-energy neutrino phenomena with substantial accuracy. However, in all of this there was a basic, deep-rooted difficulty. The theory predicted that as the neutrino energy increased, its reaction rate should increase proportionately. Above a certain energy this leads to serious difficulties which make the theory untenable. Just how the theory would have to be modified to avoid these difficulties is not at all apparent. The simplest proposal—one which actually dates back to Yukawa—is that there exists a particle which is responsible for the weak interactions. This particle, by introducing a certain level of structure to the weak interactions, could serve to moderate the interaction rate at high energies and, consequently, avoid the difficulties. The particle in question is referred to by physicists as the "intermediate boson."

One difficulty with the intermediate boson theory was pointed out by G. Feinberg several years ago. He showed that if there were such a particle involved in the weak interactions, then one should expect that once in every 10,000 or so ordinary muon decays the muon should decay into an electron and a gamma ray (rather than an electron, a neutrino, and an antineutrino). Experimental tests showed that this event happened less than once every 10^8 normal muon decays. This seemed to rule out the intermediate boson and Lee and Yang also pointed out that *any* mechanism for removing the weak interaction difficulty at high energies would run into the same problem. The only solution to this paradox and one which had been favored by numerous theorists seemed to be that the neutrino coupled to the muon and the neutrino coupled to the electron (fig. 2) are *not the same particle.* If this were the case, the decay of a muon into an electron and a gamma ray would be absolutely forbidden independent of the existence of an intermediate boson.

DISCOVERY OF TWO NEUTRINOS

It remained then to devise a proper test for this hypothesis. B. Pontecorvo of the Soviet Union and the author independently pointed out that it is feasible to do experiments with high energy neutrinos in presently existing or planned accelerators. In these accelerators, protons are brought up to energies in the multibillion-electron-volt region and are then allowed to strike a target. Out of this target come mainly pi mesons, most of which decay shortly into muons and their neutrinos. If these neutrinos were identical to the electron-coupled neutrinos, when they interacted with matter (a neutron in a nucleus, for example) they would produce electrons as often as muons.

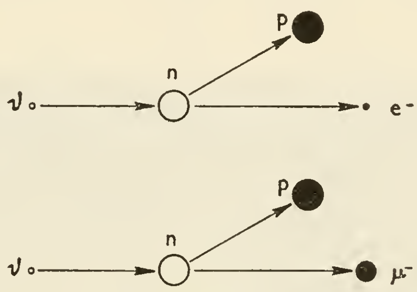


FIGURE 4

If they were different from the electron-coupled neutrinos, they could produce only muons and no electrons at all.

The proposed experiment has just been completed at Brookhaven National Laboratory by a group including G. Danby, J. M. Gaillard, K. Goulianos, L. Lederman, N. Mistry, J. Steinberger, and the author. In this experiment (fig. 5) pions produced by 15 Bev protons are allowed to travel for some 70 feet before striking a 40-foot thick steel shielding wall. During this interval, about 10 percent of the pions decay, sending their neutrinos forward. The remaining pions, muons, and all other debris are stopped by the wall, but the neutrinos penetrate it as though it were nonexistent. Behind the wall, in a well-shielded room, stands a spark chamber (pl. 1, fig. 1)—an instrument which can be made to show a track of sparks whenever a charged particle passes through it. This spark chamber also acted as the target for the neutrinos, and consisted of 10 tons of aluminium in the form of 1-inch thick plates.

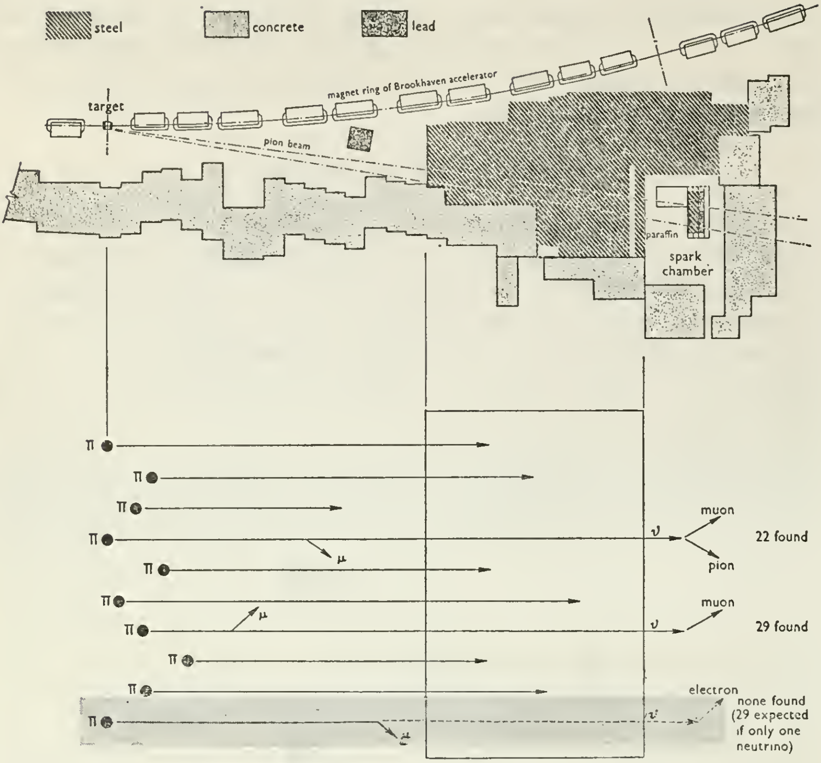
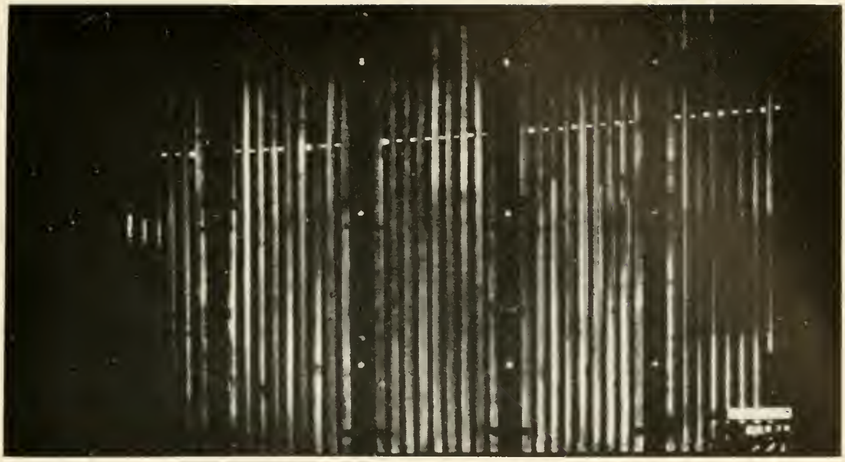


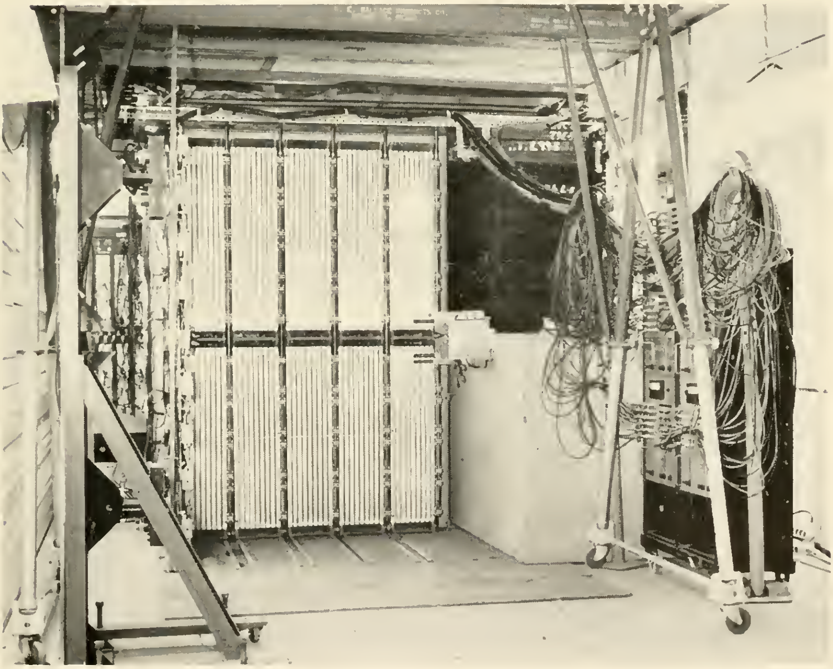
FIGURE 5.—Author and colleagues used this experimental arrangement to detect neutrino interactions. Pions from accelerator target travel 70 feet before striking steel shield; on the way about 10 percent decay to muons and neutrinos. Neutrinos pass through shield to spark chamber where about 1 in 10^{12} interact. Lower diagram shows number and types of these interactions: shaded interaction was not observed, indicating that there is more than one kind of neutrino.

Neutrinos, of course, show no tracks; but their reaction products do. The chamber is triggered whenever a charged particle originates within it. After passing some 10^{14} neutrinos through it, 51 interactions were observed. Of these, 29 showed the production of a muon alone and 22 showed the production of a muon along with a pion or something else. If there was only one neutrino, one would have also expected the production of 29 single electrons which would have been easily identified in the chamber. No such electrons were observed, leading to the conclusion that the neutrinos coupled to muons are not the same as those coupled to electrons.

One of the implications of this discovery is quite clear. It removes a major objection to the intermediate boson, and the next neutrino experiments will be designed to search for it directly. This boson, if it does exist and has a mass not much greater than the mass of the proton, can be produced directly along with a muon by presently available energetic neutrinos. Indeed, the Brookhaven



1. A typical event in the Brookhaven spark chamber showing one of the 29 mu mesons produced by the interaction of neutrinos. (See lower half of fig. 5.)



2. The 10-ton spark chamber at the Brookhaven Laboratory, used to detect neutrino interactions, showing that there are two kinds of neutrino.

experiment has some events which could be interpreted as the production of such a particle. The boson is expected to live for only about 10^{-17} seconds before decaying, and can only be detected by means of its decay products (which should include electrons, or muons, along with their respective neutrinos). An event could then be characterized, for example, by the appearance of two muons—one, the primary muon, and the other resulting from the decay of the boson.

Finally, one may hope that future neutrino physics will yield sufficient data about the weak interactions at high energies to lead to a comprehensive theory of these interactions. One may even hope to shed some light on the basic difference between the electron and the muon which, in some way, should be related to the difference between their respective neutrinos. At any rate, the future of neutrino physics seems quite exciting.

The Antibiotics from a Botanical Viewpoint[1]

By Kenneth L. Jones

Professor, Department of Botany, University of Michigan

Botanists have participated energetically in antibiotic research primarily because certain lower plants, familiarly molds, are the sole source of most of the antibiotics used in medicine and agriculture. The discovery and elucidation of the structure and growth requirements of these valuable plants have been a lively area of botanical study. There are ancillary considerations which have given antibiotic research a botanical flavor, such as the realization that the causal organisms of disease may be members of the plant kingdom, notably the fungi.

The term "antibiotic" was first suggested by Professor Selman A. Waksman, of Rutgers University, New Jersey, an eminent researcher of lower plants—the actinomycetes. The word "antibiosis" had been used at least as long ago as 1889 by P. Vuillemin to describe absolute antagonism of one organism to another and it subsequently came to denote the converse of "symbiosis." Waksman, however, gave the word "antibiotic" a special meaning in order to set off microbial antagonists from other antibacterial substances. His full definition, enunciated in 1947, was:

> An antibiotic is a chemical substance, produced by micro-organisms, which has the capacity to inhibit the growth of and even destroy bacteria and other micro-organisms. The action of an antibiotic against micro-organisms is selective in nature, some organisms being affected and others not at all or only to a limited degree; each antibiotic is thus characterized by a specific antimicrobial spectrum. The selective action of an antibiotic is also manifested against microbial versus host cells. Antibiotics vary greatly in their physical and chemical properties and in their toxicity to animals. Because of these characteristics, some antibiotics have remarkable chemotherapeutic potentialities and can be used for the control of various microbial infections in man and in animals.

When Professor Waksman formulated the antibiotic concept in 1947, three of the five antibiotics destined to revolutionize medicine had already been discovered: penicillin, streptomycin, and chloromycetin.

[1] Reprinted by permission from *Michigan Quarterly Review,* vol. 1, No. 3, Summer 1962.

Penicillin, the first to be discovered, was derived from a blue-green mold, *Penicillium*, commonly known from blue cheese or the spoilage of citrus fruits, bread, moist tobacco, or leather. The antibiotic penicillin was discovered in 1929 by Alexander Fleming, of St. Mary's Hospital, London. Its commercial production, however, waited on a cooperative effort by American scientists, engineers, and industrialists, akin to the concurrent pooling of energies to create the atomic bomb. The great healer, penicillin, partially restored life against the havoc of the great destroyer.

In retrospect, the botanical aspects of the cooperative effort concerned (1) selection and improvement of the mold, and (2) the establishment of the most favorable conditions for growth of the mold as a penicillin producer. In other words, there was a genetical approach, aimed at obtaining superlative germ plasm, and an ecological one, to provide it the best means of expression.

Since *Penicillium* is lamentably sexless, the genetical program could not exploit breeding procedures, as can be done with yeasts in the fermentation business. It was necessary to resort to an extensive selection process, in which literally thousands of molds from soil samples were tested for antibiotic (penicillin) yield. For this purpose soil samples from various remote parts of the world were flown by the military to Peoria, Illinois, the home of the federal Northern Regional Research Laboratories, where the total program was centered. As it chanced, the mold of choice resided right in Peoria and was picked up via a spoiled cantaloupe by a laboratory technician, affectionately called "Moldy Mary." This prize-winning mold was identified by Drs. Raper and Thom as *Penicillium chrysogenum.*

Now a new technique, characteristic of the dawning atomic era, was brought into play to improve *Penicillium chrysogenum.* This was radiation. Scientists set out to alter the genetical nature of the mold spores by X-radiation and ultraviolet, something never attempted before for practical purposes. These pioneer researchers met with inordinate success almost at once. New strains of mold were obtained which yielded as much as 500 times the penicillin of the original isolate of Fleming. Incidentally, radiation is today a choice means of strain improvement in molds used in industry. Each corporation has its own carefully guarded organisms, although admittedly the improvements are seldom of the magnitude attained in *Penicillium* in the days of high drama when it was about to make its debut.

The great innovation on the environmental side was the submerged-culture process. It happens that *Penicillium*, and molds generally, are avid users of oxygen and therefore grow only on the surface of liquids. It seems ridiculous to us nowadays that initially *Penicillium* was grown on the surface of liquids in quart milk bottles. For each batch of penicillin, several thousand bottles had to have their contents separately inoculated, incubated, and harvested. No wonder "practical people" despaired of the antibiotic ever coming into mass production. Then, some ingenious person had the idea of using, instead of quart milk bottles, 15,000 gallon tanks upended, through which sterilized compressed air gushed. The tanks were practically teeming with mold submerged in corn steep liquor. Soon penicillin was turned out in carload lots, and the production cost was less than that of packaging. Sir Alexander Fleming refused all patent rights on penicillin!

Professor Selman Waksman was the discoverer of the second antibiotic to come into widespread use, streptomycin. Its name stems from *Streptomyces*, the genus on which Waksman earned his master of science degree at Rutgers in 1916. He systematically tested each of some 10,000 separate cultures for antibiotic production. To students of lower plants, the fact that most of these isolates of *Streptomyces* possessed antibiotic properties was probably a more important datum than that one, *Streptomyces griseus*, yielded the valuable streptomycin. It became apparent that soil organisms, particularly the genus *Streptomyces*, held high promise for future exploitation. Antibiotics from true bacteria turned out to be dreadfully toxic to man in many instances.

The next major antibiotic, Chloromycetin, was isolated from a new species of *Streptomyces* in 1947. It was announced by a group of researchers employed in the Detroit laboratories of Parke, Davis and Company, working in collaboration with Professor Paul R. Burkholder, then chairman of the Department of Botany at Yale University, and Professor David Gottlieb of the Department of Plant Pathology at the University of Illinois. Burkholder isolated the organism from soil collected in a mulched field near Caracas, Venezuela, so that it was accordingly named *Streptomyces venezuelae.* At about the same time, Gottlieb obtained it from a soil sample taken from the campus in Urbana. Students of these lowly plants are aware of the fact that they occur quite generally in soils but particular variants, producing useful antibiotics, may be rather localized, so that it pays to explore over a wide geographic range. This is a tolerable idea to botanists, who are prone to wander and collect specimens, other than soil samples. The new antibiotic was named Chloromycetin. This name was retained as à trademark by Parke, Davis and Company, but the substance was later given the nonproprietary name, chloramphenicol. Its discovery aroused great interest, as it was active against a relatively wide range of infectious agents, including the bacteria of typhoid and undulant fever, various rickettsiae, and the larger viruses, including that of scrub typhus. The antibiotic could be administered orally, a property greeted warmly by those who had submitted to the indignities of multiple shots of penicillin.

Incidentally, the chemical constitution of chloramphenicol and methods of synthesizing it were worked out in 1949 by Dr. Mildred Rebstock. It is the first, and so far the only, antibiotic to be made commercially by total chemical synthesis, which soon displaced the fermentation process for producing it. The manufacturing plant for the commercial synthesis, belonging to Parke, Davis and Company, is at Holland, Michigan. The distaff side may well be proud of its role in the development of antibiotics. It was Dr. Mary Florey, British physician, who first used penicillin successfully on human beings suffering gravely from bacterial infection, and a woman assistant in the Peoria Laboratory, now Mrs. Steven J. Steven, of Brookfield, Illinois, who obtained the choice *Penicillium chrysogenum.*

Aureomycin was discovered in 1948 by the renowned botanist B. M. Duggar, who was in his "retirement" from the University of Wisconsin, as an employee of the Lederele Laboratories at Pearl River, New York. Fellow botanists were particularly pleased to have a great researcher in theoretical botany win laurels when he turned to an applied field. He had been a leader in plant pathology and then in radiation biology. (Parenthetically, Michigan's beloved Harley Harris Bartlett reported that it was Duggar who first grasped the parallelism between viruses and genes—in fact, he had remarked that viruses are escaped genes.) Aureomycin is derived from *Streptomyces aureofaciens:* its name denotes the golden color of the mold and of the antibiotic, and not that it is taken *orally*, as a well-known newspaper claimed!

The last of the major antibiotics, terramycin, was discovered in the laboratories of the Charles Pfizer and Company, Brooklyn, New York, in 1950. It is derived from the actinomycete *Streptomyces rimosus.* No claim can be made by botanists for the discovery or development of this antibiotic. Aureomycin and terramycin are perhaps better known to the public as the tetracyclines. Aureomycin is chlortetracycline, and terramycin is chemically designated oxytetracycline. Both are used commonly as broad-spectrum drugs, active against a wide variety of bacteria and even certain amoebae and pinworms.

It is remarkable that no antibiotic to rival penicillin or the tetracyclines has been discovered since 1950, in spite of large-scale attempts by industry to locate favorable natural sources. This may mean that the storehouse of these valuable substances in nature is indeed limited, or perhaps that the search has been too restricted. Several safe and effective antibiotics have been made available for medical use. Those derived from *Streptomyces* lead the list: erythromycin, colymycin,

Table 1.—The number of actinomycetes present as spores or viable filaments in a gram of soil from several sites in Ann Arbor. These are predominantly in the genus *Streptomyces*.

Soil site	*Top inch*	*2 feet down*	*4 feet down*	*8 feet down*
1	18, 100, 000	3, 493, 000	16, 850	67
2	18, 600, 000	600, 000	402, 000	2
3	10, 200, 000	970, 000	214, 000	680
4	13, 700, 000	1, 620, 000	31, 200	1, 770
5	25, 400, 000	1, 900, 000	27, 000	10
6	15, 100, 000	2, 091, 000	52, 000	6, 740

viomycin, cycloserine, carbomycin, kanamycin, novobiocin, and neomycin are representative. Some of these are valuable replacements of penicillin for patients who are sensitive to the latter or where, as is common in staphylococcus infections, the causative organism is resistant to penicillin. Many natural products, including antibiotics, are being tested today for possible control of cancer. The Sloan-Kettering Foundation is the center for this research.

The lower plants responsible for most antibiotics of commerce are members of two unrelated genera, *Penicillium* and *Streptomyces*. The first is a coarse-filamented fungus in which the threads and spores are of the order of 10 microns in diameter. The filaments are clearly cellular with spherical nuclei. They spread, digesting organic materials, and in the fullness of time, form a bloom of greenish spores that appear as a powder to the naked eye. Occasionally, under laboratory conditions, botanists have observed *Penicillium* to reproduce sexually with the formation of a special type of spores, ascospores. This characteristic places the genus with the ascomycete fungi, to which also belong various mildews and even the delectable truffles and morels.

The actinomycetes, or "actinos," to which the genus *Streptomyces* belongs, abound everywhere in topsoils where they thrive on plant residues. Table 1 gives a characteristic census of actinomycetes, essentially *Streptomyces*, per gram of dry soil. A gram corresponds to a "pinch" as used in recipes for baking biscuits. These data were obtained in Ann Arbor at fresh excavations for dwellings in this burgeoning community. The numbers of viable cells which plate out as colonies in the laboratory are seen in the table to decline rapidly the farther down in the subsoil one samples. This is attributable partly to decrease in nutrients (dead leaves, roots, and twigs) but largely to the lack of oxygen. The prevalence of *Streptomyces* in soils is manifest to all of us in a more direct manner, as the spores are responsible for the pungent, spicy odor of newly turned soil which one can sense while cruising at 90 miles per hour over a country road in springtime. Volatile aromatic substances are wafted from the spores of *Streptomyces* into the atmosphere. Incidentally, the relatively few "actinos" that occur in the deeper layers of the subsoil are liable to

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be of a less common genus of a nonsporing nature, termed *Actinomyces.* These aberrant, anaerobic plants have their own unique chemistry, structure, and life potential. Some of their representatives were known to the medical profession as far back as 1860 as the causal organisms of "lumpy jaw" in cattle and man. They are now identified as agents of dangerous pulmonary abscesses and other infections ("actinomycoses") which are very stubborn—often yielding only to appropriate antibiotics *derived from their kin*, the Streptomycetes.

An actinomycete of any description exists in the soil as a spiderweblike entanglement of filaments of the diameter of bacteria (one micron). Under a light microscope, these filaments are too narrow to reveal their internal structure, as is true of bacteria generally. The electron microscope becomes the instrument of choice in delineating the finer parts of the protoplasm of all microorganisms, as it gives a magnification up to 150 times that of light microscopes, with the disadvantage, however, of portraying only dead, dried specimens as mounted in a high vacuum. The filaments thus treated portray complicated, infolded membranes, granules of diverse sizes and compositions, and irregular islands of nucleoplasm. The continuous (nonseptate) tubular filaments branch profusely. The branches may impolitely disregard one another or be more amicable and intertwine, interlock, or even fuse. Filaments from two or more plants may thus contain segments of a polyglot character, with opportunities for a mixing of diverse genetical materials.

The actinomycetes are usually classified as a filamentous order of bacteria. *Streptomyces* is one of a half-dozen genera of actinomycetes. It is characterized by the formation of spores in long chains, at the end of special coarse, aerial filaments which protrude above the substance on which the plant is growing. In nature the spores are blown helter-skelter by the wind, to germinate into filaments if they chance to fall on a moist, comfortably warm surface. They may, however, remain dormant for months, protected as they are by a thick waxy wall, derived from the filament within which they formed. The walls have recently been observed under the electron microscope as smooth or variously ornamented, for example, with spines like a miniature cocklebur. The ornamentations prove to be a convenient criterion for the delineation of species.

The fine structure of the interior of the very small spores and filaments is being studied at the University of Michigan by Dr. Pearl Lui Chen, a botanist of the Albion College faculty. The spores are killed and preserved by chemical treatment, with as little distortion in structure as possible. They are then imbedded in a plastic, sectioned on a machine into several serial slices per spore. These slices are appropriately mounted on grids for observation under the electron microscope, which has an inbuilt camera to record the selected observations for publication in scientific journals.

The spores contain nuclear material which is not identical in quantity or configuration from spore to spore, even within a given chain. This may explain why cultures established from single-spore isolations of sister spores are dissimilar. In other words Streptomycetes may have inbuilt "reasons" for being variable which have enhanced their natural survival. Charles Darwin delighted in extolling the case for evolution in the large, variable, wide-ranging genera. *Streptomyces* would have qualified eminently.

How to identify and classify species within the genus *Streptomyces* such as *Streptomyces griseus*, *S. rimosus*, *S. venezuelae*, and *S. albus* has not yet been satisfactorily resolved. The first monographer, Rudolph Lieske, of Leipzig, in 1921 gave up the task as insuperable because of the inordinate variability of the Actinomycetes. The difficulty has been many times compounded since then by the enormous size of collections of *Streptomyces* in industrial laboratories, gathered from the four corners of the earth. Never have biologists been presented with such a welter of representatives of a genus in any group of living things. This is a worrisome situation both for industry and for science. Industrial establishments, seeking to recoup expenses incurred in developing an antibiotic, wish to obtain patents that will protect them from competitors using the same streptomycete. This requires that a botanist write a description for the species (perhaps in Latin!) that will be so firm and unequivocal that no other pharmaceutical manufacturer will produce the same drug. Unfortunately, the species in question may be exasperatingly variable, alienating the affections of the botanist. If he describes it too narrowly, other companies may land on variants which do not fit the description and proceed to produce the same antibiotic with impunity. On the other hand, if the species description is too loose, the patent lawyers may disallow it and rival interests contend that an unfair attempt is being made to corner the fungi!

On the scientific side, there is, as I have intimated, no generally agreed upon system of classification of *Streptomyces*. Official commissions in this country and in Europe, including Russia, are still struggling over "valid criteria" for classification. Many members of the commissions are experimentalists who have not served an apprenticeship in taxonomy, which is really a great science, requiring years of experience before one can hope to have a "feel" for apprehending characteristics and judging their significance in the delineation of species. Darwin was not writing in a moment of levity in the Origin when he stated that the concept of species is subjective. It has validity only insofar as the individual researcher "knows" his organism, much as a shepherd knows his sheep.

Western readers should be informed that Russian and American taxonomists of Actinomycetes have enjoyed excellent relationships. For example, immediately on announcement of a committee in the United States to study actinomycete classification, G. F. Gauze, of the Institute for the Study of New Antibiotics of the Academy of Medical Sciences of the USSR, made available for English translation his monograph, Problems in the Classification of Antagonistic Actinomycetes, which was just going to press in Russia. Through Dr. Gauze's personal assistance the English version was published promptly. He and several colleagues have paid visits to the United States in recent years, and have shown a lively and friendly interest in the mutual exchange of scientific data.

The Actinomycetes have been under investigation in the Department of Botany at the University of Michigan since 1938. One of the more significant and unexpected findings was that normal filaments of *Streptomyces*, freshly isolated from nature, may carry a temperate virus. Dr. Elwood Shirling, now professor of the Department of Botany at Ohio Wesleyan University, made this discovery. The viruses and the Streptomycetes are in harmonious relationship. Only when there is disharmony is the presence of the virus evident. Then the filaments dissolve and a mass of free infectious virus particles is released. It has been confirmed that temperate viruses are commonly present in normal filaments of *Streptomyces*. There is practical concern to alter Streptomycetes favorably by inoculation with foreign, temperate viruses. Theoretically, we should like to know how the viral genes intercalate into the inheritance mechanism of the filament.

In quite another branch of science and technology from those we have been considering, botanists serve medicine, agriculture, and forestry. As we mentioned in the introductory paragraph of this article, the causal organisms of disease may be members of the plant kingdom, notably the fungi. Botanists are employed in isolating, identifying, classifying, and establishing the life histories of the myriad of fungi that parasitize man, animals, crop plants, and forest trees. There is a lively demand for medical mycologists, as fungus infections, including the deep ones which are lethal, have been considerably on the increase during the past 15 years, whereas those attributable to bacteria have declined. Actually, the reported increase of fungus diseases may reflect improved diagnostic measures, as well as the fact that people are living to be older and the physiologically senescent are probably more prone to fungus infection.

Since 1957 relief against deep fungus infections has come through treatment with a new antibiotic, Amphotericin B, derived from *Streptomyces nodosus* and developed by Squibbs as "Fungizone" and "Mysteclin F." It has been used quite successfully, administered with tetracycline, by an intravenous drip method.

Ringworm infections, including athlete's foot, which are actually caused by fungi and not by worms, are a pesky annoyance. They are a fringe or filamentous benefit of modern bargain-basement existence. A remarkable remedy against the fungi of ringworm has recently come upon the market in the antibiotic griseofulvin, which incongruously must be administered orally. This antibiotic was among the very first to be discovered. It was tried only topically and found wanting as a deterrent to ringworm, and promptly disregarded. Recently, a chance oral administration revealed its extreme effectiveness. It is readily absorbed by the gastrointestinal tract and exerts its fungistatic action in the newly growing skin, hair, and nails which, with shedding or cutting, are replaced by normal structures free of fungi. Dr. John Ehrlich of the Parke, Davis and Company reports: "It is the only major advance in the therapy of infection caused by dermatophytes [skin fungi] in at least a half century." The antibiotic griseofulvin, is named from the mold which produces it, *Penicillium griseofulvin.*

Flowering plants and conifers are parasitized by fungi which may cause great destruction; witness the loss of our elms from a fungus which is transmitted by a bark beetle. Any plant has countless fungus spores on its exposed surfaces, and it is not unusual to have localized networks of fungus filaments within the healthy tissues. One of the well-established, symbiotic, natural associations in plants is the mycorrhiza (mycor-, fungi, and -rhiza, root) in which particular species of fungi form a mantle over the young, active roots and may penetrate into the cells. Mycorrhiza occur commonly among conifers, heaths, and orchids but probably are of wide occurrence. These associations are apparently of a symbiotic nature: the fungus acquires a food source, and the higher plant derives vitamins and a more adequate mineral supply, as the filaments of the fungus spread beyond the roots into leaf mold, where their presence is detected by the fruiting bodies, mushrooms or toadstools, which they produce seasonally. In orchids, the filaments of the fungus grow throughout the plant from root to topmost leaf; in fact, the developing seeds within the flowers are inoculated with the fungus and carry it away when they are shed, tucked within their cells. Conifers cultivated in a new area may not succeed unless the appropriate fungus is introduced into the soil.

Where trees in a forest are manifestly diseased one would do well to suspect the growing conditions, rather than the entrance of a new virulent pathogen. Something is usually awry ecologically or physiologically, such as the water supply or mineral nutrition. These conditions bring on a lowering of disease resistance.

Under cultivation, the entire situation may be so unnatural for plants that diseases become a major problem to the grower. Approximately 30,000 important plant diseases have been studied by botanists.

Fungi are particularly common disease agents in plants where they are responsible for such ailments as white pine blister-rust, corn smut, potato scab, wilt of fruit trees, blights of vegetables and ornamentals, and root rots of many crops.

One scientific approach against plant diseases is to exploit the natural disease resistance of individual plants by producing disease-resistant strains. Apart from the time such a program obviously entails, often special difficulties are encountered in attempting to combine disease-resistant factors (genes) with those for high-yield or favorable appearance. Always lurking under cover is the adaptable parasite, able to evolve and grow on the new "resistant" plants.

The use of sprays to kill fungi has become a widespread practice. However, on a large scale this may be prohibitively expensive, as nearly all fungicides are ineffective except at high concentrations. Unfortunately, many are detrimental to the plants and poison birds and even man, if proper precautions are not taken.

Since antibiotics operate at extremely low concentrations and may be absorbed by plant cells, it was logical to try them as sprays against bacterial infection. This was first done successfully in the United States by W. J. Smith, of the Wyoming Experiment Station, in 1949. He used a streptomycin preparation against the bacteria that cause halo blight of beans. Subsequently, antibiotic preparations came into rather wide use against bacterial infections, including bacterial spot of tomatoes and peppers, blast of stone fruits, wildfire of tobacco, seed-piece decay and blackleg of potatoes, and bacterial wilt of chrysanthemums. Special preparations of streptomycin and the tetracyclines have been developed by commercial companies for agricultural use.

The Upjohn Company of Kalamazoo, Michigan, has pioneered in the development of the antibiotics effective against fungus infections of plants. Their Actidione is derived from *Streptomyces griseus*, the same organism that produces streptomycin. Actidione controls such fungus infections as melting out of golf turf, onion mildew, and mint rust. As little as one-third of an ounce of Actidione is sufficient for the treatment of 50,000 square feet of turf. Antibiotics, unlike ordinary fungicides, become a part of the cell sap of each individual cell of the plant, "grow" with the plant, and are proof against rain.

It has been found by R. L. Wain, of the University of London, for example, that griseofulvin can be transported freely within plant tissues and confers a systemic fungicidal effect. As pointed out above, griseofulvin was the first compound found to be effective in the systematic treatment of ringworm in man.

Professor Wain has indicated that:

Natural resistance to infection may also be associated with the presence of protective chemicals within the plant cells. Whilst animal cells are completely filled with protoplasm, adult plant cells contain only a thin layer of this material lining their walls. The remainder consists of vacuoles filled with a watery solution of salts. In plant defensive mechanisms the protoplasmic layer may have a detrimental effect on the parasite, and there may also be protective substances present in the aqueous contents of the cell. Among the examples which have been cited to illustrate chemical protection against fungi under natural conditions are the presence of protocatechnic acid in the scales of onions resistant to smudge, phenolic substances in wheat varieties resistant to rust and linamarine in varieties of flax showing resistance to *Fusarium* wilt. Again, it has been recently shown that various phenolic compounds present in apple and pear leaves are toxic to the fungi causing apple and pear scab. Fungicidal compounds have also been isolated from rye, maize and wheat plants.

One must of course question the advisabilty of man using regularly, as food, plant or animal tissues that carry even a trace of antibiotics. Poultry, beef, and pork may thus be suspect, as farm animals are raised on feed fortified with antibiotics to speed meat production. It is not an easy matter to determine accurately the effects of very slight doses of antibiotics taken into the human alimentary tract over a period of several years. I do, however, believe that the food and drug regulations in this country are carefully formulated and realistic from the public health point of view.

My colleague, Professor Dow V. Baxter, renowned forest pathologist, has kindly called to my attention that, since 1947, penicillin has been successfully used to control a severe bacterial infection in the giant cactus which graces parts of the Arizona deserts. Diseased cacti attacked by the bacterium *Erwinea carnegieana* were treated by injecting penicillin with a hypodermic needle into the lesions. The tissue is largely of a succulent nature, and the antibiotic diffuses through the plant for a considerable distance.

A recent lead article in the Journal of Forestry (September 1960) states that "a major breakthrough in the control of white pine blister rust caused by the fungus, *Cronartium ribicola* Fischer, has been accomplished with the antibiotic Actidione. Sprayed on the basal portions of trunks, Actidione is absorbed and translocated upward to kill the causal fungus in blister rust infections on western white pine (*Pinus monticola* Dougl.). This work was carried on by joint efforts of the Forest Service and The Upjohn Company, of Kalamazoo, Michigan." It is pointed out that control of the blister rust has been so phenomenal that "danger exists in becoming too optimistic abut the possibilities of discontinuing a ribes destruction program to prevent new infections." Ribes is a generic name commonly used to indicate both currant and gooseberry bushes, the intermediate host-plants of the white pine blister rust fungus.

The role of antibiotics in nature is not easy to demonstrate directly because their concentration is so extremely low. To what extent soil microbes, such as *Streptomyces* and *Penicillium*, ward off competitors by their antibiotic production is unknown, as is their effect on crop plants.

An American audience may well be interested in the comments coming from a leading Russian scientist on this fundamental subject.

> We enriched the soil artificially with actinomycetes—producers of streptomycin, and we grew in this soil plants—peas and wheat. The sap of such plants was tested for its bactericidal effect on *Bac. mycoides* and *Staph. aureus.* Death of the bacterial cells in the sap of the experimental plants followed after 8–12 hours, and in the sap of the control plants which were grown in soil not enriched with actinomycetes, there was only suppression of growth, but death of the bacteria was not observed.

The extrapolation of these results to nature is expressed by Krasil'nikov as a very intriguing hypothesis of plant immunity!

> Actinomycetes, bacteria, and fungi which produce antibiotic substances grow in the soil in the rhizosphere of plants [rhizosphere means in the immediate vicinity of the roots]. They saturate this zone or microfoci in the soil with the products of their metabolism, including antibiotics. The latter enter the plants through the roots and exert their action there. It is self-evident that the concentration of antibiotics in soil, when formed under natural conditions, will be lower than the concentrations created upon artificial introduction. However, under natural conditions these substances are constantly formed and therefore one would assume that their entrance into plants is not stopped during the whole vegetative period.
>
> Having entered the plant tissues substances protect them against the penetration of microbial parasites, suppress the growth of those that have already invaded, produce or elevate the toxicity of the plant sap, and thus elevate to a larger or smaller extent the immunological properties of the plant.
>
> In other words, microbial agents are factors which increase the resistance and insusceptibility of plants to infection.[2]

In this article, I have deliberately selected items of botanical interest in the field of antibiotic research and development. It is not too generally appreciated that the source of most of these remarkable drugs has been lower plants whose structure, life history, natural occurrence, isolation, and identification have been the concern of botanists. Other specialists, including the bacteriologists, engineers, chemists, druggists, agriculturists, nutritionists, veterinarians, clinicians, and medical doctors, have each made their unique and great contributions to the discovery, development, and use of antibiotics.

One is sobered on reflection that these natural products, which assuage man's suffering and increase his food supply, came into his keeping in an era of cruel wars and unprecedented population upsurge.

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[2] N. A. Krasil'nikov, Soil Microorganisms and Higher Plants, p. 385, 1961.

Atomic and Other Wastes in the Sea[1]

By I. Eugene Wallen

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[With 2 plates]

During the production of useful devices for modern civilization, raw materials are consumed only in part with various portions remaining as wastes. Often the success of a competitive business is related to its imagination in further processing the wastes into a second product and perhaps others from subsequent wastes.

Normally the primary and secondary products do not completely consume the original raw material. Even with complete consumption the processing procedure may utilize water and other solvents for cooling, for catalyzing reactions, or as a mechanism for extraction or purification of the raw material. After extraction of the valuable portion or portions from raw material, the residue is discarded or isolated.

Waste problems follow domestic operations and human activities. Polluting agents from industry or in sewage consist of more or less complex mixtures of materials which normally will be neutralized by chemical and biological processes in the sea. When effects of such materials are noted in the ocean, their disposal can be discontinued, thus permitting a reasonably rapid return to normal.

Although no plans were made initially in the nuclear industry beyond the production of nuclear material for war purposes, it was soon realized that the wastes from plutonium processing contained radioactive materials of sufficient value to justify their extraction. The very great value of plutonium had made its disposal an academic question even though it was recognized to be chemically as well as radioactively hazardous. Uncertainties concerning the hazards of other radioactive isotopes led to a continuing policy of containment of all high-level wastes until such time as adequate consideration could be given to methods for final disposition. Very low-level

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materials could be disposed if proper dilution was assured. Also, if properly packaged, these wastes could be dumped in selected oceanic areas that had been judged to be removed from accidental contact with man.

A major step in wastes management was taken when President Eisenhower announced the United States policy of "Atoms for Peace" to include the production of power and the utilization of radioisotopes in research, in industry, and for medical purposes. The diversification of uses of nuclear energy has resulted in confusion of the definition of nuclear wastes. Pure strontium 90 is an excellent material for nuclear batteries that can provide electricity for oceanic and space uses. Strontium 90 in fallout from nuclear weapons tests and from operating nuclear reactors is a principal concern of those responsible for the control of the use of nuclear products in industry.

Iodine 131 is a radioactive isotope that may be concentrated to their detriment by biological organisms on contact with fresh fission wastes. Yet iodine 131 is also a valuable material that is used for medical treatment as an often favored alternative to X-rays.

The level of wastes concentration in the ocean is determined to a large degree by the physical state of the wastes, initial mechanical dilution, rates of diffusion, and the abundance and proximity of silt, sediments, and marine populations. Radioactive wastes are peculiar in not being susceptible to biological or oxidative treatments. Long-lived radioisotopes may produce effects in a local area or in a dispersed area for many years. Thus, the most exacting requirements for any industry are placed on the nuclear industry for disposal of its wastes. If other industries met the disposal standards for the nuclear industry, the problems of pollution would be minor ones.

Until the Atomic Energy Act of 1955 was passed, the U.S. Atomic Energy Commission was totally responsible for all phases of the production of nuclear materials, their utilization, and the disposal of nuclear wastes. On the premise that a single operating agency should not have complete responsibility for monitoring its own activities, the President established, in 1960, a Federal Radiation Council. He asked this council to set standards for allowable radiation exposure and to keep watch over the routes whereby humans might be exposed to radiation.

Such standards had been estimated, with different results, by the U.S. National Committee on Radiation Protection and Measurements and the International Commission on Radiological Protection. The allowable exposure limits of the Federal Radiation Council are somewhat different from those of either of the groups mentioned above, and each differs from the other as well, since many of the assumptions were based more or less on educated guesses.

Likewise, three committees of the National Academy of Sciences considered sea disposal of nuclear wastes and came to different conclusions concerning allowable disposal limits. Two of the reports discussed packaged wastes from nuclear land facilities; the third was concerned with disposal of wastes from nuclear merchant vessels. Since they made different approaches to the problem and different assumptions, based on plausible guesses, the result was no surprise. The development of nuclear industries has been rapid, and none of the three reports is adequate to apply to all mechanisms under active consideration to release radioactive material to the sea.

HAZARDS OF OCEAN DISPOSAL

Three types of hazards may be considered in oceanic disposal of radioactive wastes:

1. Direct hazards, in which a sufficient concentration of radioactive material exists to injure anyone in contact with it.
2. Indirect hazards, from the concentration of radioactive wastes by organisms living in the sea and their subsequent use as human food.
3. Ecological hazards, that may produce unpredictable changes in the biological communities in the ocean.

Although the disposal of wastes ultimately is either through permanent containment or by dispersal and dilution into the environment, the nature of wastes can be varied by the type of treatment given to them. Waste-treatment systems may include filtration, evaporation, ion exchange, gas stripping, chemical precipitation, coagulation, incineration, and dilution.

The decisions on method of treatment and whether to contain or disperse the final product may vary depending on such influences as public health, commercial or sports fisheries, and the location of cables, buoys, channels, or other marine facilities. Since the ocean is internationally shared beyond accepted continental limits, possible international problems may be considered when disposal sites are being selected.

SOURCES OF NUCLEAR WASTES

Nuclear wastes enter the ocean from at least four major sources: nuclear power plants; research, military, hospital, and industrial laboratories; experiments to determine various oceanic physical characteristics; and nuclear explosions.

Nuclear power plants may use the ocean or its tributaries as a source of cooling waters, returning the coolant with a higher temperature and, in certain cases, substantial amounts of induced radioactivity. Nuclear power plants may propel military or private vessels, and through leakage or deliberate disposal, release wastes to the sea. The power plants for certain airborne and space vehicles are expected to be permitted, after testing or operation, to reenter the atmosphere and to be disposed of in the oceans. Other models of nuclear power plants operate within the ocean for such purposes as to recover natural resources, to provide power for military and civilian buoys and data-collecting systems, and to heat or desalt water.

More than 100 radioisotopes are believed to have useful functions in research, in medical treatment, and in military or industrial laboratories. On completion of their use, a majority of these isotopes will have undergone radioactive decay to become stable isotopes of no concern in waste disposal. The remainder are likely to be diluted or modified in such a way that low-level, waste-disposal methods may be used for oceanic disposal.

Although disposal of laboratory wastes by dumping packages into the sea is practiced by Atomic Energy Commission contractors (pl. 1), studies conducted in 1961 demonstrated that containment is achieved only partially. Casing deformation and rupture occurred in over one-third of the drums tested in a Pneumodynamics Corporation experiment. This disintegration is probably desirable since it encourages diffusion and dilution of the radioactivity. To the contrary, the intact package of radioactive wastes remains a potential hazard to future fishing, dredging, cable-laying, or other operations in the area (pl. 2, fig. 1).

The ocean must, of course, receive fallout from atmospheric tests of nuclear devices. It is inevitable that some very low-level wastes, which enter sewers or are discharged into rivers, will reach the sea. It is likely that the sea is the safest place to dispose of certain waste materials where advantage may be taken of its tremendous ability to dilute. Professor John Isaacs has calculated, in an article in *International Science and Technology* published in 1962, that an annual release of all fission products from 80 tons of uranium per year could be distributed in the ocean without obvious effect.

Project Chariot of the Atomic Energy Commission was *a proposed nuclear experiment* to excavate a shoreline and produce a protected oceanic extension that could serve as a harbor. This experiment and others that propose tagging water masses for studies of mixing and exchange processes would result in the release of substantial radioactivity into the ocean. However, the expected scientific value of such experiments would come, at least in part, from careful control and monitoring of the resultant pool of radioactivity for as long a time as possible to dilutions well past any possible hazardous level.

In March 1956, as Project Wigwam, the Atomic Energy Commission tested a nuclear device beneath the ocean surface with a release of radioactivity into the surrounding water. As reported in a supplement to the 1962 volume of the journal *Limnology and Oceanography*, the radioactive pool could be followed for about 1 month, after which time the radioactivity was so diluted that, for practical purposes, the pool ceased to exist. A second such experiment was a part of the 1962 Dominic Nuclear test series, and the results, when available, should add substantially to an understanding of dispersion in the open ocean.

For such tests in the ocean it is not a question of "clean" (fusion) devices and "dirty" (fission) devices, since the induced radioactive isotopes (zinc 65, iron 55, 59; manganese 54; and cobalt 57, 58, 60) in the vicinity of any reacting nuclear device appear to be more important to marine organisms than fission products (strontium 90 and cesium 137).

Seagoing reactors, such as nuclear submarines, may store certain wastes for later disposal on land but under many circumstances the hazard to humans is less in oceanic disposal than when such wastes are kept in proximity to ship's personnel. Since avoidance of detection is a goal in nuclear military ship movements, care is taken to insure that detection of the vessel not be possible by identification of its wastes.

NATURAL RADIOACTIVITY

Not all of the radioactivity in the ocean originates from the nuclear industry. Naturally radioactive materials are present in the earth's crust; and these materials may arrive in the oceans by way of dust, ground water, and rivers. Over geological times the quantity of radioactive isotopes from continental sources in the ocean and in sediments is believed to have become relatively constant and to be distributed evenly throughout the seas.

As cosmic rays pass into the atmosphere they strike atoms of stable elements, and a small portion becomes radioactive. These cosmic ray-produced isotopes, such as carbon 14, hydrogen 3 (tritium), and sodium 22, are often short lived as compared to ocean turnover times, so that they may occur in surface waters; but they never become evenly distributed in the ocean. The concentration of these isotopes in oceanic layers is used to indicate the circulation of the sea over a short period of time.

In the book *Radioactivity in Oceanography*, F. F. Koczy and J. N. Rosholt have computed the concentration of more than 70 radioactive isotopes in the ocean from primordial, cosmic ray, and artificial sources. Research to refine these values will assist in evaluating the distribution and effects of waste disposal on the ocean. Various population groups may be exposed to radiation from land sources as great as 16 times that of other human groups. Such differences are related to the characteristics of the soil upon which the population lives and the type of material used in housing. Persons who eat mostly seafood may receive only about one one-thousandth of the exposure to radioactivity received by those who eat only terrestrial foods, which is, of course, not considered a dangerous amount.

Although V. T. Bowen stated in 1961 that the ocean-water column contains about three times more strontium 90 per unit area than does the land surface at comparable latitudes, this quantity of material diluted in water to depths of more than 1,000 meters is of far less concern to man than a much smaller amount of strontium 90 in the first few centimeters of soil.

GEOLOGICAL ASPECTS OF SEA DISPOSAL

In the disposal of wastes at sea, several of the important considerations are geological. Sediments accumulate in coastal slopes and they may shift down the slope by sliding or slumping. On occasions when water becomes mixed with mud, a mudslide can form and move as a turbidity current onto an adjacent, more level sea bottom, thereby smoothing the original topography to form abyssal plains. Sediment slides of considerable magnitude occur on the continental slopes at unpredictable intervals. A waste container caught in such a slide could be broken or rolled along with it. Crustal fracture zones, or areas where the bottom sediments may be subjected to unusual stresses from tides, waves, storm surges, and tsunamis, result in unpredictable effects on waste containers.

Coastal waters often contain relatively large amounts of suspended solids. The suspended material usually includes some living organisms, and substantially larger quantities of organic and inorganic particles of detritus. The ability of these solids to adsorb radioactive materials is variable, depending on the mineral composition of the solids, the composition of the water, and the past history of the solids. Although prediction values cannot be given accurately for such adsorption, solids are believed to play a major role in controlling the dispersal of liquid radioactive wastes, as well as of those that may escape from a waste package. A relatively large accumulation of radioactive substances is known to occur on the sediments in the area around the outfall of the British Atomic Energy Authority processing plant at Windscale, on the Irish Sea.

Sedimentation, if its occurs at large distances from shore outside of bottom-fishing areas, can be considered a favorable process in removal of radioactive wastes from the environment of man. Since it is a concentrating process, however, it can enter into one of the routes of radioactivity from the sea to man through contamination of fish products, edible seaweed, fishing gear, and beaches.

Sedimentation is the ultimate step in the transfer of materials from sea water to the sea floor, and a number of physical-chemical processes determine the degree. These processes include the physical-chemical actions of absorption and adsorption, flocculation, ion exchange, precipitation, coprecipitation, and mineralization. Working in conjunction with these physical-chemical forces is gravitation, which acts on the flocs and aggregates of particles to settle them. Attractive forces between the suspended and the dissolved particles are critical factors in sedimentation. Also important are the chemical characteristics of the wastes and the composition of seawater itself.

FLOCCULATION

Certain elements have the peculiar property of forming gelatinous precipitates when subjected to an aqueous alkaline medium. Aluminum and iron are the principal elements of concern in oceanic waste disposal. Aluminum-rich wastes added to sea water form a gelatinous precipitate. Release of wastes containing iron also results in rapid precipitation at sea. First a characteristic green color of ferrous hydroxide appears. Then after oxidation has occurred, a flocculent, red precipitate appears which is characteristic of ferric hydroxide. Both of these constituents can scavenge ions having the opposite charge as they aggregate, exchange, and settle to the bottom.

Rivers often carry a high clay and silica content into the sea. These constituents are chiefly colloidal and negatively charged. They flocculate when subjected to the cations present in sea water. Such flocs can be dispersed and reformed by chemical processes encountered at different depths in the sea.

ADSORPTION

When man adds particulate matter by waste disposal, the wastes may be adsorbed to alter the rate of sinking and change their availability to man. The nature of adsorption of solutions is not clear. The physical and chemical characteristics of finely divided particles appear to bind molecules to the surface of solids in suspension on a more or less permanent basis. The degree and permanency of adsorption depend on the relationship between charge and size of ionic particles, and upon the charge and topographical character of the adsorbing surface.

Dissolved radioactive isotopes from fallout or from disposal of liquid wastes may be readily adsorbed by particulate matter in sea water. Sinking particles fall through the water, and eventually come to rest on the bottom. Cerium 144 apparently sinks at a rate of from 50 to 100 meters per month, which indicates its association with organic particles. Promethium 147, which sinks at rates much faster than 100 meters per month, seems to be associated principally with inorganic particles.

PRECIPITATION

A precipitate forms when ion concentrations exceed their solubility. The relatively large concentration of various ions in the sea favors the formulation of precipitates when certain wastes are added. Radioactive and normal elements precipitate together. Any excess in a waste effluent of such elements as calcium, manganese, iron, and nickel will precipitate.

Although in coastal areas a more concentrated and relatively rapid coagulation time is observed for sediments of terrestrial origin and a substantial proportion of the mineral suspensoid is precipitated near shore, the open ocean has abnormally low rates of coagulation and unexpectedly long residence times for particles, this permitting wide areal distribution of sediments. The average rate of accumulation of sediments is believed to fall in the range of millimeters per thousand years. Accumulation rates in the South Pacific were about 0.3 to 0.6 mm per thousand years (Goldberg and Koide, 1962).

Since the sea-floor accumulation of minerals seems to be very slow, and since the sinking time of fine particulate matter is in the order of hundreds of years, those radioisotopes of very long half-life are of principal concern to waste disposal in the open ocean.

COPRECIPITATION

When two elements that are chemically similar occur together in a waste, these elements may be coprecipitated. For example, calcium and strontium apparently precipitate together during the formation of calcium carbonate, thus assisting in the removal of any strontium 90 that might be present.

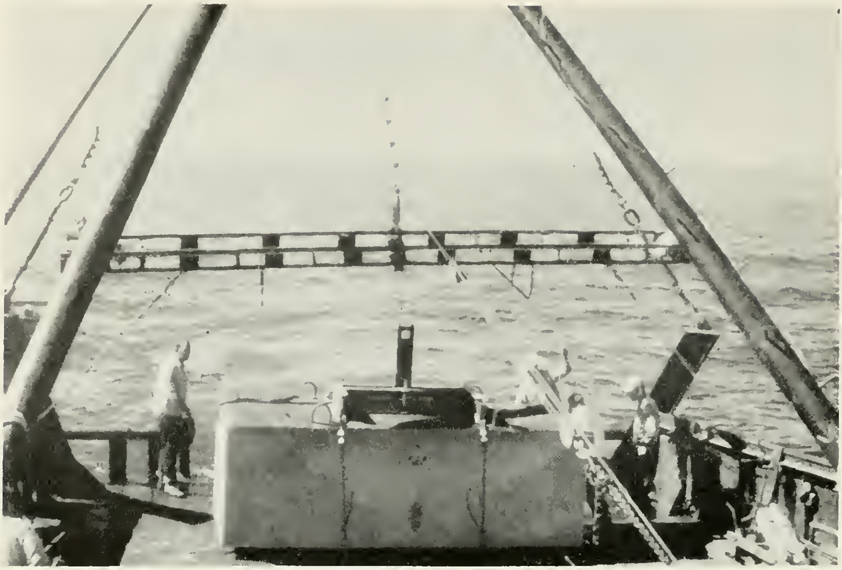
ION EXCHANGE

When an ion in an aqueous solution comes in contact with another ion and the necessary conditions are met, the ions may be exchanged. Ion exchanges are used in varied chemical processing, including the processing of wastes. Various solid constituents in the sea have good ion-exchange properties. Natural clays, including those in deep sea deposits, have an appreciable ion exchange capacity. Wastes which come in contact with clay particles in the waters and in sediments will undergo some exchange. In such cases the waste material appears to be held within the lattice of the clay particles in an exceptionally firm manner. Uranium and thorium may be chelated by minerals such as zeolite so that they are no longer available to the biota on the ocean floor.

MINERAL FORMATION

Certain wastes can serve as raw materials for the formation of minerals through biochemical actions and organic transfer in the ocean. Carbonate secreting organisms form calcite and aragonite in

Radioactive wastes of uncertain composition are incorporated or enclosed in barrels or blocks of concrete, the containers are loaded on oceanic vessels, as shown in the picture, and dumped at sea in depths greater than 1,200 fathoms (more than one mile). Courtesy of Brookhaven National Laboratory.



1. Concrete package containing radioactive wastes ready to be dumped into the Pacific Ocean. In a limited area these packages may accumulate and remain a potential hazard to local plants and animals.

2. Using a pump and hose method, seawater containing rhodamine dye is pumped from as much as 300 feet below the surface of the ocean to the deck of a ship where its concentration is determined. As a method of study of distribution of particles in the sea, rhodamine is substituted for the possibly hazardous radioactive isotopes.

their shells. Carbonates may be formed by precipitation or secretion in shell formation by marine forms. E. D. Goldberg stated in *Chemical Scavengers of the Sea*, published in 1954, that zirconium and titanium, present as anions in sea water, are scavenged by iron oxides and deposited in sediments. Alteration of suspended detritus into apatite may occur in the ocean with attendant uptake of radioactive elements. Bonelike materials of marine invertebrates may be modified into minerals and metals, or alkaline soils. A host of elements are concentrated by the minerals in the sea through accumulation into the disordered structural layers, or by ion exchange mechanisms.

Although no economic method of harvest has been discovered, about 10 percent of the abyssal area of the ocean floor is covered by aggregates of iron, manganese, and other minerals which together are called manganese nodules. Manganese, nickel, cobalt, copper, iron, and perhaps other minerals are present in these nodules in such quantities that they may be economically mined in the future. If radioactive wastes contain substantial quantities of long-lived isotopes, they should not be discharged into areas of the ocean covered by these mineral resources.

BIOLOGICAL TRANSFER

In addition to the translocation of waste materials through uptake and migrations, the remains of dead organisms, undigested wastes, and skeletal parts of marine organisms may sink to the bottom and form a substantial portion of the bottom deposits in the ocean. Generally, the deeper sediments have relatively few biological organisms, and no species are believed present that would readily concentrate radioactivity to present a potential hazard to man's food resources.

In 1961, G. Arrhenius proposed that biological extraction of barium, strontium, and lead is evident in surface sea water, resulting in vertical transport of these and other heavy metals to the sea floor where they may be accumulated. Certain species of Protozoa (Acantharia, Radiolaria), pteropods, and heteropods are believed to play an important role in this vertical transport. The skeletons of certain Radiolaria appear to sink rapidly through the water and then to dissolve entirely before burial in the sediment. In this manner, strontium 90 could be transported at a more rapid rate than would be assumed from its behavior in the open ocean.

Since colloidal clays tend to form stable suspensions on the sea floor of the open ocean, the adsorption of radioactive wastes by sediments normally would be a safety factor in their disposal. However, in a situation where bottom areas adjacent to a disposal site are the source of seafood products such as oysters, clams, mussels, and bottom-dwelling fishes, the accumulation of wastes on the bottom may provide for increased contamination of the fisheries.

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PHYSICAL OCEANOGRAPHIC ASPECTS

What is the fate of wastes that have been released into the ocean? It depends on: chemical and physical forms in which the materials are introduced and changes that occur when the wastes are added to sea water; initial dilution of liquid wastes as they mix to attain the density of the surrounding sea waters; dispersal of wastes away from the area of introduction with related turbulent diffusion; and uptake and concentration of any contained radioactivity on silt, sediments, and biota.

The form of wastes after they have mixed with sea water will vary, depending on chemical composition; but three principal categories of chemical form may be expected: ionic, colloidal, and particulate. Consideration of the ultimate distribution of wastes must include evaluation of three chemical forms. In 1954, A. E. Greendale and N. E. Ballou tabulated the physical states of elements following detonation of an atomic device. Since this tabulation compares favorably with other nuclear wastes, their table is reproduced here.

PHYSICAL STATES OF ELEMENTS IN SEA WATER

(Percentage in given state)

Element	*Ionic*	*Colloidal*	*Particulate*
Antimony	73	15	12
Cerium	2	4	94
Cesium	70	7	23
Iodine	90	8	2
Molybdenum	30	10	60
Niobium	0	0	100
Ruthenium	0	5	95
Strontium	87	3	10
Tellurium	45	43	12
Yittrium	0	4	96
Zirconium	1	3	96

Those elements, such as strontium, cesium, and iodine, that are principally in ionic form, should go into solution in the ocean and follow pathways and residence times that are equivalent to those of other solutes in sea water. Surface currents and diffusion preclude the accumulation of "hot spots" of radioactivity after its initial dispersion into the ocean.

Since stable strontium is an abundant element in the ocean, radiostrontium will be diluted by the stable isotope. Any uptake of radiostrontium by organisms will be in competition with uptake of the stable isotope. The result, as demonstrated by studies following nuclear bomb tests, is that there is no evident accumulation of radioactive strontium in marine fishery organisms. A few days after large releases of strontium 90, it was difficult to locate the isotope even with precise chemical separations of sea water, according to F. G.

Lowman's article, "Marine Biological Investigations at the Eniwetok Test Site," published in 1960.

Perhaps the most uncertain factor in evaluating the problem of waste disposal into the ocean is lack of adequate knowledge of the diffusion, mixing, and transport processes in the ocean. So-called ocean rivers have been discovered that carry more water than the largest inland rivers at speeds up to at least 5 knots. One of these rivers, the Gulf Stream, meanders toward and away from shore in such a way as to make questionable its use as a mechanism for diffusion. Most oceanographers felt that, because of the possible contamination of coastal beaches, the area within the Gulf Stream, at least its southerly reaches, should not be used for disposal of wastes.

Strong equatorial currents and countercurrents also leave open to question any attempts to dispose of substantial quantities of wastes in these areas. Since the source of such currents is unknown, the tendency is to avoid consideration of the immediately adjacent waters either north or south of the equator as possible disposal sites.

In the upper layers of the ocean, even in the absence of strong undirectional flow, the transport of radioactive nuclides occurs at a significant rate. According to Allyn H. Seymour, one year after the 1954 test series in the Marshall Islands, some activity from close-in fallout from those tests was found in the North Equatorial Current, with the highest activity in an area about 3,500 miles west of the Bikini-Eniwetok area. The activity in this area was about one-fourth of the naturally occurring radioactivity in sea water. However, it was measurable.

Low-level wastes introduced into the upper, well-mixed layer of the ocean or into coastal waters will quickly be transported and diffused away from the source. This diffusion process is best understood in tidal and unstratified waters, where three mechanisms may be noted: initial diffusion brought about by the method of introduction, i.e., by jet stream, by release into the wake of a ship, etc.; primary dispersion due to adjustments in relative density, temperature, etc., in the first hour or two after release; and secondary dispersion due to currents and tidal flow.

In relatively isolated waters, the mixing of wastes with sea water continues principally by molecular and turbulent diffusion processes. Although for practical purposes molecular diffusion is relatively unimportant as compared with turbulent diffusion, molecular processes establish an end point of mixing, and contribute most to the later mixing stages.

Turbulence adds about one millionfold to the rate of molecular diffusion. Vertical diffusion in surface waters occurs at a rate about one thousand times greater than molecular diffusion. The dispersion rate depends on tidal and other currents, the surface wind speed, density gradients, the direction of principal dispersion, and the volume of the containing water. Predictions of the rates of dispersal of wastes from any type of introduction are very difficult. Such estimates await the data from experimental releases of dyes or radioactive materials.

Turbulent diffusion results from the state of motion and the existence of gradients in the ocean. The warm surface layers are separated from the cold bottom layers by an area that exhibits rapid temperature decreases with depth. The intermediate layer may extend to about 1,000 meters in depth, with waters below that gradually decreasing in temperature. Changes in salinity and density accompany the changes in temperature and provide a base on which diffusion operates with various pressures from gravity, tides, storms, and other forces.

The averaging of the effects of turbulent diffusion in computations of waste disposal have been relatively unsuccessful. Thus, the recent development of techniques to measure diffusion rates experimentally has been noted with great interest. In one case the fluorescent dye, rhodamine B, serves to make large-scale tracer studies in the open ocean feasible scientifically and economically. Such experiments help to predict the effect of an accident to a seagoing reactor, or of deliberate disposal of an operating nuclear space vehicle (pl. 2, fig. 2).

In the Eastern Pacific and at various other places, the oceans exhibit areas of upwelling. Within these areas, often many square miles in size, colder water is transported from the deep oceans to the surface. Care must be exercised in the location of waste-disposal sites to avoid the sea bottom where upwelling occurs.

Consideration has been given to the location of waste disposal sites in areas where relatively isolated water occurs beyond sills that approach the surface of the ocean.

Others have suggested the use of deep trenches, although reasonably strong currents, in the order of centimeters per second, may be noted near the bottom of certain deep trenches. The most recent National Academy of Sciences report of waste disposal recommends that such trenches not be used.

MARINE ECOLOGICAL ASPECTS

The biological oceanographer is concerned with the disposal of radioactive wastes at sea from five standpoints: the role of organisms in increasing or decreasing the vertical and horizontal transport of radionuclides, the ability of organisms to concentrate radioactive materials, the interaction of radioactive materials with the biota, the biological effects of radiation on organisms, and the utilization of added materials to trace biological processes and to study productivity of marine waters.

From the biological standpoint, the disposal of wastes is much more complicated than from geological, physical, or chemical standpoints. The thousands of marine species have differing metabolic requirements, at many different concentration levels, for different chemicals that may or may not be abundant in the sea. Certain trace elements that are required for rapid growth may be present in nuclear wastes. Consideration must be given to the possible use of contaminated fish or seaweed as fertilizers on the land, as well as to the possibility of beach disposition of radioactive materials. Tolerances for radiation and susceptibility to genetic changes vary widely depending on the chromosomal structure, the stage of development, and many other poorly known criteria.

The scale of allowable concentrations for a single constituent of nuclear wastes is a complex one with variations between 1 and 10^{-7}, a 10 millionfold difference. Living organisms may concentrate certain isotopes to at least 10^{6} times, a millionfold increase. If radioactive wastes are of known quality and quantity and if the organisms in an area are known to concentrate the specific wastes at a known rate, a reasonable answer could be given to the question concerning potential effects of given disposal rates. In the absence of this information a number of guesses must be compounded on at least a 10 million-million scale in estimating permissible disposal levels.

The extent of accumulation of a radionuclide is dependent on its availability to the organisms. This is regulated by the abundance of the element, and to some extent, by the abundance of other elements. Not only must the specific elements be considered; but also it must be remembered that certain radionuclides may be present in chemical combinations not readily available, or, conversely, more available, to the marine biota.

Most organisms appear to have a greater affinity for certain elements than for others. Goldberg (1957) noted a relationship between concentratability of metallic ions and their chemical stability. In seaweeds it was found that nickel is concentrated 550 times, zinc 900 times and strontium 23 times that of seawater. Bowen and Sutton (1951) reported concentration in sponges as 1,400 for copper, 420 for nickel, 50 for cobalt, 0.07 for magnesium and 3.5 for calcium.

In the open ocean after massive close-in fallout from nuclear tests, most fission-product isotopes are found within a few hours of detonation to be associated with biological organisms, especially plankton, and with particulate suspensoids. Within a week the cation fission products seem to have been mostly removed from living biological surfaces. Induced radioactive isotopes are produced from materials in the containment vessel of a nuclear device or from elements in the water. The biological demand for these materials is such that they be concentrated thousands of times in tissues of marine organisms and remain in the tissues for much longer times than the cations.

The fission-product isotopes, strontium 90 and cesium 137, that are of great concern in land contamination from fallout, appear to be of substantially less concern in the ocean where the biological demand is apparently met by stable isotopes of the same or related elements. Although there was a great uproar in 1954 when a Japanese ship, transporting newly caught tuna, was discovered to have been in the path of radioactive fallout from a weapons test, it later developed that the particles of radioactivity were on the surface of the fish and that they could be removed by surface washing. No hazard has been found from uptake of radioactivity by tuna.

Only one example is known of marine organisms being destroyed as a result of the uptake of radioactive isotopes. Following the detonation of nuclear devices in the Marshall Islands in 1958, Aubrey Gorbman, then of Columbia University, found evidence that herbivorous fishes concentrated radioiodine which had already been concentrated by seaweeds. These high concentrations of radioiodine were again concentrated to destroy the thyroids of carnivorous fishes which fed on the herbivorous ones. Such carnivorous fishes were collected, with death apparently due to destruction of thyroid tissues. Although radioactive iodine may be concentrated by marine organisms, it is of little serious concern except in cases of close-in fallout since its radioactive decay rate is relatively rapid and since some dilution is present from stable iodine in the ocean.

Information is being accumulated that will provide basic information on the uptake and concentration of isotopes near waste outfalls. Less information is available and little useful data has appeared to answer the question of biological effects of radiation during the lifetime of individual marine organisms.

A particularly interesting project now underway at the University of Washington exposes salmon eggs and fingerlings to low-level gamma radiation over the first 3 months of their existence. On release they will go to sea to return in from 2 to 5 years. Comparisons of return rates of irradiated versus unirradiated controls should give some indication of the nature of the problem.

In considering the uptake and effects of radioactive isotopes on marine biota, attention must be given to the location of elements in different organs of the body. Strontium 90 may be concentrated in the skeletons of clams, scallops, oysters, and Radiolaria of the suborder Acantharia. Cesium 137 is concentrated about thirty to fifty times more in the muscles of clams than in sea water. Zinc 65 may be concentrated several thousand times more in the muscles of oysters, clams, and scallops than in sea water. Marine fishes concentrate zinc 65 especially in the kidneys. Cobalt 60 is concentrated in the liver and kidney of hard clams.

Biological activities of marine organisms are important to waste disposal in the ocean. The ratios of the mineral salts of calcium, sodium, and chloride are not much different when taken from any part of any open-ocean area. On the other hand, biological nutrients, such as nitrogenous compounds, phosphorus, and dissolved oxygen, may vary significantly from one area to another. The Pacific Ocean differs from the Atlantic by perhaps 2 percent in salinity, but the deepwater concentration of phosphates in the Pacific is twice that in the Atlantic. Phosphate concentration in the Mediterranean is about one-third that of the Atlantic. This difference may be accounted for by the sinking of dead organisms, and to a certain extent, by the vertical migrations of marine species.

Zooplankton and certain fishes migrate diurnally to a varying degree in the oceans. Such migrations usually are limited to the upper 100 to 400 meters. Although less than one ten-thousandth of the radioisotopes present were attached to organisms as compared with those dissolved in the water following Pacific tests, daily migrations with rapidly exchanging isotopes may result in the transfer of substantial quantities of radioactivity from one level to another in the ocean. Seasonal vertical migrations also may affect such transfer. For example a copepod, *Calanus finmarchius*, lives for most of the year at depths from 600 to 1,000 meters, but spawns close to the surface from May to August.

Fish migrate horizontally as much as 70 miles per day, and wastes may be transported with them. Since the migrations of fishes are related to their aggregations, which makes them more vulnerable to being caught, it is necessary to estimate the effect of such movements on the possible return of pollutants to man.

A complex feeding interrelationship exists in the sea where survival appears to require the production of vast numbers of offspring. The growing population of the ocean is dependent on microscopic algae which incorporate nutrient materials into foods. In a microscopic world, predator and prey species compete by eating smaller or, in some cases, larger organisms. Radioisotopes incorporated into cells of algae or adsorbed on their surfaces appear in the digestive apparatus of tiny animals that, in turn, are eaten by other predators. Each of the organisms in such a food web has its own distinctive chemical requirements, accepting certain elements and rejecting others.

How does one measure the abundance of organisms in the ocean? Only a few marine biological groups have been collected and recorded quantitatively, and most of these groups vary in abundance locally and seasonally. It is known that water currents, temperature, and abundance of nutrients play a vital role in the production of many organisms.

On the other hand, some marine species appear to be almost independent of the usually recorded physical-chemical constituents in the oceans. In areas where water masses come together, nutriently rich waters may be forced to the surface to produce an abundant and diverse fauna. Predators thrive on the concentrated food organisms, and human food organisms may be unusually contaminated by waste disposal into such aggregations.

Discharging rivers bring important trace nutrients to the coastal area, and these result in a large increase in the production of marine organisms. In such areas it is obvious that caution must be exercised with respect to the location of waste disposal sites. The shallow waters near the shore provide a principal habitat of commercially important oysters and clams, as well as for valuable game fish. Disposal of wastes in packages may provide an artificial reef that is attractive to fishes. After benthic fouling organisms begin to grow on the surface of such packages, a food chain relationship to man is possible. The continental shelf and its overlying waters serve as a habitat for many important game and commercial species. Since fish populations shift their location diurnally and seasonally throughout the shallow-water area, it is difficult to select any part of the continental shelf and give reasonable assurance that no human resource will be adversely affected by waste disposal.

The only real basis for oceanic disposal of wastes rests in the deep sea beyond the continental shelf. Here in tropical and temperate waters, the established layering processes and the paucity of commercial or game organisms in the waters below 1,200 fathoms leads to the conclusion that adequate mixing times (up to 1,000 years or more in the North Pacific) must be present to dilute most pessimistic estimates of the quantities of wastes to be produced during the next 40 to 50 years.

As mentioned in the previous section, the chemical nature of the wastes is very important. Particulate wastes will be trapped during the normal activity of filter or mucous feeders and taken into the digestive tract. If the particles are of such a nature that they can serve in the metabolism of an animal, they may be retained. A substantial portion of particles, particularly cerium 144 and other rare earth elements, pass on through the digestive tract.

FATE OF RADIOACTIVE MATERIALS IN THE OCEAN

In disposal of radioactive wastes into the ocean it is desirable to make a "materials accounting" of the radioactivity. Only estimates are available of the important parameters in many cases. Radioactive isotopes undergo decay to become stable elements. Decay is independent of environmental conditions, and all isotopes decay independently of all others. When the chemical composition and quantity of individual isotopes are known in discarded wastes, it is simple to calculate the length of time necessary for the radioactivity of the waste to decay to negligible levels. Likewise, if the composition and chemical state of the wastes are known, it is possible to predict their ultimate distribution in biological organisms, in sea water, and in sediments.

The United States approach to nuclear wastes research differs from that of the British. In establishing its nuclear power plant at Windscale, the British Government encouraged scientists to investigate openly the specific area to be exposed to radioactive wastes. Following extensive studies the nuclear plant began operations and predictions could be checked. Such an approach was favored by the scientific community and by the public to the extent that an editorial in *Nature* magazine commended the government for its waste policy.

By contrast the United States Government has preferred to investigate and evaluate its waste disposal sites under a cloak of Government classification of data, and no clear picture of the adequacy of such studies has been made public. The result is that no broad scientific endorsement has ever been given publicly to the Atomic Energy Commission policies of waste disposal.

DECONTAMINATION

When nuclear devices are tested or utilized as well as when accidents occur in or above harbors, estuaries, and the open ocean, large quantities of sea water may be radioactively contaminated. Studies of the decontamination of natural sea water have had some support. Mostly theoretical, the investigations have considered the use of various materials as decontaminating agents, including aluminum, silicates, activated charcoal, barium and iron salts, and potassium permanganate. Activated silica is used successfully as an aid to coagulation in municipal water-treatment processes, and this use justified a detailed study by the Naval Radiological Defense Laboratory of its use in decontamination of sea water.

Although results of laboratory and field tests have not been conclusive, it is believed that sodium orthosilicate is the best single coagulating decontaminant. It may absorb 90 percent or more of mixed fission products released in sea water. Liquid slurries give better results than dried materials.

The radioactive decontamination of sea water is difficult because of its high rate of chemical reactivity; however, flocculation techniques will carry the wastes down for a considerable distance. The efficiency of the removal of mixed fission products seems to be directly proportional to the volume of floc present. The elements which are chemically most similar to sea-water salts, such as radioiodine and radiocesium, give the poorest results in decontamination tests. Recycling of the water with a different floc producer gives better results.

From reports of fallout distribution near the Eniwetok test site, it may be assumed that exchange processes will bind mixed fission products for less than 1 week in the open ocean. The data from Project Wigwam, of the Atomic Energy Commission, indicates that this period would be long enough for oceanic processes to disperse and dilute the radioactivity to a point of no hazard following a predictable peacetime accident. In estuaries and coastal waters, the temporary bonding may facilitate beach contamination.

Particulate feeding organisms, especially oysters, secrete mucus in such a way as to entangle particles in a sort of rope which they may eat or bypass to the open ocean. The mucus-bound material seems to be subject to less rapid chemical exchange, thus permitting more time for radioactive decay to reduce the hazard. In areas contaminated over oyster beds, it should be possible to substantially reduce the direct hazard, but the oysters would be contaminated.

The ocean offers certain survival advantages to man in case of nuclear war, since within a few hours, dilution would bring the levels of radioactivity near the water surface to a level much lower than on land surfaces where the isotopes would be concentrated in the first centimeter of soil. In addition, since water is an excellent shield for protection from radiation damage, pelagic fish are likely to be the least harmed of all natural resources. During the early fallout periods, it would be possible to pull water from below the surface for washdown decontamination of a ship, and thus lower the total exposure of ship's personnel.

PROBLEMS NEEDING FURTHER STUDY

Although much has been learned about waste disposal in sea water, the initial effort has more clearly defined the problem than solved it. The Atomic Energy Commission, the Public Health Service, and other agencies have initiated studies designed to clarify the role of atomic and other wastes in the environment and how they may affect man's health.

Physical problems of turbulent diffusion and the circulation and residence times of water masses are of significance. Studies of the chemistry of sea water and the biogeochemical relationships involved in the sea water-sea floor interface must be continued, since not even the exact composition of sea water is known. Many naturally radioactive isotopes are present in sea water, and studies of their distribution and reactions contribute to an understanding of the added material.

Biological problems are the most complex. An evaluation of a waste effluent must identify the populations; learn the life cycles, feeding mechanisms, and nutrient requirements of each species; study the tolerance of each species for the various harmful portions of the wastes; know the physical-chemical parameters and interrelationships of sea water, sediments, and wastes as related to their dilution; and understand the optimum balance between the desirable addition of wastes as nutrients and any possible detriment to man's activities.

Although the number of fascinating research problems is legion, the natures of the problems are so complex that many years will be required to attain a reasonably full understanding of the effects of human and industrial wastes on the ocean and the routes of their return to man.

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What Is Cybernetics? [1]

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[With 3 plates]

A railway train needs no steering gear. The forces required to correct for the buffetings of wind and way are supplied automatically, by the sideways reaction of the rails against the wheel flanges. A ship, lacking such implicit means of guidance, requires a helm, normally controlled by a *helmsman.* The Latin for helmsman is *gubernator;* the Greek, *kybernetes.* From the first comes our word *governor.* From the second, in 1843, André Ampère derived the term *cybernetics* (la cybernétique), to denote the *science of government.*

In 1948, Norbert Wiener of the Massachusetts Institute of Technology independently proposed the same term for "The Science of Control and Communication in the Animal and the Machine," as the title of a book whose repercussions are among the remarkable scientific phenomena of our century. Just as it appeared, the war-born art of eliminating the human element in military missiles was being rapidly adapted to peaceful applications in all manner of industrial areas, aided by the explosive postwar development of electronic computing techniques. At the same time the physiologists and students of animal behavior, many of them fresh from wartime experience in radar and electronics, were alive as never before to the possibilities of explaining all bodily activity—even at the human level—in terms of hierarchies of "self-guided" mechanisms. In the ferment of ideas thus generated, the growing realization that scientists in these widely separated areas had a common problem was due in no small measure to Wiener's book.

What, then, is this common problem? In brief, it is to understand (or procure) the organization of effective action—of all processes, whether artificial or natural, in which goals, ends, standards are sought or maintained, and unacceptable states or events avoided. As a discipline, cybernetics thus belongs to the same family as engineering, and no sharp lines can be drawn between the two.

[1] Reprinted by permission from *Discovery* (London), vol. 23, No. 10, October 1962.

What characterizes cybernetics, however, is the generality of its ideas. Whereas much of engineering, or cell biology, or neurophysiology, or economics, is necessarily concerned with particular problems of energy-transport, or biochemistry, or finance, the cyberneticist is concerned only with those abstract features, common to systems in all fields, by virtue of which effective action is organized.

To bring out some of these essential features, let us first look at our helmsman. Basically, the chain of events by which the ship's course is governed has three stages, which we may call *indication* (of disparity between actual and desired course), *calculation* (of form of action required to diminish disparity), and *selection* (of the helm-position calculated to be appropriate). As a result of his action, the indication will generally alter, so that we have here a "closed loop" of cause and effect—the so-called "feedback loop" which is a feature of all self-regulating, as distinct from merely physically constrained, mechanisms.

Cybernetics is built upon the realization that each of the foregoing stages can in principle be mechanized. The compass, the ball-float, the centrifugal governor, and the bimetallic thermometer are long-familiar examples of sensitive devices whose mechanical output can indicate the disparity between the present state of some quantity (direction, water level, speed, or temperature) and some preset "goal state." Rudders, water cocks, steam valves, and furnace regulators are even older examples of the third stage in the regulative chain.

What is new in scale (though not so new in principle) is the mechanization of the second stage—the process of calculation. Although a mechanical general-purpose computer was devised by Charles Babbage in the middle of the 19th century, it was only the advent of electronics that gave such devices the speed and capacity needed to replace the human brain in organizing complex regulative actions. For the simplest type of ball-cock, steam-governor, or thermostat, the only "calculator" required is a simple mechanical link between indicator and control, so that supply is reduced when the indicator reads "excess."

For a self-guided missile, or a "self-optimizing" chemical process-controller, on the other hand, the calculating mechanism must continually modify and supplement the link between the indicator and the selector of action, in accordance with a multitude of other data from auxiliary receptor-organs and from the past as recorded in its storage devices.

In still more complex automata now envisaged, the repertoire of action includes means of changing the pattern of instructions or connections within the automaton itself—a kind of gear-changing operation on its own logical machinery. In this way by "trial and error" (a form of intelligent natural selection), as well as by calculation, it develops within itself the organizing routines and "conditioned reflexes" found necessary in the course of past interaction with its field of activity. The scope of "artificial intelligence" along these lines is virtually unlimited in principle. It is thus hardly surprising that cybernetics in popular thought is so closely identified today with the theory of computers.

The earliest and most characteristic mathematical developments in cybernetics, however (in a paper by J. Clerk Maxwell in 1868), were concerned with a more central problem—that of warding off *instability*. In any closed cycle of control, if the response to control is too sluggish or too violent, it is fatally easy for the system to become unstable, overcorrecting itself in a series of wild swings in opposite directions, called "hunting." Although the mathematics of unstable behavior has mostly been developed for "linear" systems (those whose responses change in strict proportion to changes in input), there are a number of general principles and rules of thumb which invite application in a wide range of fields at present plagued by instability. These include, for example, keeping the *number* of stages in a chain as small as possible; reducing *sensitivity* to the minimum acceptable; and combating sluggishness by taking *rates of change* of indication as a guide to action.

The second great area of mathematical development specific to cybernetics has become known as Information Theory. To control a task of a given complexity to a given accuracy, in an environment with given statistical features, how much information does a cybernetic governor need? The theory of information sets out to make such questions precise, and to give mathematical answers to them. Thanks largely to the work of C. E. Shannon, it has been generalized to enable communication engineers to evaluate and compare the channel capacities of different encoding or transmitting systems, and to take precise account of the effects of random disturbance, or "noise." Even more important, it has shown how statistical correlation between different elements of a signal ("redundancy") can be used to enable random errors in transmission to be detected and corrected, so that a "noisy" channel can—in principle, and given a long enough run for statistical purposes—transmit up to a definite rate with arbitrarily little error.

Once again it should be added, however, that in the bulk of cybernetic investigations to date it is the *qualitative* notions of information theory—information, encoding, noise, redundancy, channel capacity, error-correction—rather than its mathematical apparatus, which have so far found illuminating uses. No one interested in the cybernetic approach should be frightened off, or unduly impressed, by sprinkled references to unfamiliar mathematics in the somewhat uneven literature of the field. With few exceptions to date, their function will turn out to be decorative rather than pivotal.

We have confined discussion thus far to examples of natural and artificial helmsmanship—control under the guidance of information. This is what the term "cybernetics" was coined to denote, in contradistinction to the older method of physical constraint typified by our railway example. Unfortunately the popularity of the term has led to its being used in some quarters to include situations of the opposite sort—those where no element of information-guided selection is present, but (as with the railway) the necessary corrective forces depend wholly on the inertial reaction of the situation where they are required. Thus a pendulum, or a ball at the bottom of a bowl, is described by some writers as a cybernetic system under "feedback," because it automatically suffers a force opposed to its displacement from equilibrium. Even such lowly forms as the reaction of a floor to the weight of an object placed on it cannot then be excluded. It is gradually being realized that such usage trivializes the term; but for the present at least the reader must expect to find it sometimes used in confusing and even contradictory senses.

Behind the confusion there is in fact an interesting ambiguity in the cybernetic approach—in the very nature of control itself. The cybernetician seeking to understand a complex system begins by trying to discern the "pattern of subordination"—asking "which controls what?" The difficulty is to define "control." Everyone would agree that a watercock controls the flow of water into a cistern; but if two cisterns are connected together, so that the level in each affects the level in the other, can we say that one controls the other? However we decide, there is obviously an important difference between the two cases. The second shows no more than a passive tendency to equilibrium between action and reaction; but the first includes an "active" element (the cock plus water supply) whose control lever determines the flow of water without itself suffering appreciable reaction.

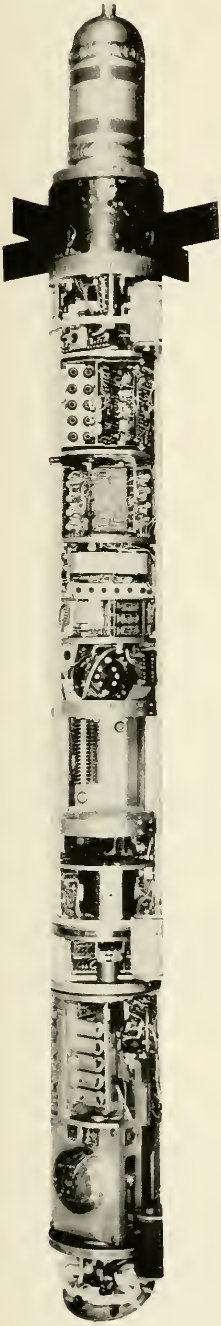
Suppose now that we link the cock lever to a ball floating on the water, as in the familiar ball-cock. What now controls the level of the water? In one sense, we may still say "the cock"; but in another and more important sense, it is not now the cock per se, but its height above tank bottom, which (other things being equal) governs the final water level. If we had means of raising and lowering the whole watercock-and-ball assembly, this would enable us to select the water level at which the cock would turn itself off.

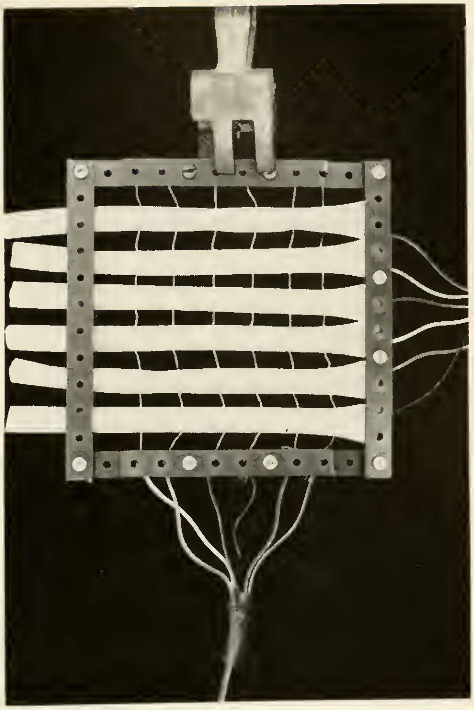
What this example makes clear, I think, is the subtle and arbitrary human element that underlies many cybernetic notions. Basically, by saying that A controls B we mean that if *we* could control A then *we* could control B. In a strictly physical sense, divorced from the human notion of "purpose," the notion of control tends to be ambiguous or meaningless. The only objective physical distinction we can firmly draw is between (1) devices, such as watercocks, steamvalves, transis-

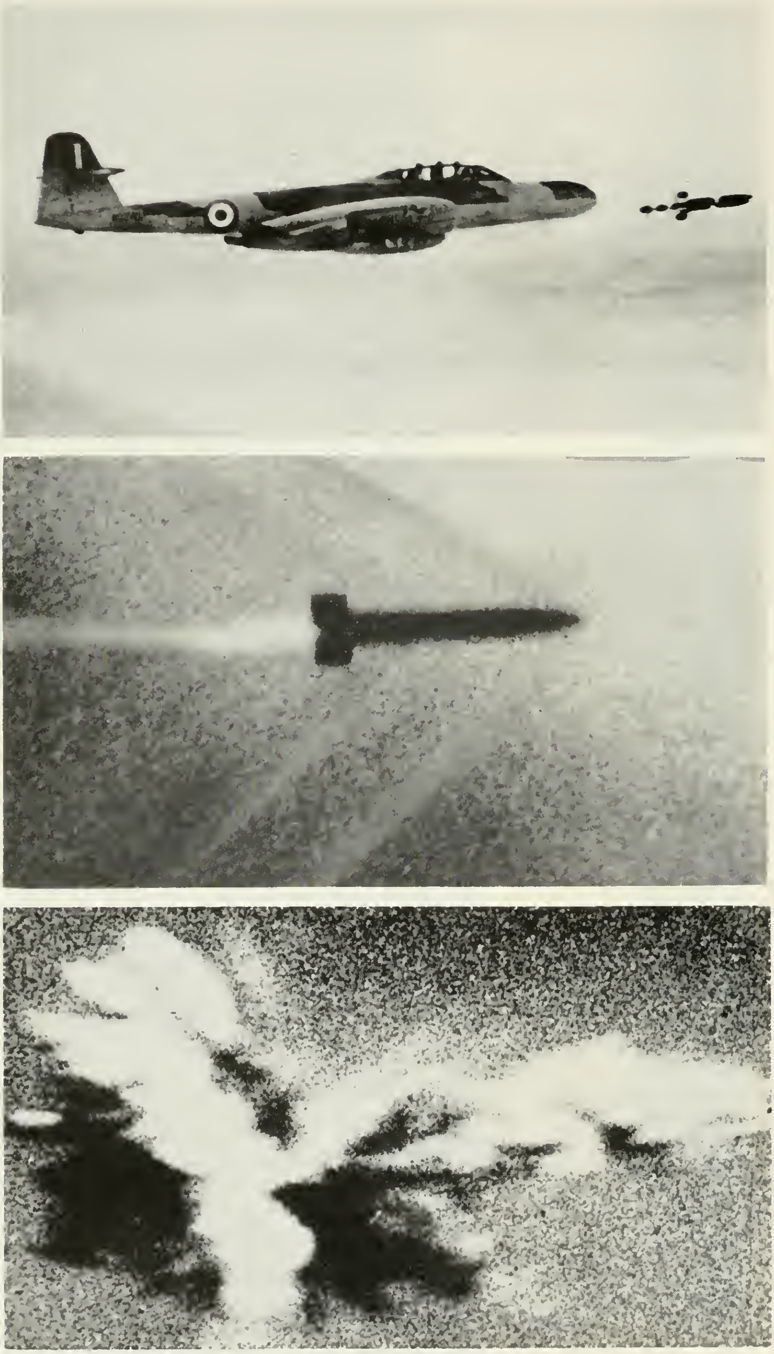
Common features of the "effective actions" shown here and in plate 3 illustrate the generality of the cybernetic approach. Both involve "indication, calculation and selection," though in contrast to missile, chameleon's action is largely precomputed. Precomputed guidance is also used in mechanical systems. Photos from "Zoo Quest to Madagascar," Lutterworth Press.

PLATE 2

These photos symbolize three stages in the advance of control systems. *Left:* This steam-engine governor, photographed in motion at the Science Museum, London, is one of the earliest examples of a practical automatic control system. Using the engine's output (speed) to control the energy input to the engine, it foreshadows the use of the feedback, so fundamental to modern control systems and to cybernetics (photo: Patrick Thurston). *Above:* A modern test vehicle used for guidance and control experiments—sensing device is at left, control devices at right. Much of the remaining space is taken up by calculating devices—it is this stage of control that has developed so remarkably in modern systems (Crown Copyright). *Right:* A look into the future of control systems. Picture shows an experimental arrangement enabling an automaton to change its own pattern of connections. Vertical tubes are filled with electrolyte and serve also as "bus bars." Insulating film of oxide can be formed electrolytically on horizontal wires at points of intersection by currents passed through them, thus altering input-output relations of the network so as to match changing patterns of demand (MacKay and Ainsworth, Brit. Pat. App. 12887/61).







These three stages of flight of three missiles show some common features with plate 1. But here guidance action is continually computed, controlled mainly by the error between the paths of the missile and its target. This guidance action is very similar to that of a tennis player returning a ball. (Photos: top, Crown Copyright; center, Bristol Siddeley; and bottom, Bristol Aircraft.)

tors, and rudders, where the input, A, determines the form of the output, B without supplying all the energy of B; and (2) devices such as transmission lines, levers, springs and gear trains, where the energy of B is totally provided from the energy of A. In the first case, the energy of A is at least partly devoted to altering the structure through which the energy for B is channeled—altering the coupling between the output, B, and its internal energy supply. In the second, no analogous process occurs. In the first case a cybernetician would say that A exerts "active control" over B. In the second (if we wish) we may speak of "passive control"; though to some of us it would here seem clearer to speak simply of action and reaction.

The important point is that in cybernetics we are concerned with the action of *form* upon *form* rather than of *force* upon *force*. The rigorous theory of such processes is still in its infancy, and a good deal of what is offered today under the aegis of cybernetics necessarily has little behind it but sanctified common sense (and not always that!).

What light do all these developments throw on our understanding of biological processes? As current scientific literature shows, they have suggested fruitful questions right down to the level of the components and chemistry of the individual cell, where both informational and cybernetic notions crop up. With the still more complex structure of the brain, our problem is to find any set of manageable abstractions whose interaction may be studied with profit.

Here the role of cybernetic models is often misunderstood. It is not a question of finding some artificial system that will behave externally in the same way as the brain. Superficial resemblances of this sort can be a curse to the theoretical neurologist. As in all scientific research, the role of a model is to serve as a kind of template, which we hold up against the real thing in order that any discrepancies may stand out more clearly, and guide us towards the making of a better one. We judge a model to be useful, therefore, not merely by its predictive successes, but also by the clarity with which its failures can be interpreted, and lead to its refinement. Only the unexpected yields fresh information; and even this is informative only when we know what to make of it—hence the crucial importance of disciplining our models as far as possible by the structural realities of the system we want to understand. The so-called "black box" approach may serve well enough in "human engineering"; but, especially if we want our models to account for pathological as well as normal conditions, our progress in science is soon halted, if not totally misdirected, unless we work hand-in-hand with those who lift the lids and peer inside.

Finally, what of the future of "cybernetic machinery"? Already, we know enough to say that any pattern of behavior which can be precisely specified—including the sorts of behavior that we would

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normally classify as "intelligent," "insightful," "recognitive," "purposeful" and so forth—can in principle be shown by an artificial mechanism, embodying only known processes. Some of us are developing ways of enabling such mechanisms to grow and modify parts of their own internal wiring as a result of experience. The design of artificial limbs, speech organs, and mechanisms of visual and auditory form-perception are all likely to make rapid progress in the next decade. Many of these and other developments will be linked with prosthetics—the effort to replace human faculties lost by disease or damage.

This prospect, though (like that of space travel 20 years ago) it may savor of science fiction, inevitably raises two serious questions. The first is whether we are now in a position (in principle—blessed phrase!) to synthesize fully human behavior. The answer, quite shortly, is "no." Those aspects of human behavior that we understand well enough to specify exactly can indeed be mechanized, given enough time and space and computer capacity. But mechanization, impracticably complex though it would be, is not the real problem. The fundamental limit to our power of synthesizing human behavior is precisely in our own understanding of what it is to be human. That this is incomplete at present needs no demonstration. That it could ever be otherwise—even in principle—I personally take leave to doubt.

The second question is whether by implication we are now entitled to regard natural human beings as "no more than" cybernetic mechanisms. This question is ambiguous. It may be asking whether the human brain-plus-body can be regarded as no more than a cybernetic mechanism. In that case, although our ignorance of brain mechanisms still far exceeds our knowledge, most scientists today would, I think, answer with a cautious affirmative. What they would emphasize is the astronomical complexity of any mechanism (whether we call it cybernetic or not) embodying 10,000 million cells, each of which is itself bafflingly complex.

There is, however, a quite different idea which is so often expressed by asking the same question. This is the fear (or the hope, according to taste) that a complete cybernetic explanation of human bodily activity, if once we had it, would debunk any higher view of human nature, in moral or religious terms. This idea, I think, is based on a philosophical mistake—the mistaking of these higher accounts of human action and the scientific, mechanistic account as mutually exclusive *rivals*, so that if one of them were complete and correct, it would leave no room for the other. The truth seems to be that when theologians speak about moral and religious factors in human behavior, they are not talking about quasi-physical (and scientifically inexplicable) *forces* at work on the mechanism of the brain. They are referring rather to the personal significance—the point—of the activity whose mechanical aspect the scientist may successfully explain. Thus the religious account not only leaves room for the mechanistic—it leaves a need for it (and vice versa) if justice is to be done to all aspects of the human being. To rest content with the mechanistic explanation would be to miss the point, rather in the way that an electronic explanation of the activity of a computing machine (though complete in itself) would miss the point that an equation was being solved.

In this sense man remains, indeed, a mystery; but that mystery stands wholly apart from any puzzlement we feel about the mechanism of his brain.

The Use of the Electron Microscope in the Study of Fossils

By William W. Hay
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[With 4 plates]

The electron microscope has proved to be a valuable tool in many fields of science. However, only in the past few years has electron-microscopy become a common technique for paleontologic research. It is now possible to investigate the skeletal hard-parts of living organisms and fossils in greater detail than was thought possible a few years ago. Two broad avenues of investigation have opened up: (1) Study of the structural building-blocks and the ultramicroscopic architecture of skeletal materials, and (2) investigation of modern and fossil skeletal elements too small to be seen distinctly with the light microscope.

The hard-parts of organisms are of particular interest to paleontologists, those scientists who study fossils, since the most likely remains to be preserved in rocks are mineralized skeletal parts. The paleontologist has been able to study the shape and surface features of shells. By cutting sections so thin they transmit light, he has been able to investigate the internal structure of shell materials in the light microscope.

In any investigation using microscopy, the resolving power of the instrument is an important factor to consider in interpretation of the results. The term "resolving power" refers to the ability of an optical system to produce an image sharp enough to distinguish between two closely spaced points. The resolution of an inexpensive light microscope may be as low as 2 μ,[1] that is, points less than 2 μ apart cannot be seen as separated points in the final image. The resolving power of an instrument depends in large part on the wavelength of the light or other electromagnetic radiation used to make the observations. It is impossible to resolve two points closer than one-half the wavelength of the light used. The wavelength of light in the visible spectrum is

[1] The micron, usually written μ, is a unit of measure commonly employed in microscopy. 1μ is 1/1,000,000 meter, or 1/1,000 millimeter, or about 1/40,000 inch.

about ½ μ, so that the theoretical limit of resolution of the light microscope is about ¼ μ. This means that no optical system using visible light, no matter how perfectly constructed, can separate points less than ¼ μ apart.

The electron microscope makes use of the fact that electrons traveling at high speeds have a wave as well as a particle character, and the very short wavelengths associated with electrons streaming down the tube of an electron microscope permit a much higher degree of resolution, so that points as close as 6 Å [2] can still be separated. As soon as paleontologists began to investigate shell structure with the electron microscope, the reason for earlier confusion became apparent—most of the fundamental building units employed by organisms in constructing shells are so small that they cannot be resolved in the light microscope. However, they are easily resolved and observed in the electron microscope.

Along with the advantages of this powerful new tool come some difficulties which do not trouble the light microscopist. First of all, it is impossible to observe shell material directly in the electron microscope, for most crystalline materials, such as calcium carbonate, are opaque to the beam of electrons streaming down the tube of the microscope. To get around this difficulty, replicas of the shell material are prepared. The replica is a film of carbon showing the details of the shell surface, but is so thin that the electron beam passes through it and produces an image of it on the viewing screen of the microscope. A replica is prepared in the following manner: The specimen to be replicated is placed in a vacuum chamber (called an evaporator) and the air is pumped out until a high vacuum is obtained. Then a strip of metal wire or carbon is heated to incandescence by passing an electric current through it. The atoms in the glowing carbon tend to "boil off" and, since there are no air molecules for them to collide with, fly out in straight lines from the source. As a result, an extremely thin film of carbon coats everything inside the evaporator. The delicate carbon film is usually freed by dissolving the specimen in acid very slowly. The film is floated off on water and picked up on support screens used in electron microscopy. Since the film was deposited as a stream of carbon atoms it reproduces surface features of the specimen in minute detail, and the term replica is a well-chosen description. One thing must constantly be kept in mind when studying replicas in the electron microscope—they represent only the appearance of the *surface* that was replicated, and do not penetrate to reveal internal structure.

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[2] The Ångstrom unit, written Å, is the standard unit of measure in the size range of atoms and molecules. 1 Å is 1/10,000 μ.

As an example of the sort of study of shell ultrastructure now possible, consider the investigations on the protozoans known as Foraminifera carried out recently by Hay, Towe, and Wright.[3]

The Foraminifera have long been of particular interest to paleontologists, since they are among the most common fossils, and are particularly useful in determining the age of strata. The Foraminifera build shells called "tests" in two ways: (1) by gluing foreign particles together with silica, iron oxide, or calcium carbonate cement, or (2) by constructing tests of crystalline calcium carbonate by secretion. The first group of Foraminifera are commonly called "arenaceous" and the second "calcareous." The calcareous Foraminifera may be subdivided into two major groups by the external appearance of the test. One group contains forms that have glistening white walls that are opaque. They superficially resemble china so closely that they are referred to as porcellaneous Foraminifera. The second group has walls that are translucent, so that the tests look as though they are made of glass, and are termed "hyaline."

There is another major difference between the porcellaneous and hyaline Foraminifera; the porcellaneous forms are also called "imperforate" since the wall is apparently solid and the protoplasm inside the test can communicate with the exterior only through a large opening at the end of the test known as an aperture. The tests of the hyaline Foraminifera are pierced by a number of minute pores, and the tests are said to be perforate. The protoplasm inside the test can communicate with the outside not only through a large aperture, but through the myriad pores as well.

Although porcellaneous Foraminifera are very common, especially in the shallow-water deposits of the Atlantic and Gulf coasts of the United States and are familiar to every micropaleontologist, the nature of the porcellaneous wall has remained an enigma. Early investigators described the walls as constructed of globular bits of calcium carbonate, but modern workers have been unable to substantiate this or to see any structure in the wall at all. Chemical analyses have shown that the wall is made of impure calcium carbonate, with magnesium atoms present at about 10 percent of the spaces in the crystal structure that are usually occupied by calcium. In reflected light some of the tests appear to glisten, indicating that the surface must be smooth enough to reflect light. Other porcellaneous tests belonging to the same species may be dull, but all are white and opaque in reflected light.

Viewed by transmitted light in a microscope, the tests of porcellaneous Foraminifera appear to be structureless, but do possess a

[3] Hay, W. W., Towe, K. M., and Wright, R. C., Ultramicrostructure of some selected foraminiferal tests. Micropaleontology, vol. 9, No. 2, pp. 171–195, pls. 1–16. 1963.

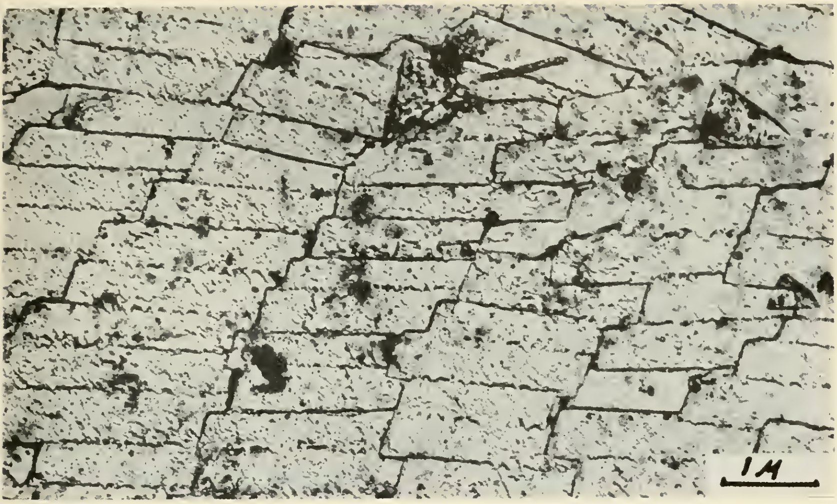
unique brown color. Examination in polarized light suggests that the wall of one large group of porcellaneous Foraminifera, the miliolids, must be made of minute, randomly oriented crystals. A bright line observed at the surface of the tests suggests that a thin layer of crystals with parallel orientation exists at the surface.

Carbon replicas of the surfaces of miliolids reveal two sorts of pattern present. In one case (pl. 1, fig. 1), there appear to be numerous stubby crystals of calcite randomly oriented. The crystals do not have well-developed faces, but even appear to be cylindrical in some cases. The ends are flat or rounded. The crystals are all about the same size, about 2 μ long and ½ μ wide. The general appearance is chaotic, like a jumble of short sticks, and indeed there seem to be numerous spaces between the tiny crystals, so that the wall may be porous even though it is not perforated by pores. Other surfaces (pl. 1, fig. 2) show a striking pattern of tiny thin rhombohedral crystals, all having more or less the same orientation. These crystals, like the others, are about 2 μ long and ½ μ wide. They are, however, distinguished by the presence of sharp crystal faces, and they are very thin. The pattern resembles the slate or shingle roof on a house. Often groups of two or three crystals appear to be joined by fine sawtooth sutures between the crystals. On some specimens the shingle pattern can be observed to overlie the layer with marked randomly oriented crystals.

The main part of the wall of a miliolid is seen to consist of a mass of more or less randomly oriented tiny crystals, and might actually be somewhat porous. The surface of a fresh miliolid test is covered by a veneer of the shingle crystal layer, and it is this layer that reflects light, producing the glistening appearance of the test. This layer is easily removed by corrosion revealing the randomly oriented matted layer, which is nonreflective, producing a dull surface.

Thus details of the structure of the miliolid wall, which could only be suggested by observations in the light microscope, have been revealed by electronmicroscopic examination of the tests. The size, shape, and distribution of the units of which the wall is constructed are now known. Some questions, such as the cause of the brown color observed in transmitted light, remain temporarily unanswered, and a host of new questions arise from examination of the electronmicrographs. How is the matted layer of crystals in the wall produced? Is the shinglelike surface layer deposited before or after the rest of the wall? How are the crystals held together? What is the meaning of the sawtooth sutures between some crystals in the shingle layer? As is common in science, the development of new techniques results in solving some problems and suggesting many new, more penetrating questions to be asked of the objects of study.

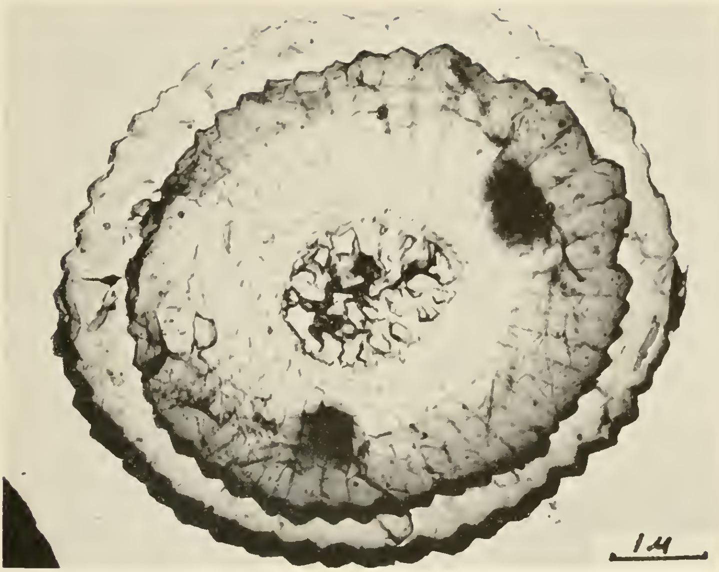
The hyaline, or perforate, Foraminifera are extremely important to micropaleontologists for it is among this group that are to be found



1. Electronmicrograph of a carbon replica of part of the surface of *Quinqueloculina seminulum* (Linnaeus), x 20,000 (from Hay, Towe, and Wright, 1962; micrograph by K. M. Towe).

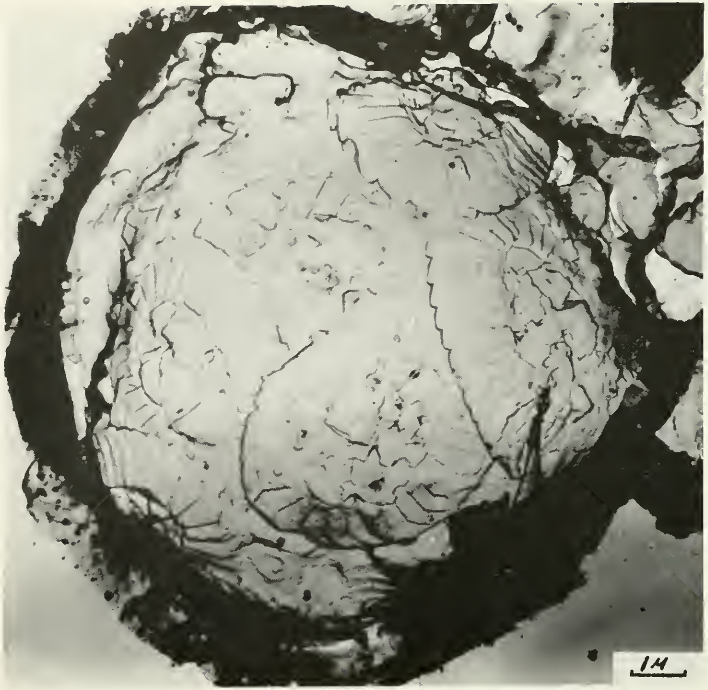
2. Electronmicrograph of a carbon replica of part of the surface of *Quinqueloculina seminulum* (Linnaeus) showing oriented crystals, x 20,000 (from Hay, Towe, and Wright, 1962; micrograph by K. M. Towe).

Electronmicrograph of a carbon replica of a sieve-plate covering the end of a pore canal of *Robulus midwayensis* (Plummer), x 140,000 (from Hay, Towe, and Wright, 1962; micrograph by K. M. Towe).

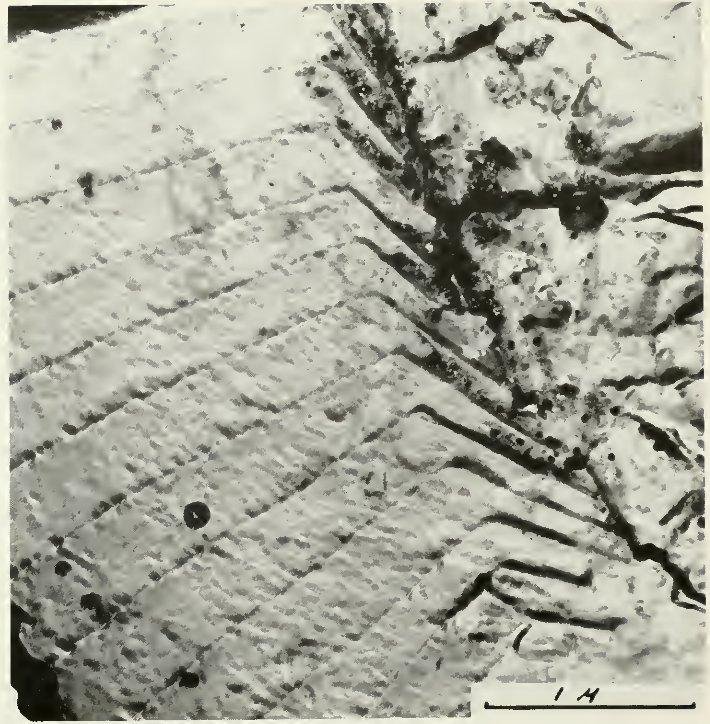


1. Electronmicrograph of a carbon replica of a coccolith from the Eocene of southwest France (Marniére de Miretrain, near Dax, Landes), x 20,000. (Unpublished micrograph by S. Gartner.)

2. Electronmicrograph of a carbon replica of a coccolith from the Eocene of southwest France (Marniére de Miretrain, near Dax, Landes), x 20,000. (Unpublished micrograph by S. Gartner.)



1. Electronmicrograph of a carbon replica of a coccosphere from the Eocene of southwest France (Marniére de Miretrain, near Dax, Landes), x 15,000. (Unpublished micrograph by S. Gartner.)



2. Electronmicrograph of a carbon replica of a coccolith from the Eocene of southwest France, showing ultrastructural detail (Marniére de Miretrain, near Dax, Landes), x 57,000. (Unpublished micrograph by B. V. Hall and W. W. Hay.)

many of the "guide fossils" used to determine the age of a particular stratum. In many of the species the pores in the test are large enough to be readily visible in the light microscope. Others, however, have such fine pores that there was some question as to whether the pores even existed or not. In the light microscope, the finely porous wall presents a "fibrous" appearance. Electronmicroscopic investigations reveal that the "fibers" of the wall are not calcite crystals at all, but are the fine pore canals, which are only ¼ μ in diameter, and thus cannot be clearly observed in the light microscope. The boundaries between the calcite crystals remain invisible, and the fine pore canals produce the image of a "fibrous" wall.

The pore canals of the hyaline Foraminifera are lined by an organic membrane and at intervals disks of organic material cover the pores. These disks can be seen vaguely in the light microscope. However, in the electron microscope they can be observed to be perforated by a number of openings and the term "sieve-plate" has been applied to them (pl. 2). The sieve-plates may even be preserved in fossil foraminifera. Very little is known about these structures at the present time. The function of the sieve-plates is unknown, but since they are located along the channels through which the protoplasm inside the test communicates with the outside, they may play an important physiological role.

Another area of paleontologic investigation which has been opened up through the development of replication techniques for use with the electron microscope is the examination of very small fossils. The term nannofossil (nannus=dwarf) is usually applied to these forms. The calcareous nannofossils constitute a heterogenous group of objects ranging from ¼ to 20μ. in size. Recently it has become apparent that many forms of calcareous nannofossils are of particular importance to paleontologists in establishing the age equivalence of rocks in distant places. When these fossils were first described during the 19th century, it was thought that such small fossils must be produced by exceedingly simple organisms, and that these organisms could hardly be expected to show any evolutionary changes. Modern studies have shown just the opposite to be true. Calcareous nannofossils are among the most complexly constructed skeletal elements yet studied, and evolution has wrought radical changes on them.

The most common sort of calcareous nannofossil is the coccolith (pl. 3). Coccoliths are button-shaped objects, mostly between 1 and 5μ. in diameter although they may range anywhere from ¼ to 20μ. On close examination, coccoliths are found to consist of two disk or shieldlike parts connected by a very short tube. Usually one of the disks is smaller than the other, so that the coccolith resembles a collar button. Coccoliths are made of calcium carbonate and are skeletal elements produced by a single-celled marine organism known

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as a coccolithophore. Coccolithophores are an interesting group of organisms that possess some of the characters of both plants and animals and thus are intermediate between the two great biological kingdoms. They are able to carry out photosynthesis, although the color of the chloroplasts in the cells is golden yellow to amber rather than green. They possess two whiplike flagellae which are used to propel the organism through the water on an erratic course. The coccolithophores secrete coccoliths and arrange them within the cell to form a hollow sphere, known as a coccosphere (pl. 4, fig. 1). Upon death or proper stimulation, the coccoliths are released from the enclosing protoplasm, and begin to drift down to the ocean floor. Coccolithophores live suspended in the water as plankton and may be found in shallow inshore waters as well as in the open sea. Usually those forms inhabiting shallow waters have smaller, more delicate coccoliths than those found in the open oceans. For this reason, they are less likely to be preserved as fossils. In oceanic deposits, relatively little material derived from land is present, and over broad areas the sediments consist largely of the remains of planktonic organisms inhabiting the upper layers of water. In tropical and temperate regions where the water is less than 20,000 feet deep, large areas of the ocean floor are covered by a deposit called *Globigerina* ooze. *Globigerina* is a planktonic foraminifer and the shells of this organism are the most conspicuous organic remains seen with low power microscopic examination. However, more detailed inspection of samples of *Globigerina* ooze reveals that the deposit is composed largely of coccoliths, so that large areas of the ocean floor are essentially covered by coccoliths.

It is interesting to consider the path by which the coccoliths have come to rest on the ocean floor. The coccolithophores which produce them live near the surface, and so the coccoliths must drift down through nearly the whole water column before coming to rest. The rate at which coccoliths settle in quiet standing water has been determined experimentally to range from 15 minutes to 2 hours per inch in fresh water. In salt water they sink more slowly. This means that in an oceanic area with depths of 20,000 feet, large coccoliths would require 10 years, small coccoliths 50 years to reach the bottom, provided there were no ascending currents to retard their descent. But because the waters of the oceans are always in motion, the coccoliths will be carried great distances, often many thousands of miles from the point where they were released, until they come to rest. The coccoliths are caught up in the oceanic circulation of the planet and distributed over vast areas. Herein lies their great importance to modern stratigraphy.

Most of the strata studied by geologists on land represent shallow-water deposits. Deep-water deposits are relatively rare on the present continents, but are present in a few areas. Much of the work of the geologist consists of correlating strata from one place to another, either by studying the nature and sequence of the rocks or by using the fossils found in the strata. A geologist who specializes in correlating strata is called a stratigrapher; a paleontologist who specializes in using fossils to establish the age equivalence of strata is called a stratigraphic paleontologist. Stratigraphers and stratigraphic paleontologists have had great success in unraveling the geologic history of large areas, but a very troublesome problem has always remained—how to correlate across the ocean basins. The fossils used in correlating beds in the shallow-water deposits which cover much of the continents often cannot be used to correlate across vast distances. At the present time, faunas in widely separated geographic areas are often strikingly different, and the same is true of the past. Faunal provinces have existed through all of geologic history, and they have presented a barrier to intercontinental correlation and detailed examination of the earth's history.

The remains of planktonic organisms of the oceans are found only rarely on the continents, but where they are present they offer an unparalleled opportunity for intercontinental correction. The planktonic Foraminifera have been used for this purpose since the 1930's. They have permitted detailed correlations between North and South America and the Mediterranean region. However, it is becoming apparent that certain planktonic Foraminifera also are restricted to particular faunal provinces, and it is excedingly difficult to correlate deposits in northern Europe, for example, with those of the Mediterranean region. Coccoliths settle much more slowly than the tests of planktonic foraminifera and the boundaries of coccolithophore provinces (if they exist) are obscured. At present it seems as though coccoliths may be ubiquitous in their distribution. They have a further advantage for purposes of correlation—they show extremely rapid evolution and a number of radical changes have taken place, making different species easy to recognize.

Little research has been carried out on the detailed ultrastructure of coccoliths, but high resolution electronmicrographs show fine structure, in the form of markings spaced about 100 Å apart on the surface of the elements which make up the coccolith (pl. 4, fig. 2). The nature of these markings is still a matter of conjecture, but they probably reflect regular changes in the structure of the crystals of which the skeletal elements are made. Further investigation of skeletal ultrastructure at high magnifications is sure to produce interesting results.

From these examples it can be seen that the electron microscope is a tool that will play an important role in paleontologic research in the future.

Color Changes in Animals[1]

By D. B. Carlisle
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[With 2 plates]

"Ten more days of this sun and I shall have a tan that should last the winter through." A common enough remark to hear on the beach any day during the summer. A few minutes later I disturbed a cuttlefish on the sea bottom 25 feet down. With startling suddenness a white rectangle appeared in the middle of its back, then a pair of "eye-spots," before it finally puffed out a cloud of ink. Here we have examples of the two chief methods of color change and illustrations of the extremes of duration of the changes. Ten days of exposure to the sun may be needed to produce the new pigmentation which we call a suntan, and several months may elapse before all this pigment is removed or destroyed again. The cuttlefish changes color by redeployment of pigments already within the skin and can achieve changes of color and pattern within a fraction of a second. Color changes which depend on the deposition of new pigment within the skin or integument or on the removal or destruction of pigment are known as morphogenetic color changes; changes which are brought about by redistribution of existing pigments within the integument with little or no metabolism of the pigments are often called kinetic color changes.

Both types of color change may be brought about in response to a great many different factors. Heat and light, diet, the color of the background, and the degree of crowding of the animals may all play a part in morphogenetic changes. A suntan is produced by the direct action of certain wavelengths of ultraviolet light on the cells of the skin, which stimulates pigment formation in each cell which is exposed to the radiation. The pink plumage of the flamingo (pl. 1) is a result of diet and the pigment is taken almost unchanged from the small shrimplike creatures which form a large part of the food. This red pigment is then deposited in the feathers where it slowly fades in

[1] Reprinted by permission from *The Times Science Review* (London), Winter 1962.

the sunlight. To maintain the pink plumage, therefore, the flamingo needs a constant accession of food rich in pigment (which it cannot make for itself), and a diet poor in carotenoids, as these pigments are called, may produce a flamingo with white plumage.

These two examples illustrate changes which involve no measure of central control. More usually the brain or central nervous system integrates the information received through the senses and exerts some measure of control of the change of color. A stick insect living in the warm dark moist condition of the Amazonian forest will be black or gray-brown, but if it moves to the treetops where it is exposed to sunlight and dryer conditions it turns green, a morphogenetic change which seems upon investigation to be under some sort of central control.

VARIETY OF STIMULI

Perhaps the most complex array of morphogenetic color changes is to be found in locusts. When the population is low and scattered, the hoppers (the juvenile stages before the wings have developed) live as grasshoppers in the vegetation and shun each other's company. Their color depends largely on the color of the vegetation in which they are living, but temperature and humidity also play a part. A hopper living in isolation on lush green vegetation with a high humidity and temperature will be green (pl. 2, fig. 2); if the grasses start to dry out it will turn the color of ripe hay; living on a few blades of grass in an area which has been burnt over it may turn black. Whatever the vegetation, in fact, the solitary hopper matches it rather well. The situation is far different if a rising population and climatic conditions force the hoppers into each other's company. They soon learn to keep together and form the marching bands which are the beginnings of a locust swarm. Under these conditions they no longer hide away in matching vegetation but take on a "warning" coloration of black and yellow or black and orange. In the laboratory this can be shown to be a direct response to crowding (pl. 2, fig. 1). Finally, the detail of this black-and-yellow pattern of the crowded hoppers is affected by temperature. If the temperature rises the amount of black decreases till after a period at 40° C. it may be almost nonexistent, so that the hopper appears nearly uniformly yellow. Conversely, if the temperature falls the amount of black increases, until after a couple of molts at 26° C., the animal is in effect black with slight yellow markings.

As a last type of morphogenetic color change we may mention the breeding dress of many animals. The drake mallard at the end of winter dons a fine new colorful plumage for the breeding season, and the female prawn adorns herself with a row of white spots like a string of pearls down each side of the abdomen when she is ready to breed. Mention of the mallard makes it necessary to enlarge the scope of the definition of morphogenetic color change, for the iridescent head of the breeding mallard owes its sheen not to pigment but to the structure of the feathers which produces color by purely physical means. Thus morphogenetic color change may involve the shedding or acquiring of structures which owe their color to optical interference, as well as the loss or gain of pigment.

Kinetic color changes too may occur as responses to a wide range of stimuli. Many of the shrimplike creatures of the plankton—the copepods and others—respond to unwelcome actinic radiation by expansion of pigment to form a sort of umbrella over the sensitive organs, just as we respond to similar unwelcome radiation by tanning. Prawns (shrimps) can change color to match the background—and pattern too, as well as color—within about a quarter of an hour, and octopus and squid can complete within a second a change that conceals them. The three-spined stickleback, the cuckoo wrasse, and the black sea-bream can adopt a breeding dress quite as colorful as that of the drake mallard, but by kinetic means. High temperatures and bright light can stimulate a prawn to change color and attack by a predator can stimulate a cuttlefish to produce the "eyespots" which serve to frighten off the larger animal. Even the chameleon, which changes color so slowly, shows more than a mere background or albedo response, for its response to background color is modified by the temperature.

EFFECTOR ORGANS

The stimuli which provoke color change are thus many and various, but the effector organs themselves which bring about the changes are more uniform. The pigment is largely contained within cells, usually in droplet or granular form, rarely dissolved. The cells containing the pigment may be dead—as in feathers, which are largely composed of dead cells—and then color change can only take place by morphogenetic means. Sometimes the pigment is found in the general cells of the skin, as in the stick insect. In this animal all the cells of the skin contain at least two kinds of pigment. About halfway down the cell is a fixed barrier of light colored pigment granules. Granules of a black pigment are free to migrate up and down the cell turning the animal black when they lie at the surface or pale when they are hiding behind the barrier of light pigment. More commonly the pigment is confined to special cells known as chromatophores. Even in dead structures such as hairs the pigment is not uniformly distributed but confined to once living but now dead chromatophores. It should be obvious that where the greater part of the body is covered by such dead structures any color change can come about only by shedding these structures and growing fresh ones of a different color. Where the pigment is contained in living chromatophores it may be destroyed or replaced by fresh pigments. Both these processes are classed as morphogenetic color change. The pigment in our own skin is located largely in chromatophores, which are known as melanophores since they contain the brown pigment melanin. The granules of melanin are not free to move about in any systematic way in these chromatophores, which remain fixed in outline, and any color change can take place only by an alteration in the amount of melanin present.

Superficially similar chromatophores are found in fish and chameleons, shrimps, and prawns, where the pattern of the integument is made up of black or brown melanophores, red erythrophores, and yellow xanthophores. But unlike the mammalian chromatophores the distribution of pigment granules within them is under precise control. The outline of the chromatophore is fixed, consisting of a central reservoir from which small channels—the chromorrhizae—radiate outward branching irregularly between the surrounding cells (fig. 1). Within these channels the pigment granules may flow about, dispersing to occupy the entire network of chromorrhizae or concentrating into the central mass as a small dot. With the pigment dispersed an area of the skin takes on the hue of the pigment concerned;

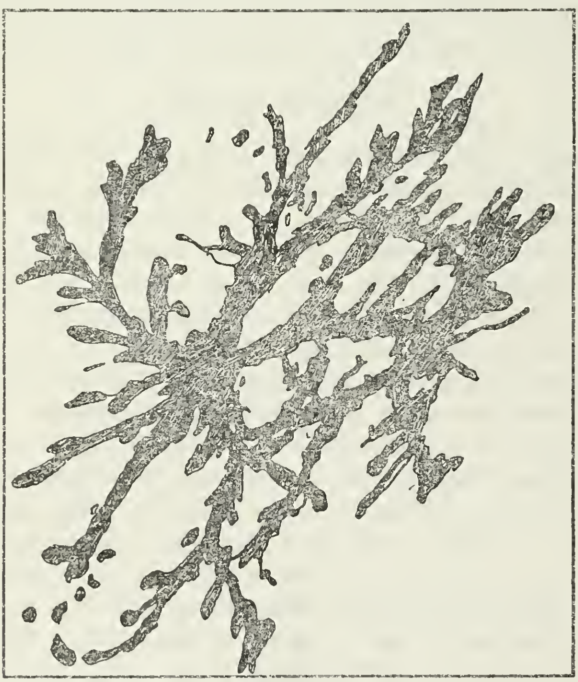

FIGURE 1.—A chromatophore of a prawn in which concentration of the pigment has just begun. The pigment has withdrawn from the finest chromorrhizae, which are therefore no longer visible. (Magnification, X 350.)

Greater flamingoes at the New Grounds, Slimbridge, England, of the Wildfowl Trust Flamingoes owe their pink plumage to diet.

1. A desert locust hopper which has lived with a crowd of its own kind is colored a vivid black and yellow.

2. A light green desert locust hopper which has lived alone.

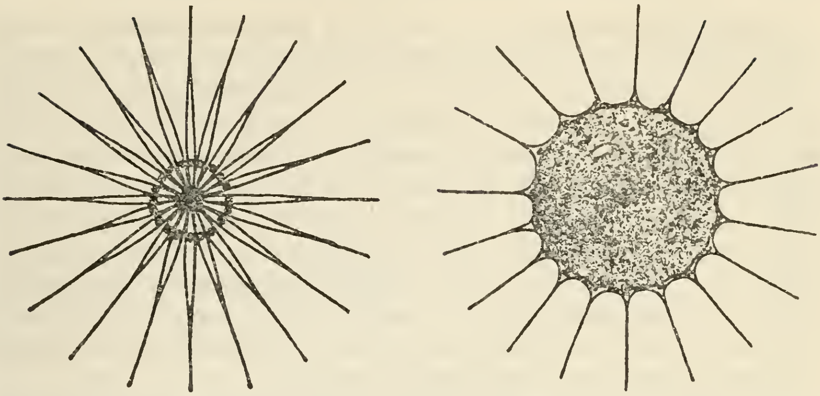

FIGURE 2.—A chromatophore of a squid: *left*, contracted, and, *right*, expanded. Expansion is brought about by contraction of muscles which spread out the sac of pigment to make a thin broad plate.

with it concentrated, the tiny dots are almost unnoticeable and the skin is blanched.

This type of chromatophore is widely distributed throughout the animal kingdom. It is found in fish, amphibians and reptiles, prawns and shrimps, sea urchins and insects. Another type of chromatophore is confined to the cephalopods, that group of mollusks which comprises the squid, cuttlefish, and octopus. Here the pigment—mainly various shades of melanin from the lightest of browns to jet black—is contained within spherical sacs each surrounded by a corona of muscle fibers (fig. 2). When these are relaxed the chromatophore is contracted to an insignificant sphere, but when the muscles contract the sac is drawn out into a thin plate covering some hundred or more times the area.

FROM STIMULUS TO RESPONSE

The final topic I propose to consider is the question of the mediation between stimulus and response. What means does the animal adopt to pass on the stimulus received by the senses to the chromatophores which produce the color change. In the simplest situation the effector organ responds directly to the stimulus—the human skin produces melanin as a direct response of each individual chromatophore to the ultraviolet radiation. A single chromatophore of a prawn may react to a spot of light, and a single chromorrhiza of a sea urchin has been found to react to a beam of light a ten-thousandth of an inch in diameter. The cells of the feather follicles of flamingos lay down the pink carotenoid in the feather they are forming in direct ratio to the amount supplied by the blood. In these examples of color change—both morphogenetic and kinetic—no central control is involved; the stimulus is received and the response is carried out by the effector cell itself.

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More often, however, the stimulus is received through the sense organs and the response is mediated via the central nervous system. The most complete and detailed control of color and pattern is found in the octopus. Here the chromatophores are never at rest. Blushes of color pass over the surface and the individual chromatophores expand and contract all the time. The muscles which operate the chromatophores in these animals are under direct nervous control and change in degree of expansion of each single chromatophore is a matter of fractions of a second. Such is the complexity of the control of the color and pattern that an entire discrete lobe of the brain of the octopus is set aside for its operation, and the color can express the mood of the animal and reflect its activity.

In the lower vertebrates, too, the chromatophores of the skin are under nervous control, but here this is supplemented by hormonal control. In an unstimulated condition the pigment in the chromatophores is more or less completely dispersed, producing a dark skin, and nervous stimulation tends to cause the pigment granules to migrate toward the center of the chromatophore, leading to paling. This migration is a much slower process than muscular contraction and may take two or three minutes. An opposing innervation will serve to reverse the process if this is to take place relatively rapidly, but if the initial nervous stimulation merely ceases, the pigment starts to disperse to fine branches of the chromorrhizae—a slow process which may take several hours. Naturally, the different areas of the skin and the different colors of chromatophores are under separate nervous control, so that pattern and color changes may be brought about. The nervous control is reinforced by hormones from the pituitary gland, which, slower to act in the first place, may maintain the response for far longer. Though the hormones in sufficient dose may serve to initiate a color change independently of the nerves, it is more likely that their main action is exerted in lower dose by maintaining the *status quo* once a pattern has been set by nervous action. That is to say a small dose of hormone may act to prevent reexpansion of the pigment which has been concentrated by nervous action and so fix a pattern and shade of color which has been established by nervous control.

Finally, many pigmentary effectors are under hormonal control alone. This is especially true of the sexual colors of so many animals. The breeding plumage of many male birds is under the control of the endocrine system—the system of ductless glands which secrete the hormones. The same is true of many fish. The male cuckoo wrasse produces a white blotch across his shoulders by concentration of the pigment within the red chromatophores. This seems to be under endocrine control, though whether the hormone concerned derives from the testis or from the pituitary gland we do not know. It is perhaps worth remarking that we have examples of both morphogenetic color change and kinetic color change mediated by the hormones of the sexual cycle.

In the Crustacea (shrimps, prawns, crabs, and wood-lice) the chromatophores are activated entirely by endocrine means; they are not innervated in any way. In the prawn there are at least 20 different types of chromatophores which respond differentially to 6 or more hormones. As a result a prawn can take on much of the color and pattern of the background, though not perhaps with such precision and speed as the octopus. One feature which many people find surprising is that all the hormones concerned are produced within specialized nerve cells, within the central nervous system. These cells are known as neurosecretory cells (fig. 3) and are grouped in discrete neurosecretory centers in various parts of the nervous system. The hormonal material is then conducted inside the nerve fibers to one of two neurohaemal organs. These consist of enlarged nerve endings grouped in masses against blood spaces and serve as storage and release centers for the hormones produced in the nerve cell bodies which supply them. One of these neurohaemal organs lying close to the eye (fig. 4) is the sinus gland which for long was thought to be the main endocrine gland of prawns. Now we know that it is simply a warehouse and dispatch center for hormones produced in a number of neurosecretory centers

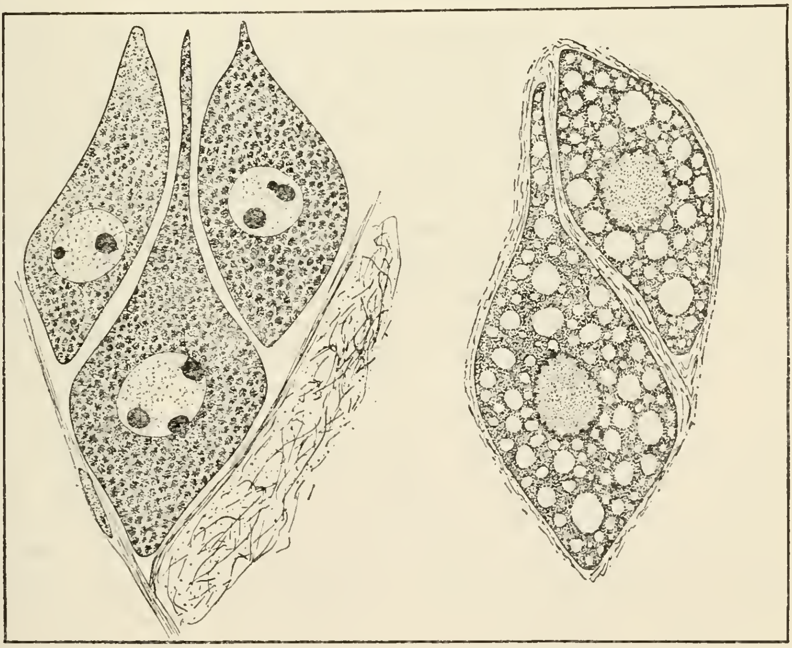


FIGURE 3.—Two types of neurosecretory cells from the brain of the prawn. (Magnification X 580.)

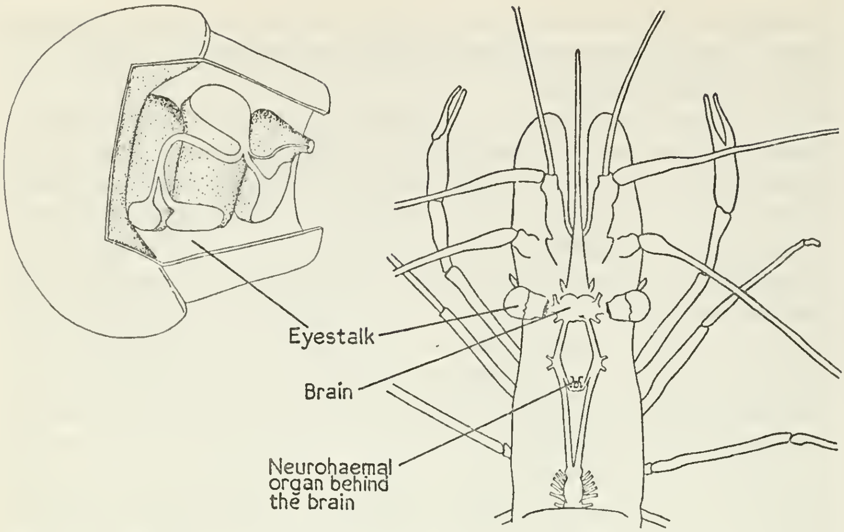


FIGURE 4.—The head of a prawn and, alongside it on the left, an enlargement of the left eyestalk dissected to show the optic medullae of the brain (stippled), which are largely concerned with visual integration. The unstippled parts of the medullae are the sinus gland (above), supplied from below by three groups of neurosecretory cells.

in other parts of the brain. The second neurohaemal organ lies behind the brain and is supplied by neurosecretory fibers from cells in the hind part of the brain.

It has long been a puzzle why there should be so many centers of production of color change hormones within the brain—there are at least five such centers in prawns. A possible explanation may emerge if we consider the detailed distribution of these centers within the brain and the functions of the various parts within which they are found. Three of the main centers lie within that part of the brain which is concerned with the integration of visual input. At the most peripheral level we find a neurosecretory center (sending its hormones to the sinus gland) which appears to receive information on the number and frequency of visual cells receiving the stimulus of light; perhaps this center regulates the degree of darkness of the body. At a second level we find a neurosecretory center in that part of the brain which is largely concerned with a comparison of direct illumination with light reflected from the background. This center seems to be concerned with the so-called albedo or background response. At a third level the pattern of things seen may result in the activation of a neurosecretory center which controls pattern—a uniform pattern when on a background of sand or a stripy pattern amongst seaweed, for example. And the center at the back of the brain may be concerned with a total integration of all stimuli and central effects, visual or otherwise, which may lead to a color change. Thus, prawns always develop a red tail at dusk. This can be shown to depend in no way upon visual stimulation and to be mediated via the neurosecretory center in the hind part of the brain, not via the centers associated with visual input.

The ability to change color gives the animal the best of several worlds. It can stay hidden from its enemies or prey and yet be able to display visual signals when needed. It can use color and pattern in sexual display, and yet not fear discovery from the prominence of these colors when they are not in use. It can, like the cuttlefish, use color change as a scaring device or, like the squid, use it to lay a false trail. I have seen a squid pursued and slowly becoming darker, as it failed to throw off its pursuer until it was almost jet black. Suddenly it shot out a jet of ink, blowing it forward in the direction it was swimming as a cigar shape about its own size. Simultaneously the squid changed color becoming pale and almost transparent, and shot off at right angles to its original course. Its pursuer continued after the dark shape which was drifting along the original course while the pale squid swam quietly away in a different direction. The ink of the squid is no smokescreen as it is usually thought, but a decoy, much more like the original dark squid than the suddenly pale squid it has now become.

History of the Corbin Preserve

By Richard H. Manville

Director, Bird and Mammal Laboratories, U.S. Fish and Wildlife Service

[With 4 plates]

In the late 19th century it was fashionable for some of the new magnates of industry and finance to establish preserves for the propagation of game and for the sport it provided. Many of these preserves have been neglected and have reverted to their natural state; others have been absorbed by Federal or State agencies and are now maintained as refuges; some have continued as private tracts, administered much as when they were established. Among the latter is the Corbin Preserve in New Hampshire, one of the largest and most successful of these areas—in a sense a holdover of the old European system of game management, with the harvest a privilege of the favored classes. It provides an interesting chapter in sociology, in history, and in the development of wildlife management—a profession which, as we know it today, was undreamed of in the 1890's. The Corbin Preserve witnessed some of the early gropings toward a scientific method of handling game, replete with successes, failures, and sometimes surprising results.

In the days before governmental agencies took an interest in these matters, such conservation as we had was practiced by private agencies. To them we owe a great debt of gratitude, for without their efforts some of our game species might not have survived. Private game preserves usually were developed on lands of moderate value, where game was or might become abundant, and where it was possible to prevent trespass. Ultimately these preserves played an important role in the preservation of game, as well as in providing recreation and diversion. At the turn of the century most of them were still in an experimental stage, and many later were abandoned or absorbed. But the Corbin Preserve thrived and is a going concern today—unique in the annals of American game preserves.

Austin Corbin (1827–1896), a native of New Hampshire, went west and became eminently successful in banking, railroads, and other enterprises. After retiring from business in 1886, he returned to his boyhood home to develop a tract for wildlife on the grand scale. In this he did amazingly well. The early years of the Corbin Preserve were reported by Spears (1893) in a paper which the Smithsonian Institution reprinted 70 years ago in its Annual Report for 1891. The present account aims to review those early experiences and trace the history of the tract to the present. Additional biographical data on Corbin are included in an appendix to this article. Unfortunately, his untimely death in 1896 prevented his seeing this favorite project mature.

ESTABLISHMENT OF CORBIN PARK

Corbin selected an area a few miles north of Newport, centered upon Croydon Mountain and falling within the townships of Cornish, Croydon, Grantham, and Plainfield (fig. 1). Starting in 1886, Corbin and his agents, under the direction of Sidney A. Stockwell, bought up more than 350 individual parcels of land, including 60 sets of buildings and comprising a tract of about 22,000 acres. To this, 4,000 acres more were later added. This area was then surrounded by 36 miles of elkproof fence, from 9 to 12 feet high. The fence was of woven wire net to a height of 6 feet for keeping out cats and dogs and keeping in small game. Above this were as many as 10 lines of barbed wire. This fencing was secured to posts 10 feet apart, with a pine or willow planted at each post to serve as a living replacement when necessary. In this fashion 18 miles of fencing were erected; only barbed wire was used the rest of the distance. The fence was completed at a cost of $74,000. It had nine gates, at each of which there was a keeper's lodge; a telephone line atop the fence connected all the keepers' lodges with a central headquarters. The average cost of the land was a fraction over $5 per acre.

From the start there was much resentment on the part of some local residents to the park Corbin was developing. This resulted from the feeling that they were being preempted by the affluent, despite the fact that Corbin paid full value and sometimes more for the land, and that subsequently he provided employment for more men than could have made a living by farming the lands. From the time of its establishment, the park has been the largest taxpayer in the town of Cornish, and likewise has contributed heavily to the three other townships of which it forms a part. Nonetheless, the antagonism has continued, and threats to cut the fence frequently have been carried out. An attitude of withdrawal and an avoidance of publicity have naturally developed on the part of park personnel.

In 1888 the Corbin Park Association, with Austin Corbin as president, was formed as a private club. In 1890 the enclosure was stocked with about 30 bison, 140 deer, 135 elk, 35 moose, some European stags,

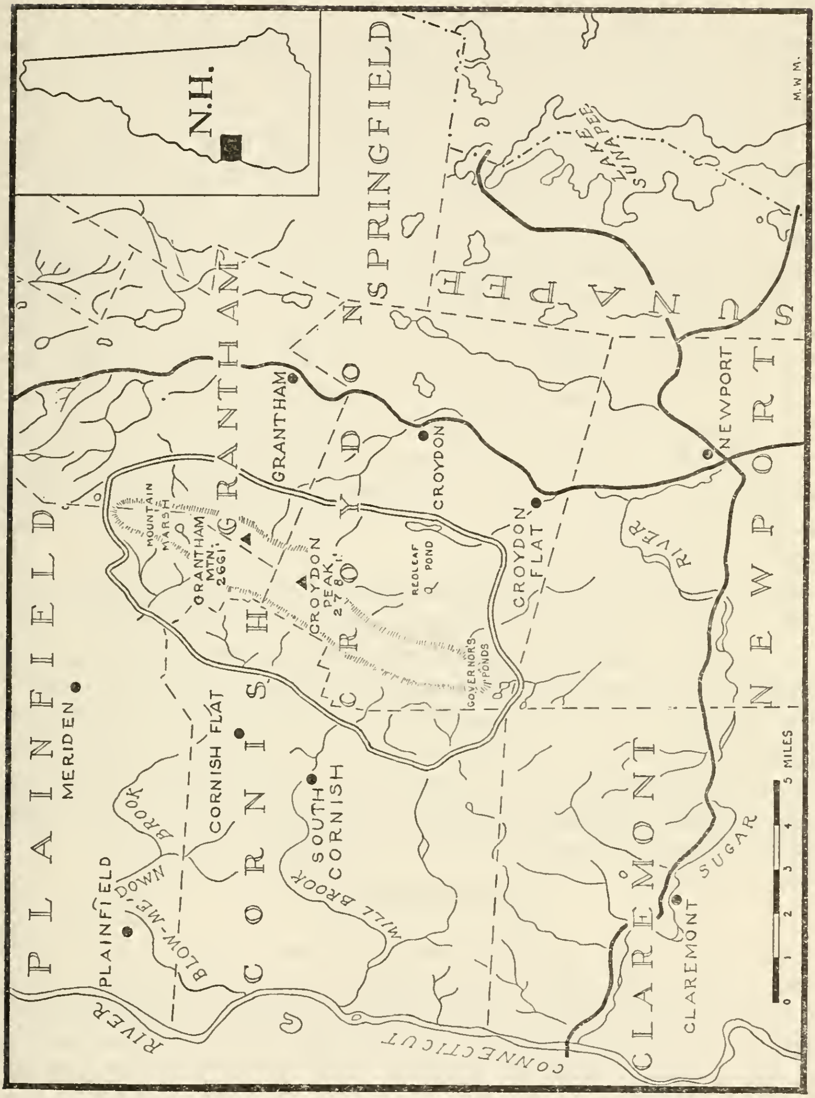


FIGURE 1.—The northern half of Sullivan County, N.H., with the approximate present limits of the Corbin Preserve.

a few Himalayan goats, and 14 European wild boar. During Corbin's life the area was open to the public, but no hunting was permitted. In time, some of the animals increased to an alarming extent and control measures became necessary. Hunting was then allowed, but only by club members and their guests.

Over the years, noted guests at Corbin Park included William E. Chandler, Grover Cleveland, Herbert Hoover, Theodore Roosevelt, Woodrow Wilson, and Edward VII, then Prince of Wales. The last, visiting the park incognito during its early days, "was given permission to shoot a bison and, to the indignation of the management, bagged five or six" (Silver, 1957: 120). Resident inhabitants of nearby areas included such personages as Herbert Adams, Maxfield Parrish, Augustus Saint-Gaudens, Ellen Shipman, and the American writer Winston Churchill, in whose novel *Coniston* the central figure was Ruel Durkee, crafty but honest political boss of Croydon. Rudyard Kipling visited the park in the early 1890's. In *Captains Courageous* he described Austin Corbin, in the person of Slatin Beeman, in these words: "Slatin Beeman he owns 'baout every railroad on Long Island, they say, an' they say he's bought 'baout ha'af Noo Hampshire an' run a line fence around her, an' filled her up with lions an' tigers an' bears an' buffalo an' crocodiles an' such all. Slatin Beeman he's a millionaire."

In 1896 Corbin died almost at the gate of his own park, in a carriage accident caused by a runaway horse. After his death the game preserve, in 1899, became a limited-membership proprietary club, the Blue Mountain Forest Association, which still operates as an exclusive hunting club. The initial lease was for 5 years, and members were mostly men from New York, Boston, and Washington, D.C. The New Hampshire Legislature, in an act incorporating the association, made special provisions for the protection of the game in the park (Palmer, 1910). These provisions remain in force today.

NATURE OF THE AREA

The Corbin tract was described by Spears (1893) as "unbroken forest that covered hills and valleys and surrounded little lakes, forests of birch and beech, maple and pine, spruce and hemlock, and balsam." The lands rise from 960 feet elevation at the southeast to the two dominant summits, Croydon Peak (2,781) and Grantham Mountain (2,661 feet). Included are four ponds, the two largest of 20 and 30 acres, and over 50 miles of trout streams (pl. 1). Drainage is into the Connecticut River, via Mill Brook, Blow-me-down Brook, and the Sugar River.

Settlers have cleared and worked some of these lands since colonial times, but the soil is thin and rocky, the topography rough, and the area is no longer productive for agriculture. When the park was established, "approximately one-third of the range was in open fields and pasture, with the balance in timber" (Silver, 1957: 119). Old orchards and vineyards persisted as reminders of earlier farms; remains of lumber camps, timber chutes, and sawmills attested to earlier logging operations. Baynes (1931) tells of Shropshire sheep, Angora goats, and other animals still roaming at large in the summer, and being kept in barns or pens during the winter months.

A reconnaissance of the area in 1940 by Neil W. Hosley (cited by Silver, 1957: 122) disclosed three main types of forest on the tract: (1) Northern hardwoods of maples (*Acer* spp.), birches (*Betula* spp.) and beech (*Fagus grandifolia*); (2) red spruce (*Picea rubra*) and fir (*Abies balsamea*); and (3) white pine (*Pinus strobus*), with occasional red pine (*P. resinosa*) and pitch pine (*P. rigida*). Small stands of other species include hemlock (*Tsuga canadensis*), white cedar (*Thuja occidentalis*), aspen (*Populus tremuloides*), and oaks (*Quercus* spp.).

Much timber was cut and sold soon after Corbin's death. The winter of 1897 was unusually severe, and many elk and other game animals perished. The most destructive agency to affect the preserve was the hurricane of September 21, 1938, which flattened about one-third of the merchantable stands of white pine (Silver, 1957: 124). Some 50 acres of salvage cuttings soon grew up to striped maple (*Acer pennsylvanicum*), raspberry and blackberry (*Rubus* spp.). A serious fire in 1953 burned about 2,000 acres, but was largely confined to steep, rocky slopes.

Weather conditions at the Corbin Preserve are best represented by the 40-year records at Hanover, approximately 15 miles to the north. These are summarized in *Climate and Man* (U.S. Dept. Agric. Yearbook, 1941: 990) by the following average figures: January temperature, 18.1° F.; July temperature, 68.8; maximum, 101; minimum, —37; growing season, 129 days between May 22 and September 28; annual precipitation, 35.52 inches, rather evenly distributed throughout the year.

ORIGINAL INTRODUCTIONS

Corbin's intention was to bring together at his preserve "all the animals of the world that can live there harmoniously." There was to be no hunting at the start, nor was the park designed with this in mind. Neither was it planned primarily for scientific research, though it soon became apparent that it might well provide useful data on the habits of the various animals. For the present account of the procurement of the original stock we are indebted to Spears (1893), who reported that "Here . . . are gathered 25 buffalo, 60 elk, over 70 deer, half a dozen each of caribou and antelope, 18 wild boars imported from Germany, and an unknown number of moose—

perhaps a dozen. He had 4 reindeer brought from Labrador, but all died."

As an agent to supervise gathering animals from Canada, Corbin selected Thomas H. Ryan, who had served him in various capacities for many years. Ryan departed in October 1890 with orders to get "any wild animals there except bears, panthers, wolves, and foxes." At Megantic, Quebec, arrangements were made with one Dan Ball to procure the deer. In December, with snow 5 feet deep, Ball and six others proceeded on snowshoes to a deeryard. The deer were approached as closely as possible without alarming them. Then, with a wild yell and the blast of a gun loaded with powder only, the deer were scattered. In the ensuing panic, the deer floundered in the fluffy snow and were easily taken, and their legs were bound with buckskin thongs. Twelve were thus captured, and in January they boarded a boxcar on the Canadian Pacific and Ryan escorted them to Newport. One died en route, and two others after arrival, but the rest remained in good condition.

At Mattawa, Ontario, a trapper contracted to supply, if possible, at least 20 each of moose, deer, and beaver. Moose, elk, and caribou, captured along the Canadian border, were procured in Minnesota. The bison derived from Montana stock, but were purchased in Minnesota. They were shipped East in the care of cowboys who unloaded them at Newport and herded them the 5 miles or so to the preserve. The last rail consignment, 4 days in transit, consisted of 16 moose, 3 deer, and 1 caribou. All arrived in good condition, but 8 moose later died; it was thought that their death was attributable to changes in their water or diet. On another occasion, with a load of 30 deer aboard, a collision with another train killed 22 outright, and 4 others succumbed later.

The source of 125 mule deer and 30 pronghorns is not a matter of record. The latter failed to survive the rigorous New Hampshire winter, and the former persisted for only a few years. The caribou died for lack of proper food. The elk, deer, bison, and remaining moose did well, all producing young the following year. Wild boars were imported from Germany in September 1891, and did well from the start. Details of the procurement of other exotic species (red deer, Himalayan goats, and pheasant) are incomplete or lacking. In table 1 are assembled such data as are available from scattered sources. These sources are not always in complete agreement as to numbers; where discrepancies exist, the smaller figure is cited.

MANAGEMENT OF THE PRESERVE

Soon after raising the fence around the preserve, work began on improving the roads. A large force worked at this for two or three years. The marginal road was repaired, with stone watering troughs

TABLE 1.—*Estimated populations of introduced species at various periods on the Corbin Preserve*

Species	1889 Corbin	1890 Squires	1891 Spears	1892 Silver	1898 Champollion	1903 Palmer	1908 Child	1940 Hosley	1962 Present account
Brook trout, *Salvelinus fontinalis*	Some	----	----	----	----	----	----	----	----
Largemouth bass, *Micropterus salmoides*	Some	----	----	----	----	----	----	----	----
Bobwhite, *Colinus virginianus*	----	----	----	500	----	----	----	----	0
Ring-necked pheasant, *Phasianus colchicus*	Some	----	----	Some	----	----	----	----	0
Beaver, *Castor canadensis*	2	----	----	2	----	----	----	----	Some
Wild boar, *Sus scrofa*	11	14	18	50	300	500	[1] 450	50	250
American elk, *Cervus canadensis*	125	135	60	90	[1] 1,750	300	50	[1] 550	200
Red deer, *Cervus elaphus*	----	Some	----	----	14	----	Few	----	0
Mule deer, *Odocoileus hemionus*	[2] 125	----	----	125	[2] 2,000	----	----	----	0
White-tailed deer, *Odocoileus virginianus*		140	70+	----		2,000	500	----	500+
Moose, *Alces alces*	25	35	12	60	200	----	Few	0	0
Barren-ground caribou, *Rangifer arcticus*	----	----	4	----	----	----	----	----	0
Woodland caribou, *Rangifer caribou*	----	----	6	----	----	----	----	----	0
Roe deer, *Capreolus capreolus*	----	----	----	----	Some	----	----	----	0
Pronghorn, *Antilocapra americana*	----	6	6	30	----	----	----	----	0
Bison, *Bison bison*	23	22	25	32	75	----	165	15	0
Himalayan tahr, *Hemitragus jemlahicus*	----	Few	----	----	6(?)	----	----	----	0
Bighorn, *Ovis canadensis*	----	----	----	----	Some	----	----	----	0

[1] Average of the range given in reference.
[2] Total of mule and white-tailed deer combined.

every 4 miles; about 15 miles of interior roads were built; a swamp was drained for a roadway to the Central Station (Corbin, 1893). Some of the old farm buildings were remodeled, and other cottages were constructed for keepers. Several fenced areas were established within the preserve. No. 1, or the Central Station (pl. 2), was an area of about 100 acres of pastures and woodlands; here were built the main clubhouse, dormitories for workmen, barns and pens for some of the stock in winter, stables, kennels, and other buildings. No. 2 was an area of 30 acres; this was a holding area for new stock, principally bison, until it was ascertained they were in good health and otherwise desirable. They then were transferred to area No. 3, of 1,800 acres, where they were bred to demonstrate that their offspring were up to standard, after which they were turned into the main preserve (Baynes, 1931: 72).

In London in 1890 Corbin had purchased 20,000 hawthorn trees. Two varieties—white and black hawthorn—were used extensively in British and French game parks; growing to 10 feet in height they were the toughest and strongest trees available. In the spring of 1892, 4,000 of these were planted at Corbin Park, some of them immediately inside the marginal fence, to eventually replace it as it weathered and to form a living hedge strong enough to secure the buffalo and other large animals. Chestnuts (*Castanea dentata*) were planted to provide food for the boars.

At the turn of the century the Corbin Preserve was the largest and one of the best-equipped game preserves in the United States, and considerably larger than similar establishments in Europe (Palmer, 1910). Fifteen or more wardens were employed; several men were occupied hunting foxes and other predators; Corbin planned to secure a forester from Germany to supervise cutting timber. Many early records are lacking or unavailable, but there persist a few names of managers and superintendents of the tract. The first "chief" was Blaine S. Viles, from Maine. "Long Tom" Currier, also from Maine, was a superintendent in the early days; Sidney A. Stockwell served in this capacity in 1899. Forest W. Kempton was a hunter and guide, and "Billie" Morrison was the keeper of buffalo, about 1900. Ernest Harold Baynes (1868–1925), writer and naturalist who in 1911 established the Meriden Bird Sanctuary in Plainfield, was long associated with the Corbin Preserve. A. H. Currier was the manager until 1957, when he was succeeded by Maurice L. Nelson, who still occupies the post.

Much attention was devoted to the bison (pl. 3). Corbin once considered crossing them with Galloway cattle, to secure a superior beef animal, but this was not accomplished. Baynes experimented at breaking them to yoke, but never achieved notable success. No bison was kept if there was any suspicion that it was not in perfect condition.

As a result, "The Corbin herd was at one time considered the finest and largest herd of pure-blooded buffaloes in the world" (Baynes, 1931: 75). Salt licks were provided for the bison, deer, and elk. All winter long corn was fed to the boars. Hay and bran were put out where the animals could get them when needed. An efficient system for patrolling the boundary was instituted. In 1891 the ponds were cleaned out, many eels "and other varieties of cannibalistic fish" were destroyed, and trout were introduced (Spears, 1893).

Many of the introduced animals soon became acclimated and multiplied. By 1891, 10 of the bison cows were in calf; the elk herd had increased by 50 percent; 6 of the moose dropped young. Gamekeepers reported three or four different herds of wild boars. Within a few years it was estimated there were as many as 4,000 of these introduced species within the Park, and many of them were sold (Squires, 1956). Needless to say, the situation was becoming impossible, even on a tract of this size.

Baynes (1931: 126) has vividly described conditions as they existed in 1904: "Going through this hardwood belt the most striking thing, perhaps, was the total absence of young growth. Not a single sapling was to be seen—not a single seedling; the animals had accounted for them all. And so it is throughout this vast preserve; scarcely a hardwood seedling anywhere. No doubt, no end of nuts and seeds are eaten up by the wild boars, but those that are left to sprout can scarcely put out a leaf before it is nipped off by some passing deer or elk. Nor is this condition limited to the deciduous trees; there is practically no young growth of any species whatever that serves as a browse for the animals I have mentioned. That is to say there are no young balsams or hemlocks, for instance, but the spruces and the white pines, not being eaten by the deer and elk, spring up and grow like weeds in every clearing."

Systematic thinning out of the population was necessary, and shooting, particularly of the deer, seemed the only practical solution. It was recognized that this was necessary, especially in a fenced area such as the Corbin Preserve, or overcrowding would soon lead to deaths from hunger, degeneration, and disease. Many animals were disposed of to zoological parks and other institutions; as late as the 1940's many deer were sold for meat.

Predation has never been too serious a problem on the preserve. Red foxes, bobcats, and an occasional Canada lynx were present in the early days. Hunters were employed to control them; bloodhounds and foxhounds were imported, but were unsatisfactory for the purpose, and took to chasing deer instead. Gray foxes and black bears, able to cross through or over the fence, introduced themselves. In the unusually deep snow of 1949–50, bobcats killed 22 deer (Silver, 1957: 120). More recently, wild dogs have made their way into the preserve. Spreading from the Adirondacks and Vermont, coyotes have invaded New England (Pringle, 1960). In the winter of 1959–60, wild canids were thought to have killed 19 deer in Corbin's Park, 11 of them within 9 days in February. One 39-pound male was trapped and killed; its skull was examined and resembled most closely that of a police dog. A litter of five pups, their eyes not yet opened, were found and raised in captivity; at 5 months they weighed 30 pounds apiece. There has been much speculation as to whether these wild canids are "wolves, coy-wolves, coyotes, coy-dogs, or wolf-dogs" (Randolph, 1960)—or just feral domestic dogs. During the winter of 1961–62, four or five wild canids were thought to be in the area, and were charged with killing 22 deer in the preserve.

For a period just before 1946 the park was privately owned, but much of it fell into decay. It was later reorganized, again as the Blue Mountain Forest Association, with membership limited to 30. No dues were assessed, but expenses were shared in proportion to the number of membership certificates held (1 to 4 per person). An open season was set from September 15 to January 15; hunters were assigned to one of several marked areas; a tract about 1 mile in diameter around the Central Station was maintained as a sanctuary. Bag limits were determined just before the hunting season. Each member might invite as many guests as he chose, but the game taken was prorated among the members according to the number of certificates each held (Silver, 1957: 123).

INTRODUCED SPECIES

In the following accounts, information has been freely appropriated from scattered sources. Most useful were the general references (*see* Literature Cited) in publications by Baynes (1931), Champollion (1899), Child (1910, 1: 216–219), Corbin (1893), Palmer (1910), Siegler (1962), Silver (1957), Spears (1893), Squires (1956, 2: 524), and Woodbury (1960). Because of frequent use, these references are not individually acknowledged throughout. Those of more limited scope, however, are cited where applicable.

Brook trout, *Salvelinus fontinalis*.—In 1891, after attempts to clear out undesirable fish, trout were introduced into several of the ponds and streams.

Largemouth bass, *Micropterus salmoides*.—According to Champollion, black bass were stocked in Governor's Pond in the early days of the park.

Bobwhite quail, *Colinus virginianus*.—About 500 were introduced in 1890, but failed to survive their second year.

Ring-necked pheasant, *Phasianus colchicus*.—Chinese pheasants were liberated at the preserve in the early years, and soon became established. Some of the farmlands were planted to buckwheat to carry

1. General view of the Corbin Preserve from the southeast; Croydon Mountain in the background. From Palmer (1910).

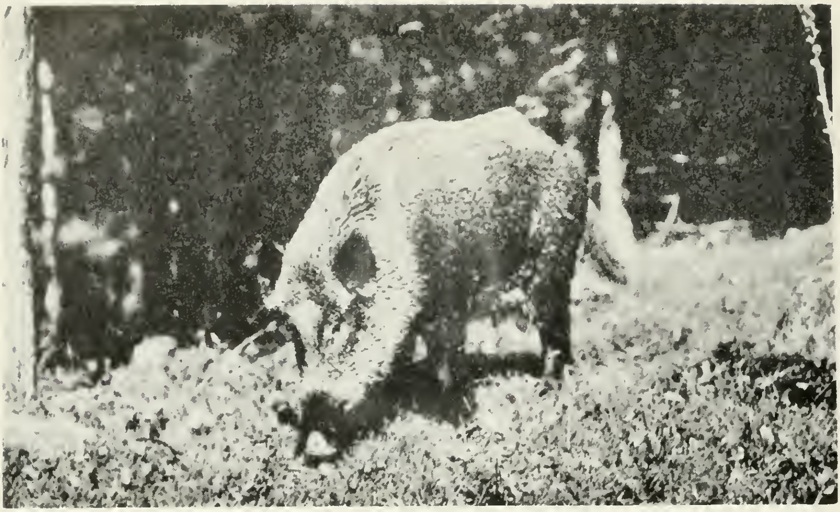
2. Mountain Marsh at the north end of the preserve. From Baynes (1931).

1. The Central Station, with clubhouse and other buildings, in the southern section of the preserve. From Palmer (1910).

2. Cleared lands in the northwest section of the preserve. From Palmer (1910).

1. The bison herd in winter quarters. From Baynes (1931).

2. One of the large bull bison on the range. From Baynes (1931).



1. A young wild boar in the forest. From Baynes (1931).

2. Boundary line and one entrance to the Corbin Preserve, photographed in 1904 by Baynes
From Garretson (1938).

the birds over the winter. The success of this release encouraged the State in 1895 to undertake a program of introducing exotic game birds. New Hampshire, however, has never been well suited to pheasants; overwintering birds still require supplemental annual stocking to provide a huntable population.

Beaver, *Castor canadensis.*—Beaver had earlier been extirpated in the area. One pair was introduced, and soon caused damage to timber for a mile back from one stream. Corbin, however, decided to keep them, and the species still exists in the park.

Wild boar, *Sus scrofa.*—A dozen European boar, from the Black Forest of Germany, were purchased from Carl Hagenbeck of Hamburg. One died on the high seas, and the other 11 were released on the preserve in 1889. By 1891 they had increased to three or four herds, seen simultaneously at different localities by the gamekeepers. Several writers speak of two lots of introduced boar, one of them the larger, darker Russian race. Squires speaks of 14 and Spears of 18, in the early years; it is possible that some Russian stock, probably from the Ural Mountains, comprised the lot received in September 1891. Certainly free interbreeding soon obscured any racial differences. By the autumn of 1896 they numbered not less than 500. There was a failure of the beech crop that year, and the boar were not artificially fed during the winter of 1896–97; all but 50 of them perished. Thereafter they recovered satisfactorily and reached an estimated population of 500 by 1903.

The boar took naturally to the forests of the preserve where—except for the corn they are fed in winter—they live off the land (pl. 4). Perhaps their rooting for food and destruction of insects contribute somewhat to the productivity of the soil. In winter they build large nests of boughs or grass, resembling huge bird nests, where several may sleep together or where the young may be born. Their habits are described in some detail by Baynes (1923). In Corbin's day they were hunted from horseback with javelins, and were tracked with Austrian boarsetters. In 1917, when staging its first municipal winter carnival, the town of Newport featured a boar hunt on the preserve (Mahoney, 1959). Hunting, with prescribed bag limits and a 4-month open season, is the chief population control in the park. From 1948–55 a total of 317 were taken, the largest number (79) in the 1951–52 season. A boar hunt in the surrounding country is described by Lineaweaver (1955).

An unknown number of boar escaped soon after the park was established, and persisted in the adjoining country, where they constitute a hazard to crops. Still others escaped after the hurricane of 1938, and a loose population exists within a radius of about 15 miles of the preserve. In 1955, one was shot across the Connecticut River in Hartland, Vt. (Angwin, 1955), and another near Danbury, N.H. The State

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legislature in 1949 passed an act encouraging capture and killing of wild boars, and fixing responsibility for property damage by them. Outside of the preserve, they may be hunted without limit at any season; a license is required, and hunting at night is not permitted. The reported kills outside the preserve in recent years have been as follows: 25 in 1958, 20 in 1959, 12 in 1960, and 3 in 1961. This is a sport for the rugged, and relatively few attempt it.

American elk, *Cervus canadensis*.—Sixty were introduced from northern Minnesota in 1891. They did well from the first, and were said to have increased by 50 percent after a year; at one time they were estimated at 1,000. "Many perished during the severe winter of 1897, and in 1903 the estimated number was only 300" (Palmer, 1910). The elk—particularly the cows—soon became nearly as tame as cattle; furthermore, they provided serious competition for the deer's fodder, and were not considered desirable on the preserve. However, they have persisted to the present.

In 1903, Corbin presented eight cows and four bulls to the State for release by the Andover Fish and Game Club. In time, they caused damage to orchards and other croplands. Concerning restoration efforts in the Adirondacks of New York, Seton (1929, 3:17) notes that in March 1906, "We obtained from Austin Corbin 26 Wapiti, which were successfully released." In 1933, 2 more bulls and 10 cows were released on the Pillsbury Reservation, in Washington and Goshen townships, New Hampshire, where they increased. The hurricane of 1938 leveled many fences, permitting the escape of elk which still range the surrounding country. Elk records in Vermont since this time have been attributed to wandering individuals from this herd (Foote, 1944).

Red deer, *Cervus elaphus*.—Five were originally imported from England, and six more in 1895. The population in 1898 numbered 14, of which only 2 were known to be hinds. The stags were suspected of breeding with elk cows, and six supposed hybrids were noted. A few red deer persisted until 1908, and then they disappeared.

Mule deer, *Odocoileus hemionus*.—Several writers mention black-tailed and mule deer among the early introductions, but their source is not stated. Apparently they soon disappeared. Whether they were absorbed by the increasing population of white-tailed deer, or represent a case of mistaken identity, may never be known.

White-tailed deer, *Odocoileus virginianus*.—Native deer had disappeared from the region long before the establishment of the park. In 1891, Corbin imported over 70 from near the northern Minnesota border and from Ontario and Quebec. The first shipment evoked much interest when unloaded at the Newport railhead, for none of the local residents had ever seen a deer alive (L. M., 1959). As would be expected, they did extremely well. Within a few years they numbered 250 and, according to some estimates, surpassed 1,000 by the turn of the century; 500 were estimated in the park in 1908. Hunting was done, but was too slight to hold the population in check.

The history of the area is obscure for several decades. Deer and other ungulates increased; browse lines developed on striped maples and other preferred food plants; ground hemlock disappeared. Supplemental foods were provided. In 1940, the deer population was estimated by the park manager at from 1,000 to 1,200—a minimum population density of one deer to 25 acres. This number had remained fairly constant for about 10 years, with an annual kill of about 100 deer, which were said to be in good condition. The preserve may still be overpopulated, but attempts are made to provide for the surplus. Food plots are planted with mixtures of rye, buckwheat, clover, turnips, and carrots; salt licks are provided; openings are cut in the woodland to provide browse; supplementary rations are provided for deer and boar—17 tons of corn were distributed by plane during the winter of 1952–53. From 1948–54, inclusive, a total of 575 deer were harvested. In 1956, the kill was 156, or about 3.9 per square mile.

Moose, *Alces alces*.—Sixteen moose from the Canadian border of Minnesota originally reached the preserve, but eight later died. Corbin continued picking them up, but also losing them. One carload of 15 all died, for lack of understanding of their habits. In 1892, Corbin estimated that he had 25 or 30. Spears states that later shipments, plus births, brought the number up to 60—Champollion says 200! Further efforts to establish them were abandoned after a few years (Merrill, 1916: 36), but actually they persisted until about 1940, when the last of them died of starvation.

Barren-ground caribou, *Rangifer arcticus*.—Four "reindeer" were brought from Labrador in 1890, but all soon died.

Woodland caribou, *Rangifer caribou*.—A small herd (about six) from northern Minnesota was imported in 1890, but soon died off for lack of suitable food.

Roe deer, *Capreolus capreolus*.—Champollion states that "roebuck also were put in, but died probably on account of the severe New Hampshire winters." No other details are available. This was a popular game species in Europe, and introductions were attempted at other places at about this time, some of them with fair success (Manville, 1957).

Pronghorn, *Antilocapra americana*.—Six antelopes were introduced in 1890, but their exact source is not recorded. They apparently survived for a few years, but then succumbed to the rigorous winter climate.

Bison, *Bison bison*.—In 1851, Corbin had seen "one hundred thousand buffaloes at one time" on the Western plains. The great herds of these shaggy animals numbered perhaps 60 million in the early 1800's. "By 1883 they were practically gone, and by 1900 only 20 wild bison were known to exist" (Anon., 1955). Corbin procured his original stock prior to 1890, "three or four in Wyoming, and a dozen in Manitoba, etc." In 1888 he purchased six male and six female calves from Col. Charles J. "Buffalo" Jones, who had just acquired them from the Sam I. Bedson herd at Winnipeg. In 1892 he purchased two male and eight female 5-year-olds, at $1,000 each, from Jones; these were captured in 1888 from the last wild herd in the Texas Panhandle (Garretson, 1938: 219). By 1898 Corbin had about 75, "probably the largest herd in the world" (Champollion, 1889). They avoided the forested tracts of the preserve, foraged in the cleared lands in summer, and were fed on hay in the pens at the Central Station in winter. The bison herd gradually increased, and by 1908 numbered about 165.

In the fall of 1896 Corbin loaned 25 bison to the City of New York. They were shipped, in the care of Billie Morrison, to a 100-acre pasture in Van Cortlandt Park. Presently two or three sickened and died, presumably from gastroenteritis. In 1897 the balance of the herd, except for two that were left in New York, were returned to the Corbin Preserve. Three or four died en route, and the rest of the group were kept isolated from the original herd. However, they never recovered completely, and ultimately nearly the whole group died, despite the attentions of Morrison and Stockwell (Garretson, 1938: 76).

Starting in 1898, many bison were sold or donated for various purposes, both in this country and abroad. The bull "Cleveland" was sold about 1898 to William C. Whitney for his October Mountain preserve near Lenox, Mass.; this was one of the original wild calves captured by Jones in the Texas Panhandle in 1888, but he proved to be very vicious. In 1901 Whitney presented him to the New York Zoological Park, which later contributed to the nucleus herds on the Wichita (Oklahoma) and Wind Cave (South Dakota) National Game Preserves. In 1911 Corbin sold a male and a female, and in 1914 a bull and a heifer, to Gen. Harry C. Trexler for his game preserve near Allentown, Pa.

In 1905 the American Bison Society, an active and effective organization in the preservation of bison and other North American big game, was established in New York; Ernest Harold Baynes, long affiliated with Corbin, was the first Secretary (B. B. Holden, 1959). Under the impetus of this Society, and with the active interest of Theodore Roosevelt, William T. Hornaday, and others, Congress appropriated funds for the Wichita National Wildlife Refuge (1906), the National Bison Range in Montana (1908), and the Wind Cave National Park (1913). To these Government-owned herds Corbin contributed by frequent and generous donations. In 1910, a bull and two cows were given to the National Bison Range herd. In 1915, three males and three females were offered for establishing a nucleus herd on the Pisgah National Game Preserve, in North Carolina; delivery was not accomplished until January 1919, due to wartime transportation problems (Garretson, 1938: 208, 210).

As these other herds increased, it was deemed advisable to reduce the Corbin stock to a permanent herd of about 25 head. Actually, the Corbin herd numbered 86 in 1911; 78 (41 males, 37 females) in 1913; and 96 (46 males, 40 females, 10 young) in 1918 (Amer. Bison Soc., 1913, 1918). Reference is made to an apparent change in the stature and character of the Corbin bison, which were perhaps 10 percent larger than normal, attributed to the excellent conditions on their range. Gradually the herd was allowed to dwindle. Numbers in the last years (H. H. T. Jackson, 1944; and Fish and Wildlife Service files) were 21 in 1937, 26 in 1938, 22 in 1939, 15 in 1940, and 6 in 1941. By this time the remaining bison were in an almost domestic condition. Contagious abortion, later identified as brucellosis, became prevalent, and the herd was destroyed. It was not until after an 18-month hunt, however, that the last one was shot in 1945.

Himalayan tahr, *Hemitragus jemlahicus*.—The "few" Himalayan goats originally introduced were probably of this species, though they may have been Siberian ibex, *Capra ibex*, and Champollion speaks in passing of about six "European goats or chamois." There appears to be no record of their origin or of their ultimate fate. Certainly they disappeared soon after their original release on the preserve.

Bighorn, *Ovis canadensis*.—Champollion intimates that bighorn sheep were introduced, but "also failed." No other record gives a hint as to their source or numbers or the circumstances of their brief sojourn at the Corbin Preserve.

OTHER WILDLIFE

General accounts of the native wildlife of this area have been presented by Baynes (1931), Siegler (1962), and Silver (1957). The wood duck (*Aix sponsa*), ruffed grouse (*Bonasa umbellus*), turkey (*Meleagris gallopavo*), woodcock (*Philohela minor*), and upland plover (*Bartramia longicauda*) were the principal game birds in the early days, though most were reduced before the establishment of the Corbin Preserve. There was little suitable habitat here for waterfowl.

Native game mammals included the snowshoe hare (*Lepus americanus*), cottontail (*Sylvilagus transitionalis*), gray squirrel (*Sciurus carolinensis*), and black bear (*Ursus americanus*). Among important furbearers were the beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), red fox (*Vulpus fulva*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), marten (*Martes americana*), fisher (*Martes pennanti*), mink (*Mustela vison*), striped skunk (*Mephitis

mephitis), otter (*Lutra canadensis*), Canada lynx (*Lynx canadensis*), and bobcat (*Lynx rufus*). Besides the coyote (*Canis latrans*), previously mentioned, and the various species intentionally introduced, the opossum (*Didelphis marsupialis*) made its way into the area (R. P. Holden, 1959) early in the century.

As was so often the case in the early days of colonization, the larger game mammals and predators were the first to be reduced. The white-tailed deer disappeared until reintroduced by Corbin. Woodland caribou and moose were apparently never common (Goodwin, 1936; C. F. Jackson, 1922). The cougar (*Felis concolor*) and wolf (*Canis lupus*) are now gone (Cram, 1925; R. P. Holden, 1959), and the Canada lynx and black bear are rarities.

DISCUSSION

Of the 14 species of mammals which were introduced, four—the beaver, boar, elk, and deer—now remain on the Corbin Preserve. Except for the boar, all the exotics were destroyed or died out—mute testimony to the need for ecological information before embarking on a transplanting program. In 1962, it is estimated there are over 200 elk, upward of 250 boar, and at least 500 deer on the area. Beavers remain, and bears, foxes, and bobcats climb over or through the fences. The principal other game species are ruffed grouse and snowshoe hares. Most of the game is artificially fed during the winter; sacks of feed are dropped from airplanes into clearings for the boar. Fields are mowed to keep them open for grazing. Food patches are planted for wildlife.

Almost from the start, "No rare, exotic, or purely imaginative beast has been too strange to have 'escaped from Corbin's Park' " (Silver, 1957: 122). Elk, moose, and wild boar, derived from the preserve, still roam a considerable surrounding area. Corbin also provided the state with game for stocking purposes. It was through his example and recommendation that pheasants were introduced to New Hampshire. His experiments in breeding and keeping bison in captivity were almost unique in his time.

Today, over 70 years since its establishment, the Corbin Preserve still maintains its integrity as a private hunting area. Speaking of this and other parks, Young (1956: 18) writes that "the record of deer parks, when maintained solely for private gain, is with few exceptions that of financial failure." The Corbin Preserve is no exception—but then it was not intended as a financial investment. Its profits lay elsewhere—in the recreational enjoyment it provided, in its contributions to conservation, and to the economy of its community. With reference to the Corbin bison herd, Trefethen (1961: 94) states that it "expanded rapidly and assumed great importance in the later restoration efforts." Indeed, this sentiment was expressed nearly 60 years ago by Corbin's longtime friend, Ernest Harold Baynes (1931: 120), as follows: "The thought came to me that, of all the works of the late Mr. Austin Corbin, the preservation of that herd of bison was the one that would earn his country's deepest gratitude. . . . His experiment led to the founding of the American Bison Society, and was connected, directly or otherwise, with the formation of some of our National Parks."

APPENDIX

With the thought that the development of the Corbin Preserve might be better understood by an insight into its founder's background, further biographical notes are presented here.

In the small town of Newport, Sullivan County, N.H., Austin Corbin was born in 1827 to a family of modest circumstances. Here he grew up, went through grade school, and worked in local sawmills as roller, scaler, and sawyer. Intent upon greater things, in 1846 he departed for Boston and work as a shopkeeper. With his savings, supplemented by earnings as a clerk in Boston stores, he worked his way through Harvard Law School, and in 1849 began practice in partnership with Ralph Metcalf, later Governor of New Hampshire. Then, in 1851, with his younger brother Daniel (who later pioneered as a banker and railroad man in the Pacific Northwest), he went to Iowa. At Davenport he soon abandoned the law, speculated in land, and with money saved he organized a private bank.

This was a time of wildcat banks throughout the expanding West. The financial bubble burst with the Panic of 1857, but Corbin's bank was one of the few to survive. The First National Bank of Davenport received the first charter granted under the National Banking Act of 1863, and soon became one of the leaders in the field. But Corbin was still restless. He returned to New York and established the firm of Austin Corbin & Company, private bankers, which flourished at Broadway and John Street. He helped finance recreational developments on Long Island, and developed Manhattan Beach and Coney Island, including the building of two hotels. Railroading attracted him and he ministered to the Long Island Railroad, which was ailing even then. He later was active with the Philadelphia and Reading, ultimately becoming its president. He explored the possibilities of a subway system for metropolitan New York, but in the 1880's this was still premature. He seriously considered developing the extreme eastern end of Long Island as a steamship terminus, considerably lessening the traveltime to Europe, but this scheme was forestalled by his death.

In 1853, Corbin married Hannah M. Wheeler, of Croydon. The couple had five children—three daughters born in Davenport and two sons born in Brooklyn, N.Y. The oldest daughter married a Frenchman, René Champollion. They made their home in Paris, and had one child, André. As a young student in an American college, André visited the Corbin Preserve and, for a class in English composition, wrote a series of naïve but enlightening essays about it which were published in 1899. In later years this grandson became a director of the preserve. Corbin's first son lived but a few years. His second son, Austin, Jr., succeeded his father in his banking and other business interests, and also in the administration of the preserve.

The elder Corbin made his home at a fenced woodland estate on Long Island. In 1885 a friend presented him with a few young deer, which he kept because of the interest of his son, Austin, Jr., though he himself was not then a sportsman or a naturalist. The deer thrived, and presently there were added antelope, elk, and bison. In addition, Corbin had 25 elk in a 10-acre enclosure at Manhattan Beach; but the land was insufficient. Corbin was interested not in pets or domesticated animals, but in wild creatures. He had observed the vanishing of the bison from the Iowa plains and he resolved that at least some of them should be preserved for posterity. In 1886 he returned to Newport to devote his remaining years to what became more than a passionate hobby.

In speaking of philanthropy and conservation, Udall (1961) has this to say: "On looking back over the history of conservation it is surprising how much of our total accomplishment is attributable to quiet men from private life who at crucial moments have provided the needed inspiration and wherewithal." Austin Corbin was such a man, though perhaps "quiet" is not altogether appropriate. A contemporary, William H. Child (1910, 1:314), described him in these words: "His robust and active mind, his keen intelligence, his indomitable will, his rugged independence and self-reliance made him a natural leader of men. Whatever he did, was done with his whole strength. He devoted his talents to the accomplishment of worthy objects. His mission was to build up, and not destroy. Aggressive, masterful, and fearless as he was, he also possessed the gentler traits of a genial manner, a hearty honesty, and kindly and generous disposition which endeared him to all his associates."

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The Southern Ocean: A Potential for Coral Studies

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[With 4 plates]

It is always amazing to me to find persons who are surprised by the presence of corals in the colder regions of the world. But then, as a specialist in the study of corals, I must admit to some personal prejudice by reason of a longstanding interest in the corals of these regions. However, it is unfortunate that some inkling of the greater distribution of these interesting animals has not leaked out into the scientific world, if not to the public at large. Lack of publicity is quite clearly the answer. So much popular and scientific material has been written about the coral ramparts of the atolls and barrier reefs; their beauty has long been praised, and the coral island paradise is a familiar symbol of the idyllic life. Today, through the personal experience of skindiving, hundreds and thousands of people are entering the sea and seeing the living coral reefs under ideal conditions, and comprehending its diversity of life. Even at the turn of the century the spotlight of notoriety was focused on coral reefs, as the controversy among such scientific greats as the four "D's"—Darwin, Dana, Daly, and Davis—concerning the origin of coral islands and atolls went far beyond academic walls, and captured the fancy of the public. The corals from the colder regions, having no monumental structures composed of their skeletons, no large masses brilliantly and differentially colored to attract attention, have not caught the imagination of the scientist or the interested layman.

Then, what about these corals? Are they sufficiently interesting to warrant study? Do they, in their aggregate, represent hazards to navigation? Do they represent potential sources of fishing grounds? Is it worthwhile to study corals which are difficult to approach, can be studied only under some special conditions, and with discomfort resulting from heavy seas, cold weather, and other meteorological vicissitudes far removed from the amenable tropical conditions? We might well question the reasons for doing any basic research, and, although many complex reasons might be given, the closest we can come to a simple and direct answer would be to say that any enlargement of our knowledge of the world about us is worthwhile. The following discussion should provide a rationale for the undertaking of a study of these corals.

There are perhaps 50 species of corals to be found in the waters of the Southern Ocean from the shallowest to the deepest portions. This variety is somewhat easier to comprehend than the 400 or more species recorded from the shallow waters on the reefs of the Fiji Islands, a number which does not include all of those corals which might be found by divers or by dredging and trawling in the deeper waters around those islands. But more significant than the number of kinds involved is the number of specimens which can be collected per unit of effort. Antarctic corals, like most cold-water bottom dwelling invertebrates, are not evenly distributed on the sea floor, but rather are scattered in clusters in what has been called a "contagious distribution." Trawl samples from the sea bottom do not usually indicate a large variety of species present; they more often yield large numbers of one kind of coral, with token representation of other types. For example, in one dredge haul from Pennell Bank in the Ross Sea, Antarctica, 141 specimens of one species were taken together with 33 specimens belonging to three other species. In contrast, a trawl made in the Sulu Sea by the Danish ship *Siboga* collected 55 specimens representing a total of 22 species. Although bottom trawls cannot be taken as a means of collecting quantitative samples of bottom fauna, they are at present the most efficient means of collecting large samples, and the examples given are probably significant in terms of magnitude if not in comparability of absolute numbers.

The Antarctic corals are generally small (seldom over 1 inch in diameter) horn corals of solitary habit. A few species of colonial corals are found, but these are loosely branching forms which construct very open colonies. The solitary forms normally live free on the bottom so that their shape is gently curved. Others are attached to rocks, pebbles, or shells and are straighter and more fan shaped. These forms are characteristic of the deeper water corals of all oceans and in themselves are not unique. Reef corals, or more properly hermatypic corals, are found in depths of water to no more than 90 meters while the deepwater or ahermatypic corals are found from the surface to depths of to 6,000 meters. The term hermatypic was proposed by J. W. Wells to include those corals which build reefs (hence the derivation of the word) and therefore the ahermatypic corals are non-reefbuilding. This distinction is an important one, but not necessarily the easiest to recognize. Reef-building corals are able to grow and secrete calcium carbonate in vast quantities because of the unique relationship between symbiotic dinoflagellates called zooxanthellae and the coral animal which enhances the physiology of the coral in its calcium-carbonate depositions. It is this same symbiotic relationship which restricts the reef corals to warm waters and to those waters which are lighted, for the symbionts require light for their photosynthetic activity. Corals of the cold waters have not yet been demonstrated to have such symbionts, and we should not expect them in the waters of the deep ocean far beyond the penetration of light.

The ahermatypic corals show much greater latitude in their choice of life sites. They are found to occur through wider ranges of depths, through greater ranges of temperature, and through a greater diversity of conditions than their more specialized hermatypic relations. This does not affect their value in studies of the relationships between animal and environment, however, for they have developed other habitat restrictions which are of considerable interest to the ecologist.

The very simplicity of the solitary corals is a distinct advantage in studying the relationships between animal and environment, for the responses of the animal are not clouded in the multiplicity of asexually produced individuals which constitute the colonial coral of the tropical reefs. The hermatypic corals are able to cope with many external factors through successive minute adjustments in each of the asexually produced members, which accumulate through their generations major compensations in the form of the colony. The solitary coral, on the other hand, records in its skeleton the entire history of its personal response to the exigencies of life.

The Southern Ocean, lying as a moat about the Antarctic Continent, is actually composed of the southern segments of the other three great oceans and as a result must be defined by arbitrary borders. Its unity and identity lie principally in the cohesive nature of the hydrology of the Southern Ocean, because through most of its extent—the Southern Ocean is unbroken by land and is overlain by a potent driving force of the Westerly Winds—it is powered by a basically simple current system widely characterized as the West Wind Drift composed of the "Roaring Forties," the "Furious Fifties" and the "Screaming Sixties." The wind-driven system carries water about the poles in a continuous broad band interrupted only by the relatively insignificant Subantarctic Islands, by the projection into its northern margin of the South Island of New Zealand, and severely constricted only by the remnants of the Andean chain extending from Tierra del Fuego across to Antarctica through the grand curvature of the Scotia Arc. The water movement in these areas is actually not directed solely around the Antarctic continent, but carries with it a strong northern component so that Antarctic water is continually

FIGURE 1.—Map of the Southern Ocean. (After G. A. Knox, 1960, Proc. Roy. Soc., Ser. B., vol. 152.)

moving northward into the subtropical regions. There are two regions in which the northward movement is strongly noted, one being where the South Island of New Zealand lies athwart the northern portion of the West Wind Drift, and the other, the tip of South America. In both cases major currents are deflected northward by these projections.

To the south, adjacent to the Antarctic Continent, there is a westward-flowing current, feeble in comparison to the West Wind Drift, but nonetheless important in the distribution of the near-ice animals, for it circulates slowly in a counterclockwise direction, opposite to the stronger West Wind Drift. The East Wind Drift is not completely circumpolar, for in the region of the Scotia Arc it is broken and there is not a completely circumpolar near-shore current.

Temperature gradients between the Antarctic waters and the warmer waters of the Tropics are not even, but are rather concentrated at two zones which surround the Antarctic Continent. These zones of high temperature gradient are known as convergences; the inner one is the Antarctic Convergence and the outer is the Subtropical Convergence. Two zones of water within the Southern Ocean are defined by these (the Subtropical Convergence being used here as the northern boundary of the Southern Ocean). Both zones are relatively shallow, for the ocean is layered vertically as well as horizontally. Innermost of these water masses is the Antarctic Surface water which surrounds the Antarctic in a sinuous fashion. This is the area of floating ice or pack ice, and is completely dominated by the East Wind Drift. The waters are cold, being below or only slightly above the freezing point all year round. The water is less saline in the summer because the melting ice adds fresh water, but becomes more saline in the winter as ice is frozen. Across the Antarctic Convergence, which has a tem-

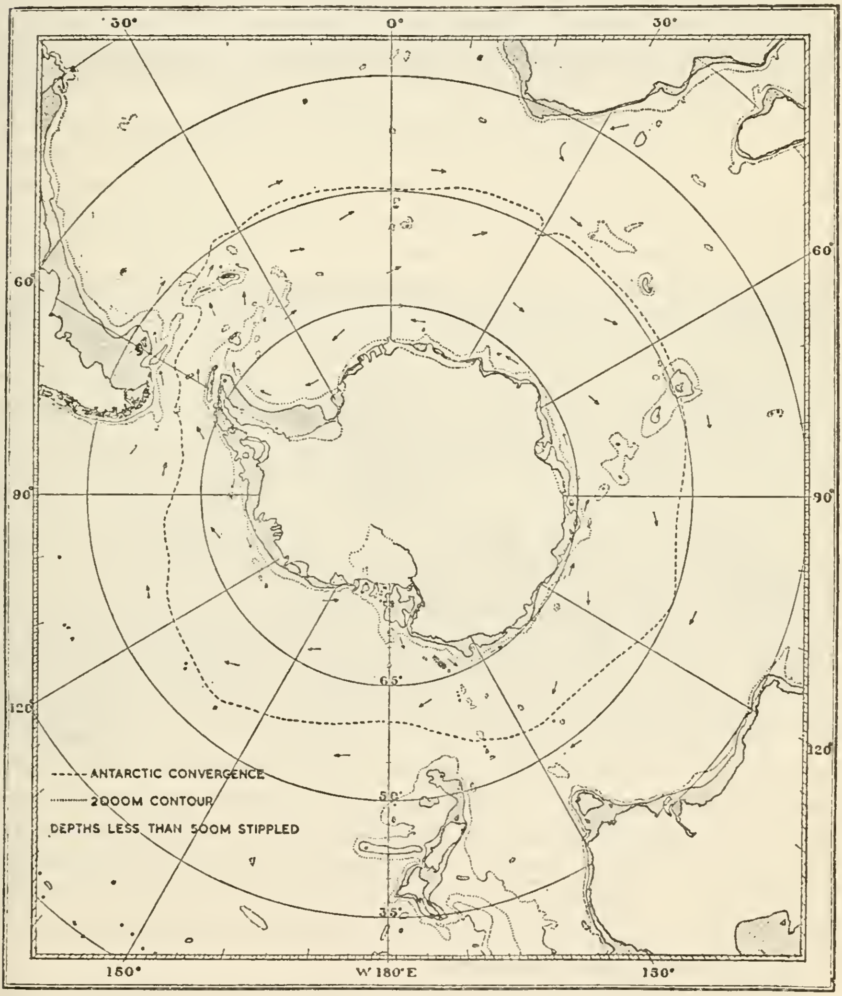

FIGURE 2.—Map of the Continental Shelves, Southern Ocean. (After N. A. MacKintosh, 1960, Proc. Roy. Soc., Ser. B, vol. 152.)

perature difference of 2° C., lies the body of the subantarctic water, dominated and moved by the West Wind Drift. This water is warmer than the Antarctic Surface water and is less variable in its salinity. Because of the roughness of the region, the surface-water zone is very thick and well mixed. The Subtropical Convergence is a region of very sharp temperature changes, the average change from one side to the other being about 4° to 5° C.

At the Antarctic Convergence, the northward moving Antarctic Surface water meets the Subantarctic Surface water and, because it is denser by reason of being colder, slides beneath the Subantarctic Surface water and forms the Antarctic Intermediate Current. Lying beneath that mass is a warm, deep current of water which formed well to the north of the Southern Ocean. The most important water body of the Southern Ocean is probably the Antarctic Bottom water, for this is the water which flows along the bottom of the entire Southern Ocean region and is the water which is in contact with the benthic animals, although the effect of the surface conditions upon bottom animals is not to be underestimated. During the winter, as the freezing of ice withdraws fresh water from the sea, the cold, saline, dense water formed sinks below the surface waters and slowly flows outward along the bottom to the edge of the Antarctic Continental Shelf and thence outward to the deep waters below the West Wind Drift. Knowledge of this body of water is not complete for there is still much to be learned about where it forms, and to what extent it maintains its identity. G. E. R. Deacon stated that deepwater formation was largely in the region of the Wedell Sea and that Antarctic Bottom water then flowed eastward about the continent. Bottom water forming in other areas is kept isolated by the ridges of the bottom topography.

The cold saline waters of the Antarctic sink below the warmer, less saline waters of the West Wind Drift along the Antarctic Convergence, the boundary between the eastward- and westward-flowing currents (fig. 4) and then flow northward along the bottom as the Antarctic Bottom current. In general then, the bottom animals of the Antarctic are living in an environment which is broadly uniform and one which has very little seasonal change when considered from the aspects of temperature, salinity, oxygen content, and nutrients and in comparison with the variation of these factors in the shallow tropical environment. The glacial history of the region has made one feature of the environment quite variable: The bottom sediments, which change constantly, both laterally and in time, imparting a variety of habitats upon the scene. This aspect of the environment seems to have a particularly striking effect upon corals.

Still to be answered is the question "Why study the corals of the Southern Ocean in preference to the deepwater corals of other oceans?"

1. Living *Flabellum curvatum*, the common cup coral of the Argentine shelf. Closely related species of this coral live through the Antarctic and New Zealand.

2. An assortment of invertebrates collected in the Ross Sea area of the Antarctic. Echinoderms (sea stars, brittle stars, and sea urchins) predominate with sponges, alcyonarians, and pyconogonids (sea spiders) also present. (Courtesy U.S. Navy Oceanographic Office.)

1. Bottom fauna collected by a triangular dredge. Pebbles, echinoderms (brittlestars and sea-urchins), bryozoans, a clam, sponges, and other invertebrates are present. (Courtesy U.S. Navy Oceanographic Office.)

2. A triangular dredge being prepared for lowering. In many instances these are more satisfactory than trawls, particularly on rocky bottoms. (Courtesy U.S. Navy Oceanographic Office.)

1. A trawl being prepared for lowering over the side of the ship. The mouth of the trawl is held open by the steel structure. A weight may be attached to the line in front of the trawl to keep it on the sea bottom. (Courtesy U.S. Navy Oceanographic Office.)

2. A trawl coming out of the water. The bottom of the bag is filled with the miscellaneous animals dredged from the bottom, together with mud and sand which composed the bottom. (Courtesy U.S. Navy Oceanographic Office.)

1. Contents of the trawl being examined immediately after being dumped from the bag. The mass is largely composed of sponges. (Courtesy U.S. Navy Oceanographic Office.)

2. The contents of a bottom trawl from which the large soft-bodied animals have been removed. The residue is largely composed of plates of barnacles and stylasterine corals. (Courtesy U.S. Navy Oceanographic Office.)

The answer lies in the postulate that the physical and biological characteristics of the Southern Ocean which have been outlined above should provide us with an area in which to study the effects of environmental factors upon corals, distribution mechanisms, and the changes which occur in the organisms as they move broadly throughout a tremendous area such as the Southern Ocean. In short, how do the corals react to their environment and how does the environment (and time) modify the corals?

Corals distribute themselves about the sea floor during a portion of their life cycle in which the developing larval form is free. In tropical corals the free portion of the larval life may last from several days to several weeks, but this period is apparently much shorter in the cold-water corals. One observed instance of the production of planulae in a subantarctic coral showed that the larvae were highly developed and ready for a sessile life almost at "birth." Some caution must be placed between this observation and a conclusion, for it is known that when tropical corals produce larvae over a span of time, those first produced are less well developed than those which come later.

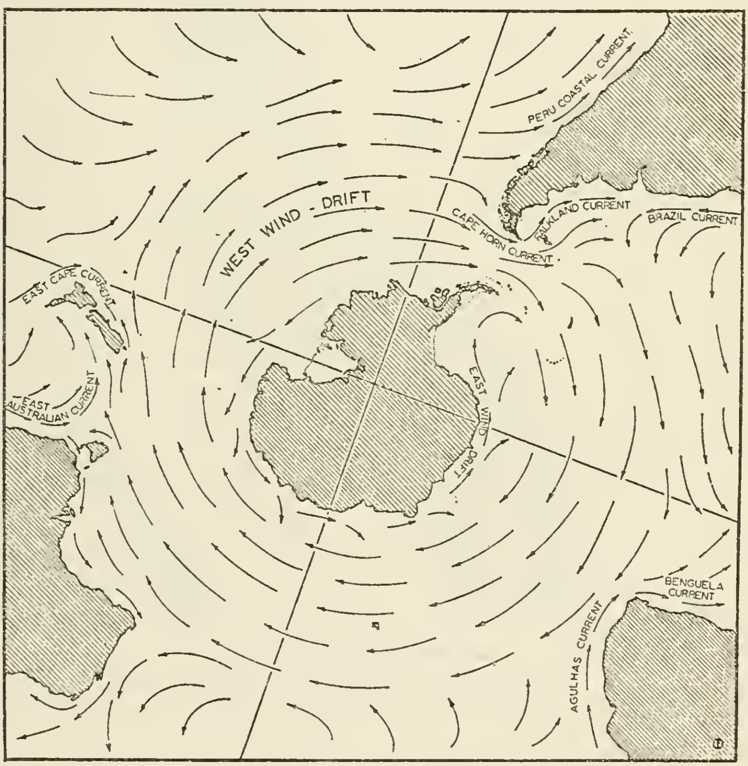

FIGURE 3.—Map of the currents of the Southern Ocean. (After G. A. Knox, 1960, Proc. Roy. Soc., Ser. B, vol. 152.)

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By this mechanism the coral provides for long-range exploratory colonization by the first produced larvae which have a long free life, and for more assured colonization of the immediate environment by the later produced forms which are ready for sessile life almost immediately. The observable contagious distribution of corals in the Antarctic argues that the latter distributional means prevails; corals occur in local high density populations because of their short larval life.

The current pattern of the Southern Ocean is well calculated to develop a widely distributed shallow-water fauna about the Antarctic Continent. The West Wind Drift should effectively carry the shallow water marine fauna of South America to the Subantarctic Islands along the route of the sea mounts and high ridges, as should the fauna of the southern portion of New Zealand be distributed through its Subantarctic Islands. The range of these faunas is now being studied. One feature that has emerged is that the West Wind Drift, while being effective as a transportation agent, is also acting as a barrier to the distribution of animals from the subantarctic regions to the Antarctic. For example, the Scotia Arc should provide an excellent series of steppingstones for the shallow fauna of the South American coast to reach the Antarctic. Instead, we find that the region between Cape Horn and Shag Rock (fig. 2) is apparently a barrier—that the Antarctic fauna extends to Shag Rock, while the South American fauna has not been notably successful in crossing Drake Passage. The strong winds and current which are a means for such short-flighted birds as the Rail to make the jump from Tierra del Fuego to South Georgia are an effective barrier to a number of marine organisms. Near shore the East Wind Drift should be the distributing mechanism about the Antarctic, and the circumpolar aspect of the fauna attests to its effectiveness. However, we are basing our claims upon the supposition that surface currents are effective to the depth of the continental shelves. It may be that bottom currents acting in different directions are the actual distributing mechanisms, for the larvae of the corals do not rise far above the bottom if they are advanced in development upon liberation. A fascinating, but as yet incompletely tested hypothesis dealing with this aspect suggests that the direction of movement of the Antarctic Bottom water should influence the distribution of species. One shred of evidence for this was collected when at approximately 2,000 meters on the Argentine Continental Slope a trawl containing a few species of "Argentine" corals also contained individuals of a species characteristic of shallow waters on the Antarctic Shelf. Could this be an instance of the animal following the temperature gradient and possibly migrating across the Drake Passage? Many more finds of a similar nature will be required to give a definite answer. The distribution of corals at depths greater than those of the Continental Shelves is difficult to generalize about, for as

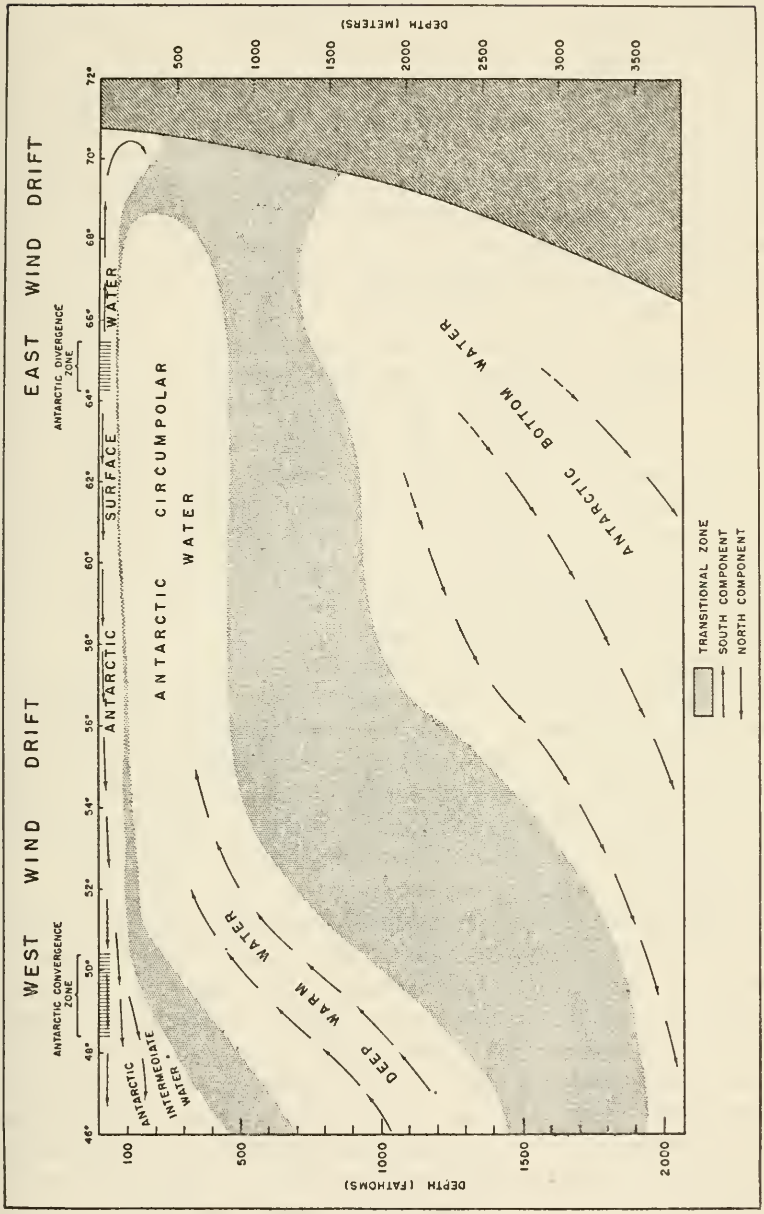

FIGURE 4.—A cross-section of the Southern Ocean. (After U.S. Navy Oceanographic Publication 705.)

yet very few collections have been made. Collections now under study, made by the U.S. Antarctic Program, the Navy "Deep-Freeze" Program, and others, will ultimately yield some of this needed information, but the distribution of collecting stations is still very sparse.

From examination of the shallow-water corals of the Argentine Shelf, the Chilean Region, the Antarctic Shelf, and the New Zealand Shelf, it is apparent that a plexus of very closely related species exists. Highly specialized species, living in special environments, differing from one another only in minor features which make them difficult to identify, and having counterparts in each of the areas given above, apparently signify recent evolution. In other words, the stock is not an old one which has had opportunity to diversify greatly and to become quite specialized morphologically, but is a recent one, probing into new areas. For example, there is a plexus of species, not all members of which have been as yet distinguished, within the genus *Flabellum*. On the Argentine shelf are the species *F. curvatum*, *F. thoursii*, and *F. patagonicum*. The first lives free upon the bottom, while the second lives only where there are pebbles to which it may become attached. In the Antarctic are *F. impensum* and *F. antarcticum* and a third unnamed species. In New Zealand there are *F. gracile* and *F. rubrum*. This closely knit group of species is not found elsewhere in the world and has, as yet, been only partly studied. It appears to be a recently evolved plexus.

Recent evolution should not be unexpected, however, for during the Pleistocene glaciation it would be presumed that mass mortality occurred among the animals living on the Antarctic Shelf. As the glacial ice moved out across the shelf, many were physically exterminated, the remainder of the species found their lebensraum severely curtailed. With the retreat of the glacial ice, whole new areas were opened to colonization and it would be only from the areas to the north that the new immigrants could come. But from where did they come?

To logically answer this question one inquires into the historical aspects of the observed distribution of the animal. How much of the distribution noted today is the result of past factors? Were past migration routes, current patterns, or land connections the same as, or in some degree similar to, present-day situations? There are two possible approaches to problems of this nature: One, to understand the geological history of the region and to deduce from this knowledge, what the patterns of seas, currents, and physical environments were during any given episode of geological time. A second approach would be to observe the distribution of animals in the past by means of the fossil record and to obtain from this a series of working hypotheses about the arrangements of the physical and chemical environments which would have fostered the observed distribution.

Unfortunately, it is here that the Southern Ocean fails to provide us with the required data, for as yet the Antarctic Continent has refused to yield information on the distribution of Tertiary Corals. To date the oldest records of corals are from raised moraine deposits in the McMurdo Sound area of the Ross Sea and these have been dated as Pliocene. The coral identified from these deposits is *Gardineria antarctica* and it is a member of the modern fauna. However, there are two other areas which have close relationships to the Antarctic: South America and New Zealand. Although the fauna of the former has been studied only in a most general way, it apparently is of restricted age range and of restricted environmental types. The Tertiary fauna of New Zealand has, on the other hand, been demonstrated to be extremely rich and to represent a wide span of ages and of environmental types.

Perhaps one of the most interesting aspects of a study of the New Zealand Tertiary Mollusca by C. A. Fleming was the apparent movement through time of the position of the Subtropical Convergence deduced from the distribution of these fossils. This movement, later also found to be demonstrated by the distribution of corals is recorded in the fossil record by the progressive migration, first south, and then north of the cold-water faunas of New Zealand. For example, during the Miocene, coral reefs existed in the northern portion of the North Island, indicating that the Subtropical Convergence was farther to the south than at present, for water temperatures in the vicinity of North Cape are now only just about warm enough to support the most hardy of the reef corals. However, after a brief episode, these coral reefs were exterminated by cooling marine climates and the warm-water fauna which had penetrated far to the south was slowly driven northward. Finally, all New Zealand was occupied by a cool-water fauna during the Pleistocene. Now there is apparently a reversal and new immigrants from the northern, warmer waters are appearing. It may well be that in some time not too long in the future, the northern portions of New Zealand may again be ringed by protective coral reefs.

From this type of study, we can expect a picture of the present-day distribution of corals and hypotheses of their past distribution to emerge. From these results much can be deduced regarding the mechanism by which the corals (and other faunal elements) have migrated, and of the controls upon their distribution. Because many elements of the study of larval life are as yet beyond experimental means, requiring pressure and temperature controls which make them prohibitive, deductions based upon distributional information regarding larval life will be the sole means for gathering this type of data for some time to come. Much information regarding the geological history of the Antarctic region can be derived from additional faunal information. For example, the Scotia Arc undoubtedly was once more continuous than at present. Because the influence of such a continuous structure upon the faunas must have been great, a study of the faunal continuity may give us information on the "how" and "when" of such connections.

But aside from such broad-scale regional studies, what values are there in the study of the Antarctic corals? One of the most important features of the coral fauna of the Southern Ocean is the availability of large numbers of individuals of one species, making possible studies of intraspecific behavior and ecological relationships rather than only the broad application of ecology to a faunule. We are therefore able to phrase such questions as: How does the form of an individual coral vary in response to the local differences in environment? What are the mechanisms by which the animal adapts to these local changes? How do these animals which possess only a rudimentary nervous system (members of the Coelenterata, the group which includes the corals, have the most primitive nervous systems of the animal kingdom) orient themselves and sense the environment? These questions could be answered to some degree on other corals in other places. Reef corals are very accessible and satisfactory for certain types of physiological experimentation. Shallow-water occurrences of solitary corals are now being utilized for experimental studies in temperate and tropical regions. But these latter are essentially the studies of individuals and of individual reactions, and colonies give only a summation of the collective response through time. The large populations of individuals of a single species to be found in the Southern Ocean permit studies of population response and behavior, on a statistical basis.

Among the questions being studied are: How does the animal react to the unfavorable cold climate in the secretion of calcium carbonate? What mechanisms are involved in the protection of the skeleton from the effects of the environment and from predators? In progress are studies of the way a coral reacts to the instability of its environment, as in the instance of the coral which attaches to a pebble. While the coral is small, the pebble is proportionately large in mass, but as the coral grows, the pebble becomes proportionately smaller and smaller in respect to the coral until it does not afford the stability that it once did. Some species apparently do not "care" and continue to live quite successfully even after they have fallen over; others do not thrive in a prone position and deposit a variety of structures and roots to better secure themselves in their environment. Once some of the basic questions involved in this sort of performance are answered, such as (1) How does the coral (lacking sense organs as we generally think of them) know it is not vertically aligned? (2) How does the coral know where and what type of roots or supporting structures to form? (3) How do the larvae know what size pebble to select before settling?

and a host of other questions, we may be able to get to such fundamentals as the relationship between age and calcium-carbonate deposition. All of these problems bear upon the entire animal kingdom and the lessons learned here may be applied elsewhere.

Having considered the whys of the Southern Ocean coral situation, it may be well to discuss the hows. With the exception of a few New Zealand and Patagonian shallow-water corals, most of the species being studied occur on the continental shelves in water depths of 40 meters or more. Some are found in depths of 6,000 meters—the deepest known occurrences of corals. Because of these depths, much of the work is done from oceanographic ships. Collections are made with many different types of equipment dragged on cables from the ships. Bottom trawls, rock dredges, grab samplers, etc., are all used in special instances to obtain special samples, and all yield corals. At present we are not concerned with some of the finer problems such as population density, and the techniques requiring quantitative sampling, for we are still obtaining on a regional basis such basic knowledge as which corals are found where. For this sort of data, cruder instruments are used. However, bottom photography utilizing any of the many cameras which have been developed for this purpose has shown itself to be an excellent method of obtaining general bottom information, and considerable detailed information about how corals live and in what numbers.

Despite the many features of the Southern Ocean which suggest the desirability of a study such as the one outlined, when the work actually begins numerous difficulties are encountered. The Southern Ocean is an area of many moods, most of them belligerent. Much of the area is available only to marine scientists aboard icebreakers, and then for only a limited portion of the year. In much of the remaining area, seas and winds make work unpleasant or impossible for a great deal of the time. It almost seems as if the Southern Ocean is attempting to retain its own, reluctantly parting with information about itself. Yet, only a few months at sea each year will provide more than enough data for several years of laboratory analysis. At our present stage of knowledge about Southern Ocean corals, each new collection suggests new problems, often resulting in reexamination of much of the accumulated data, and opening new attacks upon older unsolved questions.

The Promise of Underwater Archeology[1]

By George F. Bass

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The great historical wealth lying on the bottom of the Mediterranean has been known to archeologists only since the turn of the century. At that time a group of Greek spongedivers stumbled onto a wreck at Antikythera that yielded quantities of marble and bronze statues, pottery, glass, and a remarkable astronomical computer that has greatly increased our respect for Greek technology. After the addition of the magnificent "Antikythera Youth" to the Athens Museum, sculptures continued to come from the sea: the Marathon Boy, the marbles from the Piraeus harbor, the jockey and horse from Artemision, and above all the Artemision Zeus.

These were chance finds and, while important in themselves, their excavation can hardly be called scientific. Only with the invention of the aqualung by Cousteau and Gagnan in 1943 did divers gain the mobility necessary for the delicate work demanded by systematic archeology. Soon after, notably along the French and Italian coasts, expeditions were able to concern themselves with hull construction, methods of lading and even the daily life on ancient ships. These excavations used the technique of sketching underwater on frosted plastic, and established the airlift, a type of suction hose, as the primary excavating tool of the marine archeologist. Unfortunately, however, the supervision usually came from nondiving archeologists who could follow the work only through sketches, photographs, and, occasionally, underwater television.

The primary duty of the field archeologist is to record and present the smallest details of his excavation so that the proof of his interpretation is readily available to other scholars. At least one ancient wreck has puzzled some experts on ancient pottery who claim that various pieces of the cargo are divided by two centuries. Their thesis, that two wrecks were involved, may be denied by the excavators of the wreck, but the proof of the denial is not to be found in the excavation report since it contains not a plan or section of

[1] Reprinted by permission from the *American Scholar,* Spring 1963. Drawings are by Eric J. Ryan.

the material as it lay on the seabed. That two ships could fall in the same spot is not at all improbable. On the treacherous reef at Yassi Island, near ancient Halicarnassus in western Turkey, wreck is piled upon wreck, and, nearby, two marvelously preserved wrecks lie within 75 feet of each other. Methods of making accurate plans and sections under water became the pressing need.

With the development of various sounding devices, metal detectors, and small, inexpensive submarines, there can be no doubt that wrecks of all periods of antiquity will be discovered and excavated in the Mediterranean. Neolithic and Early Bronze Age ships may settle forever the question of early migration routes. If Middle Bronze Age peoples came to Greece by sea, we should find ships carrying the typical grey "Minyan" pottery so closely associated with them. One or two Iron Age ships may solve the problem of the ivory trade of that period, or answer the puzzle of whence came the bronze griffin heads found from Turkey to the Etruscan tombs of Italy. And, if precise methods of excavation are followed, we will learn exactly how triremes were rowed.

The University Museum of the University of Pennsylvania in 1960 undertook a program to develop the means of recording and preserving the data from such wrecks. The first step in the program was to staff the Museum's marine expeditions with the proper personnel; it was realized at once that weekend skindivers and helmeted spongedivers, who had done so much of the previous work, had no more place in such operations than they would have on land digs. The present staff consists of archeologists and archeology students, draftsmen, photographers, an architect, a marine biologist, and a medical doctor, all of whom dive and most of whom learned to dive specifically for underwater archeology. Rounding out the staff are a number of carefully selected experienced divers and mechanics. Such a staff must of necessity be larger than most found on land for its members do the actual digging and cleaning. On land one archeologist may direct a vast crew of skilled and unskilled laborers. Underwater, however, each worker must be able to supervise himself and make sudden decisions that may radically affect the interpretation of the finds.

The areas chosen for study, along the coasts of Lycia and Caria in southwest Turkey, were charted by Peter Throckmorton. Gathering his leads while working and diving with Turkish sponge divers, Mr. Throckmorton was able to locate about 30 wrecks covering a span of over two millennia. The first of these wrecks to be excavated was dated to the Late Bronze Age by a study of the finds raised upon its discovery. It lay in 90 feet of water just off Cape Gelidonya.

A preliminary survey revealed that the wreck rested on a rocky bottom with almost no covering of sand to preserve wood and other organic material. The metal cargo was still *in situ*, but it was covered with a lime sea deposit up to 8 inches thick, and hard as concrete. The concretion presented a double problem: how to make an accurate plan of the objects imbedded in it, and how to remove and preserve fragile artifacts such as bronze knife blades and spearpoints without breaking them.

On land such problems could have been easily overcome, but on land there is not the all-important time limitation. Underwater, a diver must breathe air at the same pressure as the pressure of the water surrounding him. The deeper he goes and the longer he remains at any depth, the more pressurized nitrogen will be absorbed by his body. If the diver ascends too rapidly, the nitrogen will come out of solution with much the same effect as bubbles appearing in a bottle of champagne when it is uncorked. Such bubbles in the body may block the bloodstream in various areas, causing the crippling and often fatal divers' disease known as the bends. The only precaution is strict adherence to diving tables giving the rate of ascent following dives of various depths and duration. At Gelidonya the practical limit was only 1 hour and 8 minutes for each diver to work each day.

In order to save these precious minutes on the bottom, it was decided to cut loose lumps of concreted cargo, weighing up to 300 pounds a piece, and to raise these intact. Before being cut free with hammer and chisel, each lump was marked in several spots. These spots were triangulated with horizontal metertapes running from fixed reference points driven into the rock around the site. The triangulated points were put onto a plan and the lumps were raised to the surface with a winch and cable. In one instance wood was seen protruding from beneath a heap of concreted cargo. Winching from a small boat in a rough sea presented the real danger that this fragile evidence might be crushed. The mass of concretion was, therefore, attached to a large plastic balloon with a lifting force of 400 pounds; the balloon was inflated on the bottom from a diver's mouthpiece and carried the cargo gently to the surface.

The lumps of concretion were carried to the expedition camp and reassembled exactly as they had appeared on the seabed. Then they were cleaned with chisels so that the cargo finally lay free and could be drawn and photographed in detail. Using the points triangulated on the bottom, the architect was able to add the details to his overall plan which now showed the position of each object as it had rested in the ancient ship. A record of the work in progress was also kept in a number of "aerial surveys." These were made by a photographer, with plumb line and level attached to his camera, swimming at a fixed distance above the wreck. The resultant series of photographs were enlarged to a set scale and glued together to form montages showing the entire site.

Such work was exceedingly slow. The jumble of wood that had been crushed beneath the cargo was the only well-preserved portion of the ship's hull. Although this covered an area of little more than a square meter, it took the entire team of divers 3 weeks to cut behind the solid rock on which it rested so that the wood fragments could be raised together and studied on land.

These framents matched the elements used by Odysseus in making a small boat (not, it would seem, a raft) with the aid of Calypso (*Odyssey* 5.233–261). There were planks with bored holes and dowels, and at least two of the planks were joined together at their ends. On board, perhaps only as part of the cargo, were the main tools used by Odysseus: axes and adzes. Homer also tells how Odysseus made a wattle fence around his ship to keep out the waves, and then "spread out a great deal of brushwood." Because this last phrase has made little sense to classical scholars, it has been variously translated and interpreted as a brushwood bed, as part of the wattle fence or a backing for it, and even as ballast. It would now seem that a literal translation of the passage is all that is needed. Over the planks of the Gelidonya wreck was spread a layer of brushwood, with the bark still well preserved, which served as a cushion between the heavy metal cargo and the thin hull planks.

Not enough wood was preserved to give an accurate idea of the size of the ship, but the distribution of the cargo suggests a length of not much more than 8 or 9 meters. This would easily have handled the cargo and ballast stones that were collected from the site. The cargo was almost completely of metal. More than a ton of copper and bronze objects was preserved, making this by far the largest hoard of such implements yet found by preclassical archeologists.

Forty ingots of almost pure copper, in the so-called "oxhide" shape and averaging 45 pounds apiece in weight, were found piled neatly on the site. Traces of matting indicate that these may have been wrapped together in small stacks. Over 90 of these ingots had been known previously from the Late Bronze Age, appearing in Cyprus, Crete, Greece, and Sardinia, and many numismatists considered them a premonetary form of currency. Their superficial resemblance to dried oxhides had even led to the conclusion that one ingot was worth one ox. Careful study of the Gelidonya group, however, has revealed that the ingots were merely convenient forms for transporting raw copper. They have no standard weight (variations in weight among those from different sites had been attributed by some archeologists to local standards in use), and their resemblance to dried skins has been shown to be completely fortuitous. Their "legs," previously known as rather late developments in the evolution of the ingot shape, were merely handles for ease of porterage; the faces, one rough and "hairy," and the other with a rolled rim seemingly representing the curling of a dried skin are simply the result of the method of casting and the type of mold used. Dozens of ingot fragments, in small groups on the wreck, have proved by weight not to be fractional parts of whole ingots, as might be expected if the ingots were truly currency.

The use of these ingots is seen in a wall painting in the Tomb of Rekh-mi-rēʿ at Thebes. Egyptian smiths are shown melting down "oxhide" ingots to be cast with square white ingots. The obvious conclusion from this scene, that copper and tin were being mixed to form bronze, has been contested by some authorities who have thought that the white ingots must be lead. This is not as arbitrary as it might seem, for only two or three items of pure tin have been found from this early date. The Gelidonya wreck, however, yielded a number of piles of white powdery material that, after being carefully collected in plastic bags and analyzed, proved to be pure tin oxide. This proves that the previous lack of evidence of industrial tin had been due only to the fortunes of excavation. Not only may we now feel sure that the white ingots of the Egyptian tomb paintings are tin, but this discovery also adds an argument for the identification of *anāku* in the old Assyrian documents from Cappadocia as tin rather than lead.

Most of the ingots are stamped with Cypro-Minoan signs. The meaning of these letters might add greatly to our understanding of this still-undeciphered script. Only after careful analysis of each ingot will it be possible to say if the marks refer to different mines, foundries, destinations, or metal quality. Careful excavation again plays an important role. Stratigraphy, so essential for chronological conclusions in the excavation of land sites, might seem to be of little value in the study of an ancient wreck; most of the objects on a ship are contemporary. Even here, however, the general rule that "higher means later" has validity. If all of the ingots (or, in the case of other ships, wine jars or tiles) were not put on board at the same place, those lowest in the hold would have come from the earliest ports of call. Thus, if we find by analysis that the lower ingots from the Bronze Age ship seem to come from different mines than those above, it may some day be possible to trace the route of the vessel. This information, together with a study of ancient place names, might offer still another clue to the meaning of the ingot signs.

With the ingot fragments, often packed together in the same baskets, were hundreds of bronze tools, weapons, and household utensils. These included picks, hoes, axes, adzes, mirrors, bowls, chisels, knives, a hammer, a spade, and a spit. Some were complete and may have been used by the crew of the ship, but the vast majority were broken before being stored on board. One perfectly preserved wicker basket bottom was found still holding tightly packed scraps of metal. Similar founder's hoards have been found on land and it was known from these that old utensils were commonly melted and recast in Mycenaean times. A swage block and a possible stone anvil make it almost certain that a smith traveled on board the ship. Numerous whetstones, found in the "cabin" area, would have been used to sharpen newly made tools.

From the area assumed to be the cabin of the ship came such personal possessions as scarabs, weights, pottery, stone mace-heads, pieces of crystal, a cylinder seal, an oil lamp, and even traces of a meal: olive pits and fish bones were found imbedded in concretion. An astragal was probably only for playing the popular ancient game of knucklebones. The only nonmetallic objects certainly not from the cabin area were two stone mortars and a jar of glass beads.

A study of the ship and its cargo allows us to reconstruct something of its history. The bits of broken pottery give a date of around 1200 B.C., when the entire eastern Mediterranean was in a state of upheaval. The main part of the cargo was certainly from Cyprus, known as the copper center of the late Bronze Age; not only the ingots, but 232 of 302 bronze objects found on board find their closest parallels on Cyprus.

Although the ship loaded its cargo in Cyprus, there is no reason to assume that it was Cypriot. Egyptian tomb paintings show both Cretan Minoans and Syrians bringing copper "oxhide" ingots to the pharaoh as tribute. The pottery seems to have a mixed background, but the lamp—the most likely of the terra cotta objects to have been a permanent item in the ship—is Syrian. Some of the weights are of a type and standard used in Egypt, Syria, and Cyprus, and tell us little. The scarabs and cylinder seal, while possibly trinkets picked up en route, seem also to be Syrian. There is also a possibility that the tin originated in Syria. Such evidence, although not conclusive, led the author to believe that we were dealing with a Syrian merchantman that had picked up its cargo in Cyprus. Since that time an analysis of the wood has shown that the hull was probably made with Syrian wood, while the brushwood, surely picked up with the metal cargo, seems to be Cypriot.

With the lessons learned at Gelidonya it was possible to devise more efficient methods of working underwater for the next project. This was a Byzantine wreck lying on a slope in 100 to 130 feet of water just off Yassi Island near Bodrum. The greater depth limited daily diving times to the extent that mechanical aids, offering both speed and accuracy, became essential to the architect. Three new devices were tried (fig. 1). The first was a pair of plane tables set on opposite

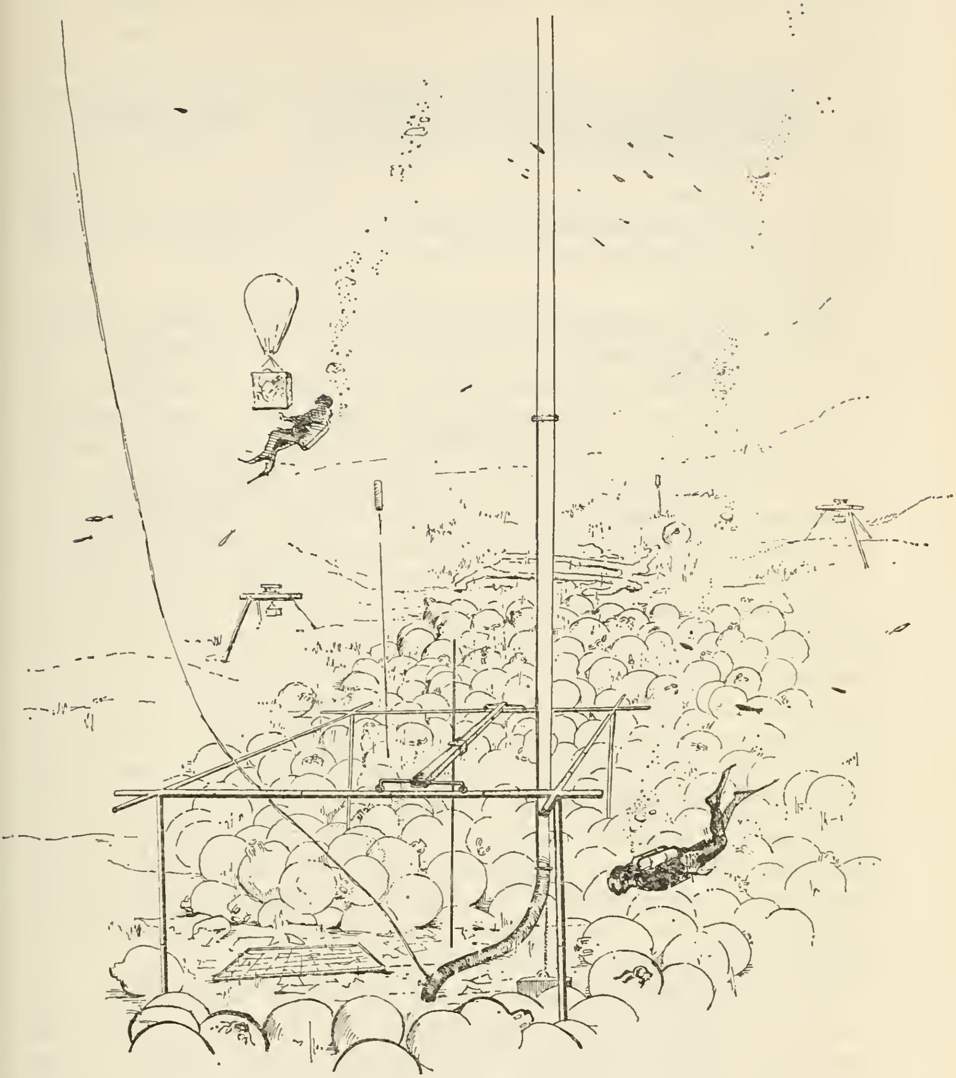

Figure 1.—Mapping devices, suction hose, and lifting balloon used in excavation of Byzantine shipwreck during 1961.

sides of the wreck. Two divers, sighting through simple alidades, could record vectors and elevations on a surveying pole held by a third diver. This proved successful for overall measurements, but demanded great clarity of the water and the use of three divers. A 5-meter square mapping frame was then placed over part of the wreck; this was leveled on its telescopic legs and positioned by the plane tables. A horizontal beam rode across the top of the frame, using two sides of the frame as tracks. Yoked to this beam was a vertical pole that could be moved back and forth on the beam as well as up and down. The sides of the frame, the horizontal beam and the vertical pole were all calibrated in centimeters. By placing the bottom of the pole on an object, therefore, it was possible to read both coordinates and an elevation for its position. Again, too much time was taken in recording each point, so a movable, 2-meter square grid was placed on the wreck. Detailed drawings, photographs, and elevations could be made through the wires of the grid, making it necessary to record only the four corners of the grid with the mapping frame.

These aids were excellent for a beginning, but all needed refinement before being used on a detailed plan of the wooden hull that came to light under the cargo. In the second season on the Byzantine wreck a variation of the mapping frame was used (figs. 2 and 3). This is essentially a combination of nine frames, each 2 meters by 6 meters, assembled like steps over the entire length of the wreck. Each step is horizontal and may be moved down independently of the others on its legs as the excavation goes deeper into the sand; this insures that the frames are always level and are always near the objects to be plotted beneath. A number of 2-meter square grids ride over the frames, each having three positions on each step. Thus the wreck is broken into 27 squares that can be independently excavated, drawn, and photographed. Photographic towers of light metal are bolted to the grids to insure perfect grid pictures of each area. Objects are identified in the photographs by numbered plastic tags attached to the objects on the wreck as they appear in the course of excavation. Distortion caused by the slope of the ground, which puts some objects at an appreciably lower level than the grid, must be corrected by the architect before he can use these grid photographs in making his plans and sections; lens distortion has not been significant when using the proper cameras.

Improvements in the airlift were also made. The airlift is no more than a large, vertical pipe with a flexible lower end. Air is sent to the lower end of the pipe through a hose. This air rises through the pipe, pulling water, sand, and mud with it. The airlift should be used only for removing loose sand and not, as is common, for actual excavating. Wood can be easily broken by it, and the original location of small objects sucked up by it is never known. Tiny pieces from time to time do enter the pipe, so at Yassi Island a wire basket was bolted to the top of the pipe. The mesh of the wire allows most of the sand to be carried away by the current, but coarse sand and small objects are trapped and fall into a bag attached beneath the basket. The bag is raised whenever full and the sand within is carefully inspected on land.

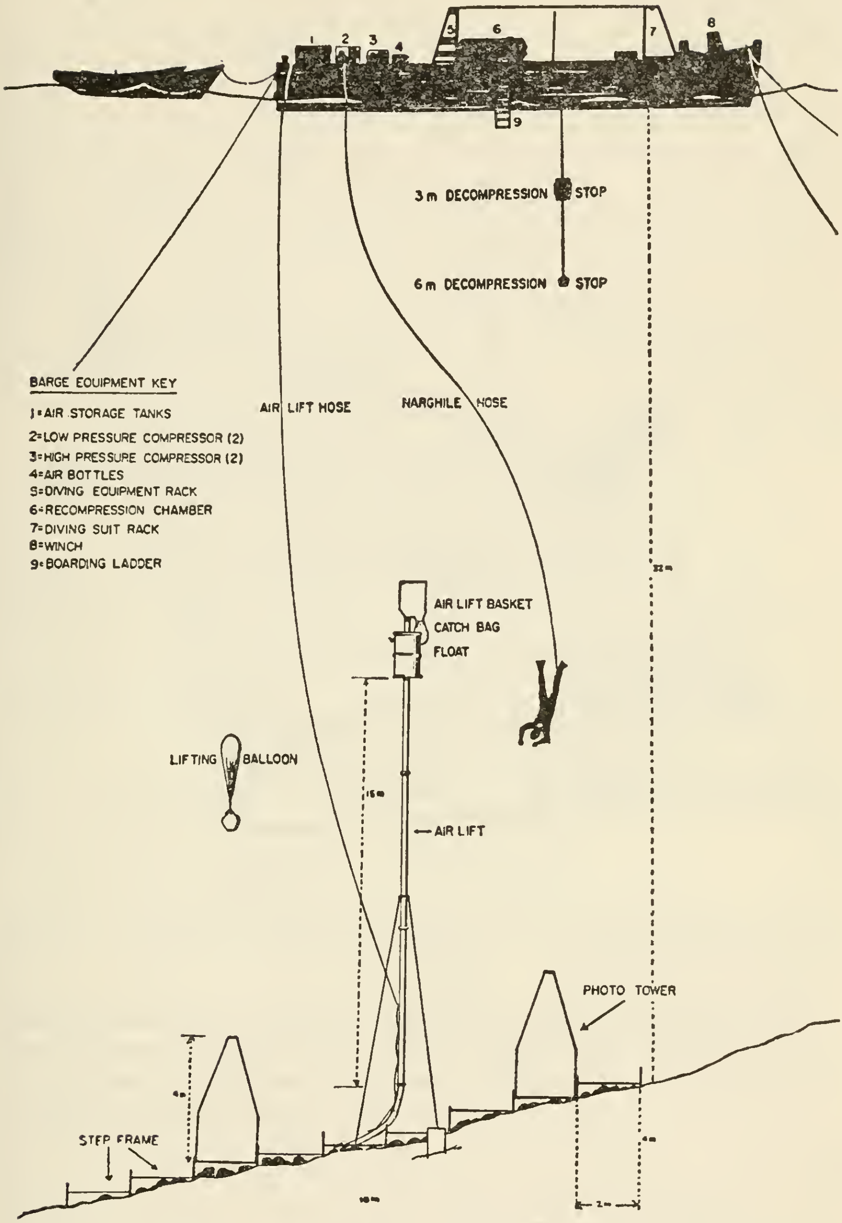

FIGURE 2.—Diagram of excavation of Byzantine shipwreck in 1962.

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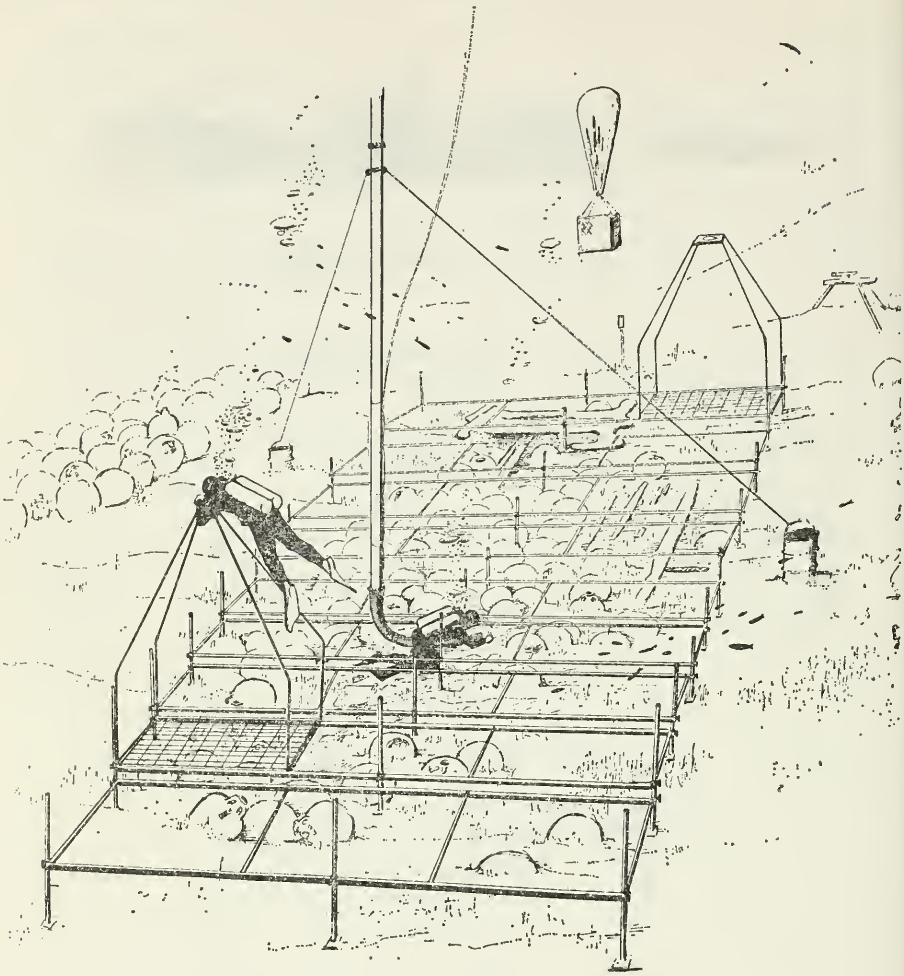

FIGURE 3.—Divers photograph and excavate seventh-century shipwreck at depth of 120 feet.

The Byzantine wreck is still being excavated, but already much has been learned. The hull was filled with a cargo of nearly 1,000 wine jars, mostly large globular amphoras, stacked in several layers. Across the bow lay six iron anchors with a seventh just off the starboard side. Toward the stern of the ship was found a flat, depressed area with scattered roof tiles that had covered the ship's cabin, and just aft of this was the crew's large water jar. Beneath the tiles were found the personal belongings of the captain. A small hoard of gold coins, all dated to the reign of the Emperor Heraclius (610–641), gives us a fairly solid date for the sinking of the ship and, therefore, dates the objects found in it. This would make the tableware from the cabin, including plates, pitchers, cups, bowls, jars, and cooking pots, probably the best-dated collection of pottery from that century. A set of silver-inlaid bronze weights, a whetstone and a stone mortar show how little the belongings of a sea merchant had changed in nearly two millennia. Thirteen terra cotta lamps, in a style often dated two centuries earlier, now provide a fixed date for others of their type. A censer and cross in bronze and a caldron and tray in copper also came to light. Two bronze steelyards for weighing cargo were found with chains and hooks in perfect condition. The bar of the larger was decorated at its ends with bronze animal heads, and its counterweight was a lead-filled bronze bust of Athena. A Greek inscription on this steelyard gives us the name of its owner: George Senior Sea Captain. A small glass medallion, with a cruciform monogram of the name Theodore, suggests the name of a second member of the crew.

All of these finds could have been turned up quickly by any diver, but much information would have been lost. The wood of the hull and scattered traces of wood from the rigging are now pinned in place on the packed sand of the seabed with thousands of sharpened bicycle spokes. A restoration, based on plans and sections of these pieces, will give the first information regarding the details of Byzantine ship construction. Because the positions of the fallen roof tiles had been plotted to the centimeter, and the angle at which the keel lies had been measured, it will even be possible to estimate the height and position of the cabin by measuring the distance between the tiles and the keel; the tiles themselves will give us the size of the cabin. All of the iron nails and spikes have long since disappeared, but iron-oxide shells remain; plaster casts taken of the hollow interiors, when the shells are sawed in half, reproduce perfectly the original shapes and sizes of the missing iron pieces.

Such work is slow and laborious, but well worth the effort. Almost any object made by ancient man was likely to have been transported by sea. Even the architectural members of temples and churches have been found as cargo on sunken ships. Seldom are archeologists offered material in such perfectly dated contexts on land, and seldom has the material been so well preserved against the destruction of men themselves. It is hoped that patience and care will be used in bringing these findings to light.

Plants in the Arctic-Alpine Environment[1]

By Stanwyn G. Shetler

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[With 12 plates]

Anyone who has ever climbed a high mountain to that windswept zone where forest shrinks and hesitatingly defers to tortured scrub; who then has scrambled on to fresh green meadows gay with splashy little herbs; and who finally has picked his way, perhaps on hands and knees, up treacherous rubble slopes to the last rock pinnacles and ledges where tiny drabas and top-heavy bellflowers cling so precariously to crevice and scree—*he* it is who knows the Alpine in all its splendor and spell with its hostile yet come-hither appeal. Poet, philosopher, naturalist, scientist, or layman—no one who has beheld the Alpine, whether on this continent or that, can fail to wonder how, amidst the primitive ferocity of this environment where life itself seems most improbable, a plant—any plant—not only survives but thrives. Yet year in and year out these alpine dwarfs, tender but tenacious, manage to stay alive and to reproduce their kind, though they lease life day by day or even hour by hour. Truly, this is biological intrigue of compelling dimension.

To those who have known the Arctic, however, the Alpine is but an overture. Forbidding though the elements of the Alpine may be, the Arctic can in all points be more hostile and unforgiving. The Alpine, if you will, is but a junior version of the Arctic. It is like a small enclave of the Arctic outside the Arctic, which has gained by altitude what it has lost by latitude—but not quite. The Arctic is a contiguous region around the North Pole, but the Alpine is fragmented into a thousand parcels, of greater or lesser area, held in common by all the higher mountains of the world, yet abruptly disjunct from each other because of the more moderate conditions of the intervening lower elevations. For a given latitude, the higher the mountain the more authentic its imitation of the Arctic, other

[1] Based on a paper read before the annual meeting of the Biological Society of Washington, June 7, 1963, as a part of a symposium on the "Adaptations of Plants and Animals to Their Environment."

factors being equal, and the nearer the Pole the lower the critical altitude need be. Thus while in Colorado one may need to scale to heights of 11,000 feet or beyond for characteristic Alpine, in northern Alaska near the continental limit of trees he may find such Alpine at scarcely more than 1,000 feet. The highest mountains of temperate latitudes can produce some pretty fancy imitations of arctic conditions, but hardly can surpass the best that the Arctic itself can produce.

From the days of the early Polar explorers, many of whom were unceremoniously swallowed up by the very land they came to explore, man has tried to solve the riddles of the Arctic—to fathom from the evolutionary pages of geological history and from the dynamics of modern-day pattern and process the conquest of life over perpetual ice and snow, perennial freeze and thaw, and eternal days and eternal nights. The conquest of man over this conquest of nature has only begun. Every year research in the Arctic is being broadened and intensified until today there is hardly a branch of science not represented in the Arctic quest.

Quite obviously the scope of my subject reaches far beyond the potential of this paper, or of any other single paper for that matter, and I shall not even attempt to cover all aspects of this topic. I will talk only *about* the subject without meaning to synthesize and summarize it. I will speak only of some aspects that have intrigued me in the course of my own research. Greater emphasis will be placed throughout on the Arctic than on the Alpine, because my own experience is primarily with the Arctic, and all the features concerned are more accentuated in the Arctic. Much of what I say about the Arctic can be applied equally though to a lesser degree to the Alpine, but the applications will not always be made here, at least not explicitly. The same holds for the Southern Hemisphere, about which nothing will be said here.

DEFINITIONS

To the astronomer the Arctic is that zone surrounding the North Pole, lying north of the imaginary and legendary Arctic Circle (66°30′ N. lat.), where on the shortest day the sun never rises and on the longest day it never sets. Mention the Arctic to a climatologist, and he thinks about low mean temperature and precipitation, early and late killing frosts, and a very truncated growing season. The geologist is likely to picture permanently frozen ground, soil polygons, and glaciers. We must turn to the botanist to whom the Arctic is a matter of vegetation, however, for a really vivid and in many ways more meaningful concept of the Arctic. He is quick to point out that vegetation is influenced by all the other factors and can be regarded as integrating them into one total response—the vegetation type.

When a botanist sets foot anywhere in the Arctic, he notices first and foremost the complete absence of orthodox trees. If any woody plants are present, they are nothing more than shrubs, usually very low and hugging the ground. There is the occasional patch of tall willows and alders, possibly achieving twice the height of a man, in sheltered gulches or on river bars and banks, but only in the lower parts of the Arctic. In the High Arctic even shrubs are scarce, and those present rarely exceed a few inches. Throughout the vast reaches of the Arctic as a whole, however, the botanist comes to expect very low shrubs (less than 18 in.), if any. The herbaceous vegetation may form a rather continuous mat or heath, or in the High Arctic it may be confined to scattered patches on barren rock and gravel slopes and plains. This treeless vegetation type is what the botanist calls "tundra," from the Finnish word "tundren," meaning treeless rolling plain; and the vast circumpolar zone without permanent tree growth, sandwiched between the boreal coniferous forest and the polar icecap, may be designated by the proper name, *the* "Tundra." In fact, to the botanist the Arctic *is* the Tundra.

While botanically the word tundra may connote primarily a type of vegetation, the Finnish word suggests also a type of landform, which is perhaps equally as important in giving us a concept of tundra as is the vegetation. This is a landform of flat or rolling plains underlain by frozen ground, dominated by bog soils or lithsols, dotted by numerous lakes and meandering rivers, and tending in many places to be quite wet and almost spongy at the surface. Patterned ground and, close up, tussocky or hummocky microrelief are characteristic. In some respects, the Tundra, in its vegetational and geological features is like a gargantuan bog, only the water beneath is permanently frozen. Above all, the Tundra always strikes me, wherever I see it, as incomparably vast and bleak—bleak, that is, until I am able to get my feet down among the tussocks and to see the many microcosms that compose the whole.

The Tundra I have depicted is of course a stereotype, which is well illustrated by the pictures in plate 3. These photographs, taken near Point Barrow, Alaska, aptly convey a characteristic expanse of tundra on Alaska's Arctic Coastal Plain. This is textbook tundra where the vegetation forms an almost continuous heath cover, but it is not characteristic of large parts within the Arctic. As already mentioned, the higher one goes into the Arctic the sparser becomes the vegetation, and the land might more properly be termed "rock desert." This is true in general of the Canadian Arctic Archipelago, which has been the subject of some very interesting papers by the distinguished Canadian botanist A. E. Porsild (1951, 1955, 1957). Some would restrict the term "tundra" entirely to the continuously vegetated portions of the

Arctic and exclude the barren grounds of the far north. For our general purposes, however, we will use the term broadly, and the idiosyncrasies of the Tundra will be largely ignored.

Let us return to the Alpine for a botanical look. By simple extension of what has already been said about the Arctic, we can now go on to say that the Alpine comprises the *treeless zone* of high mountains. Alpine vegetation is in many ways quite tundralike, as anyone who has seen both the Alpine and the Arctic can testify, and, in fact, some plant ecologists go so far as to use the same term, Tundra (or Tundra Formation), for arctic-alpine vegetation in general, calling the one "Alpine Tundra" and the other "Arctic Tundra" (Oosting, 1956). We cannot digress to argue the merits of this view or any other except for a few comments. Profound differences separate the Arctic from the Alpine, as anyone who has done research in both knows, and in any thorough-going scientific analysis these differences could not justly be ignored and glossed over by one simple terminology. Yet in the worldwide context of climates, floras, and vegetation one is amply justified, I believe, in thinking singularly of *one* environment, *one* flora, and *one* type of vegetation common to both the Arctic and the Alpine, as I am doing in part here. Without other modification, however, I will use the proper term "Tundra" only for the Arctic, as in widespread usage.

In the final analysis we are not so much concerned here with a carefully circumscribed area as with a concept. Whether, for example, we define the Arctic by latitude, landform, isotherm, or vegetation type, all definitions tend to converge on roughly the same area around the Pole. What is far more crucial than a specific area is the concept of environment and vegetation in concomitant transition. Relative to organisms of ordinary tolerances, the environment gradually becomes more rigorous and hostile as one moves poleward or upward from sea level, and this transition is accompanied by gradual changes in the vegetation toward ever more hardy types. The opposite ends of the transitions are strikingly different, but the changes in between are for the most part too subtle to permit the delineation of sharp boundaries between one zone and another. If, however, a definition is necessary, then let us think simply of the *Arctic* as being *north of treeline* and the *Alpine* as being *above treeline.*

Treeline, by which is meant here the *upper limit* of continuous forest, is seldom a sharp line either in the Alpine or the Arctic, at least when seen close up. Unless there are very steep or abruptly discontinuous changes in topography or climate, the proverbial tree- or timber-*line* is more likely to be a band or broad zone, which in the Arctic may be many miles wide, where trees only gradually thin out from forest to scattered clump and finally give way to open meadows and tundra. Here there is a certain tension between forest and tundra, where the trees can't decide, as it were, when to give up. This vacillation is depicted well for two Alpine areas in some of the pictures of plates 1 and 8.

THE ENVIRONMENT

Frigid temperatures, low precipitation, high winds, permanent frost, and a very asymmetric annual light regime are a few of the problems that confront plants of the Tundra. Add to this the contingent factor of an extremely short growing season, and you have quite an order for any plant species to tolerate.

If there is any one fact that virtually everyone thinks he knows about arctic-alpine regions, it is that the climate is cold—*very* cold. The average person pictures the Arctic as a place of perennial snow and subzero weather, barren and virtually lifeless—in short, nothing but an icebox. One cannot deny that the Arctic can be very cold and very barren, but this "icebox" image grossly distorts the true picture and hides the real significance of temperature as a variable in the arctic-alpine environment. Throughout vast parts of the Arctic there comes a perfectly orthodox shirtsleeve summer, which though abbreviated permits a remarkably diverse and luxuriant growth of plants.

Temperature is critical in the arctic-alpine environment both for its low extremes and low means, although perhaps more so for the latter than the former. We can gain some insight into this variable by examining a specific case. The data on climate which follow have all been drawn from the U.S. Department of Agriculture's Yearbook of Agriculture for 1941, Climate and Man. Despite the date of publication, there is no reason to believe that the overall picture has changed over the past 23 years.

Let us examine in some detail the conditions at Point Barrow, Alaska, which lies north of 71° N. latitude, well within the Arctic by any definition, and about as far north as one can get on the North American Continent. Over a 25-year period the average temperature for the warmest month, July, was 40° F., only 8° above freezing, and for the coldest month, January, −17° F. The recorded minimum over this period was a frigid −56° F. and the maximum a balmy 78° F. Thus the average range here is from −17° to 40° F., or 57°, which is more or less typical for the Arctic coast of Alaska in general and for many other areas throughout the Arctic. This range is of course less than half as great as the 134° range between the 25-year extremes. Quite clearly arctic plants have got to exist on a relatively low annual heat budget, when the temperatures of the warmest month do not average more than 40° F. In fact, at Barrow they drop below zero an average of 170 days a year, almost half the year, and some snow falls in every month. Note that I said *below zero*, not merely below freezing. But, while summer temperatures average dangerously close to freezing, winter averages are milder than one might expect, and there obviously cannot be many −56's coming along to allow such a relatively mild January mean of −17° F. Nonetheless, even a single −56° cannot be ignored as a factor in the destiny of arctic plants.

Barrow gets neither the most extreme nor the mildest temperatures of the Arctic, but on the average it is reasonably typical. Despite increasing latitude, average temperatures are remarkably uniform throughout the Arctic, owing largely to the ameliorating effects on all sides of the polar sea. The average temperature for the warmest month is commonly between 40° F. and 50° F., and in fact the 50° F. isotherm is often taken as the climatological southern limit of the Arctic.

Temperature is an extremely capricious variable anywhere in the arctic-alpine environment, and its effects are not all measured by means and long-term extremes. Drastic short-term or sustained fluctuations during the critical growing period are common fare year in and year out for arctic-alpine plants, which must be adapted to withstand these hazards. In the Arctic of Alaska I have frequently seen the temperature fluctuate 40° F. or more in less than 24 hours, going in one case from near 80° F. down to very near freezing. Porsild (1951) recounts a fascinating experience he had east of Great Bear Lake, northern Canada, one April, watching the frost play with a clump of Richardson's willow (*Salix richardsonii* Hook.). During a brief thaw the buds swelled to the point where the catkins were ready to expand, even while the basal parts of the clump were buried in 3 feet of ice and snow. Then, abruptly, freezing temperatures set in for another 3 weeks, and the buds froze solid. When the final thaw came, they began where they had quit and went on quickly to flower and produce seed, apparently unaffected by the frigid interlude. He tells also of one July night in the Yukon when he saw the large purple flowers of *Epilobium latifolium* L. freeze solid like wax flowers, only to thaw out again next day looking no worse for having frozen. One need not reflect long on his own experience to realize that these are not ordinary tolerances.

Along the Arctic coast fog and cloud cover are significant factors in regulating surface temperatures during the growing season, and they can be responsible for very rapid fluctuations. As anyone knows who has ever been to Barrow, for example, the skies can be bright and sunny one moment and almost the next be blanked out by a "soupy" fog. In a land of frozen ground, where the surface holds little residual heat, temperatures spiral downward rather dramatically sometimes when the skies become even partially overcast.

The arctic-alpine environment in general scarcely has what might be called an annual *safe* period, insofar as frosts are concerned. There may be an annual period during which *on the average* frosts do not occur, but an occasional frost may descend upon the plants anywhere at any time even in the dead of summer. Over an 18-year period the average frost-free period at Barrow was July 4–21, for an average growing season of *17 days* a year! Doubtlessly, the *effective* growing season is considerably longer, yet we get some idea of just how truncated the Arctic summer can be for plants. On the basis of the few comparative data available, we can safely conclude, I believe, that the growing season is no longer than 50 days throughout a large part of the Arctic, and it is often much shorter. Still, this can be an adequate season for the arctic plants, which are physiologically adapted for getting the reproductive cycle over with a rush. The ubiquitous purple saxifrage (*Saxifraga oppositofolia* L., pl. 5), for example, can begin growth and set good seeds within a month (Porsild, 1951). As for the Alpine, we know even less about the growing season from systematic weather records, but we do know from casual observations alone that late-lying snows reduce the effective growing season in many alpine situations to approximately that of the Arctic.

Subsurface temperatures in most of the arctic region are continuously below freezing from one year to the next, and the ground is permanently frozen. This soil frost, called "permafrost," extends from the surface or near it, depending on the season, downward several feet to hundreds of feet; in places the permafrost zone is more than 1,000 feet deep. Each summer the top few inches to 2 or 3 feet—in alluvial sites to 6 or 8 feet—thaw, and the average annual depth of thaw establishes the nature of the vegetation that can colonize the area. Permafrost is impenetrable to plant roots, and the annual frost-free layer must serve as the effect root zone where water and mineral exchange can occur and roots can take anchor. This zone is usually very narrow, and deep-rooting species are harshly selected out, which surely is one important reason why trees cannot establish themselves on the Tundra. Deeper thawing in alluvial sites, where the soil is coarser, explains perhaps why taller shrubs and certain typically deeper rooted plants, such as some legumes, are often found here.

The formation of "soil polygons" is one of the most celebrated geomorphic phenomena in the Arctic. Their occurrence is widespread in permafrost areas, and despite much study their development is still a matter of controversy. From a high vantage point, as from a plane, they are most conspicuous, imparting to the land surface a polygonal pattern like giant mud cracks (pl. 4). They can be described as a series of mounds or dishlike impressions, usually at least 25 feet or more on a side, separated from each other by a reticulum of more or less rectilinear ditches. Mounded polygons are called "high center" polygons, and hollowed out ones "low center." The basins of the latter type usually hold a few inches to several feet of standing water (pl. 4). The ditches of both types also usually contain at least a little standing water. In very general terms, soil polygons can be said to arise through the differential effects of perennial freezing and thawing in the surface layers. Convection movements churn and sort the particles into a more or less regular pattern. Some kinds of polygons are related to the development of discontinuous ice lenses in the subsoil. Whatever their precise geomorphic origin and significance, they are extremely significant to plant growth in that they create considerable microrelief in many areas otherwise flat and thereby create a greater diversity of habitats. Consequently, xerophytic and hydrophytic species can exist side by side.

Let me digress for a moment to emphasize the extreme importance of microrelief in general to the development of vegetation in the Arctic. Vast areas of tundra are essentially flat (pl. 3) and poorly drained, and the slightest difference in elevation, even a few inches, can change the moisture-holding capacity and drainage characteristics of the soil toward a more xeric condition. Often the texture of the soil is coarser on the mounds too. Consequently, on the drier tussocks and hummocks one finds a slightly more xerophytic vegetation. If the differences in elevation are pronounced, the differences in vegetation may also be quite pronounced. Phenological traits are frequently affected. The wetter the soil the longer it takes in early summer for the soil temperature to warm up sufficiently for growth, and I have seen again and again the same species in full bloom in the depressions but with nearly mature fruits on the adjacent mounds, with scarcely more than a 6-inch difference in relief. This can only be due, I think, to a relatively slight differential in soil moisture and/or temperature.

Frost action leads to still other phenomena of significance to plants. On medium-to-steep slopes broad bands or lobes of surface material, rubble or turf, tend to slump during the early thawing period when the soil is saturated. This is one of several phenomena referred to as *solifluction* (pl. 10, fig. 1). The hard upper surface of the permafrost zone functions like a shear plane, and large masses of surficial material, consolidated and unconsolidated, simply creep slowly downslope under their own weight. After a period of years, sizable ruptures may be created, where primary ecological succession can begin again. Whole turfs and herbmats may be displaced downslope, but the movement is usually slow enough that little if any significant damage is suffered, apart from the actual displacement itself.

On the higher slopes and plains of the Tundra, Arctic and Alpine, annual freezing and thawing may eventually have almost violent consequences for the soil, heaving it upward and rupturing the surface in small patches (pl. 4, fig. 2). These "frost boils," as they are called, keep the surface soil churned up and unstable for plant growth.

One of the most curious aspects of the Arctic environment is that while water is almost universally evident on the Tundra in bogs, pools, lakes, and streams, the climate is basically arid, and water is frequently a limiting factor for plant growth. Mean annual precipitation is extremely variable but seldom exceeds 20 inches, except for certain localized zones especially in mountains. Probably more than half of the vast Arctic gets 10 inches or less, and Barrow averaged only a little over 4 inches a year for a 23-year period. This low figure compares favorably with the annual rates for many warm temperate desert situations. Summer rainfall can account for as much as half of the annual precipitation in the Arctic, but snowfall commonly contributes the greater portion.

Under conditions of good drainage and rapid drying, such a low precipitation would give rise to lifeless desert. What prevents this in large part in the Arctic is the presence of permafrost, which keeps surface water from percolating downward out of the root zone. Also, the land is very flat and geologically youthful, and drainage patterns are generally erratic and poorly developed. Most of the annual precipitation accumulates in depressions, large and small, and stagnates, forming bogs, wet meadows, pools, and lakes in very large numbers. On the other hand, evaporation and transpiration are relatively high owing to frequent winds and generally low humidity, and a plant must have a ready water supply in order to survive. The abundant hummocks, terraces, ridges, and low slopes of the Tundra often become extremely xeric after the spring thaw and brief initial saturation period, and here only plants with adaptations not unlike those required by desert plants can grow. As noted earlier, the higher one goes into the Arctic the more desertlike the habitats become.

Despite popular misconception, the Arctic is not generally deluged each year by large deposits of snow. Average annual snowfall decreases as one moves northward on the continent, and in arctic regions it is usually less than 40 inches. This is about equal to the *minimum* average fall for the State of Pennsylvania and about half the *maximum* fall! Insofar as the plants are concerned, then, the nature and distribution of the snow, not the quantity, are the significant features. In winter, except for depressions and leeward slopes, the mantle of snow is very thin over most of the Tundra, and large areas get swept completely bare by high winds. The plants are afforded little if any insulation over these enormous areas and must be adapted to withstand the freezing winds that sweep the tundra slopes and plains. The very cold temperatures cause the snow to be dry and gritty, which in the wind does considerable damage to exposed plants by mechanical abrasion. In summer, a light snow may fall at any time and linger for a few minutes to a few days, and the plants must be hardy enough to withstand such chilling cloaks (pl. 7).

Snow does accumulate, of course, in sheltered places and slight depressions, where it will linger, depending on its depth, well into the summer season and much beyond the general snow cover, which disappears almost overnight once thawing begins. On river flats and flood plains large fields of ice will accumulate (*Aufeis*) and persist sometimes well into August or even until new ice begins to form. I remember particularly such a large icefield along the outlet of Old John Lake, in the Brooks Range of eastern Alaska, back in 1957, which was still very extensive in early August. Here, at the southern limit of the Arctic, pussy willows (*Salix alaxensis* (Anderss.) Cov.) and the early spring purple saxifrage (pl. 5) were just bursting into flower in the wake of the retreating ice, in effect just emerging from winter even though the calendar said summer was about over for the Arctic. The immediate environs of a lingering snowbed or icefield are always choice spots for visiting botanists to find; such a spot is usually a mecca for late-blooming stragglers of many species that have long since gone to fruit elsewhere.

There are basically two types of snow accumulations: the *snowbed* (or snowbank, icefield) and the *snowpatch.* Snowbeds form in large depressions or on leeward slopes and usually are several to many feet deep at peak accumulation. Seasonal snowbeds are common sights both in arctic and alpine situations, but they are particularly familiar to many of us in the Alpine (pl. 6). As a snowbed melts, it creates a saturated flush area along the lower margins, where plants emerging from the overburden of snow quickly burst into flower. With increasing radius from the snowbed, the stage of development becomes later and later, so that within a snowflush area one can usually find a given species in all stages of development from bud to fruit. Because of the abundant and steady water supply snowflush areas generally support rather luxuriant herbmats, but the species must be adapted for cold soil temperatures, caused by the meltwater, and very short growing seasons. Obviously, a plant that does not emerge from under the snow until mid or late summer has got to go through its reproductive cycle in high gear.

Snowpatches are relatively small and shallow accumulations in slight tundra depressions, which melt very rapidly in the spring only a little behind the general snow cover. They leave saturated soil patches in which lush turf or herbmat develops. These patches stand out conspicuously from the surrounding drier areas.

The Arctic suggests glaciers to many, yet glaciers are a relatively insignificant factor to plants in the present-day Arctic as a whole. Except in Greenland and in parts of the Arctic Archipelago, the primary significance of glaciation lies in its historical role in shaping the Arctic as we now know it. Most of the present-day Arctic is simply too arid and flat for large accumulations of ice. There are, however, scattered montane glaciers of local significance in the Low Arctic. Nonetheless, one is conscious of the recent geological past in this youthful land where in many instances primary ecological succession has only just begun since the retreat of Pleistocene ice. In the Alpine, on the contrary, glaciers and glaciation are still a present factor in the environment. This is particularly evident in subarctic Alaska, where receding glaciers annually continue to bare new land surfaces and moraines for plants to colonize (pl. 7, fig. 1).

Snow and snow accumulations *per se* are considerably more important in the Alpine than in the Arctic, at least the nonmontane parts of it. Annual snowfall is usually much heavier, to be measured in feet not inches, and this makes not only for a deeper accumulation, hence later thawing, but also for much greater mechanical hazards. Heavy deposits may crush woody plants, especially at timberline, and violent snowslides may sweep whole slopes clean of vegetation in one swift moment, not just once, perhaps, but again and again. Frequent snowslides apparently account for some large open areas at timberline that might otherwise have been overgrown with trees (pl. 6, fig. 1).

Flooding can be an important influence in the development of vegetation both in the Arctic and the Alpine, but particularly the former. Annual spring thaws send torrents of meltwater rushing down gulches and ravines, which in the Arctic feed large rivers that flood the tundra slopes and plains, sometimes altering the landscape markedly. During unusually rainy summers, as our party experienced in the Alaskan Arctic in 1963, flooding may be prolonged and repeated. While camped along the lower reaches of the Noatak River (northwestern Alaska) in late June and early July, in less than a week we watched that mighty river rise ominously to a flood stage of more than 5 feet above normal. Virtually every flat and gulch along the river was inundated, as the water backed far up into the tributaries. Many willows, legumes, and other plants in full flower became partially or wholly submerged by the icy water not many degrees above freezing and remained submerged for several days to nearly a week before the flood completely subsided. One small patch of mountain avens (*Dryas integrifolia* M. Vahl; very similar to other species in pl. 9) stood completely buried in about 6 inches of clear cold water for nearly a week without showing any apparent damage; all the while its big white flowers looked as fresh as ever. It was as though they and many other flowers had been put in the refrigerator for a week to prolong their life, and outside of a little silt deposited on the leaves and flowers the plants looked no worse for having been submerged. Nonetheless, even a week of arrested development during the growing season could be crucial in preventing seed development.

Wind, desiccating in summer and freezing in winter, is a relentless force in the arctic-alpine environment, influencing both the form and function of the plants. Tender young shoots have a veritable gantlet to run in order to become established, especially if they project any distance at all above the protection of the surrounding vegetation. At timberline, the low trees and shrubs often betray this ceaseless pounding of gusts and gales by pointing all their limbs in the direction of the prevailing winds (pl. 8), and arborescent growth here is in general likely to be gnarled and dwarfed from winds (pl. 8). Instead of growing vertically, the plants, plied by the winds during their tender years, sprawl horizontally over the meadows and screes. This prostrate twisted habit, typical of tree limit anywhere, is sometimes called *Krummholz* after the Germans. Beyond tree limit *all* growth, herbaceous or woody, is dwarfed except in sheltered spots, and we know from horticultural and ecological research and experience that the dwarf habit of many arctic-alpine species is at least in part genetically controlled. This habit surely must be an adaptive response in large part to the factor of wind. I must hasten to append the caution, however, that constant strong winds are not universal in the Arctic, and therefore the dwarf habit cannot be so easily explained as to attribute it simply to wind.

Everyone knows that the Arctic is the land of midnight sun. Indeed, to the plant the annual light regime is very bizarre. Each summer for several weeks or more the days last for 24 hours and light is continuous. In view of the short summer, it is doubtful that any vascular plant could propagate itself by seed if it were not for this additional daily insolation. In large part the longer days compensate for the shorter season. Light intensity is not uniform throughout the 24-hour day, of course, but falls off sharply at night. The nights are often like an extended early twilight or early dawn. Owing to the more oblique angle of incidence throughout the higher latitudes in summer, the sun's rays must pass through a thicker layer of atmosphere than in temperate and tropical regions, and they strike the land surface with less intensity, hence less heating capacity. As one might guess, the longer duration, lower intensity, and somewhat different quality of the light have definite effects on the plants. Quite a few arctic plants are "long-day" plants; this means that they require relatively long days and short nights for flowering and cannot be brought into flowering at lower latitude without supplementary light. Rosette-forming species are very common in the Arctic, and there is some evidence to suggest

1. Timberline meadow (subalpine) in saddle at 8,500 feet on Joseph Mountain in the Wallowa Mountains of northeastern Oregon. Owing probably to different exposures or soil conditions, forest extends much higher on the background ridge than into foreground saddle.

2. Alpine ridge just east (to the right) of meadow in fig. 1 (only slightly higher than meadow). A few low trees straggle to summit on east side. For close-up view of rubble slope in center of picture, see pl. 2, fig. 1.

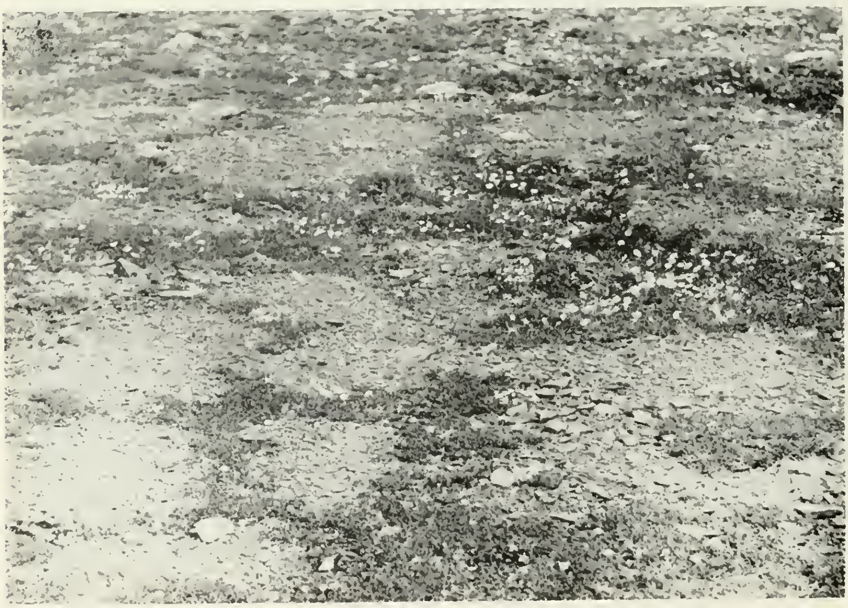
1. Rubble slope with only scattered clumps of vegetation on the alpine ridge pictured in plate 1.

2. Boulder field high on north slope of Oyukak Mountain, 3,500 feet, overlooking the Upper Noatak River Valley in the vicinity of Lake Omelaktavik, Alaska. This area is wholly within the Arctic Tundra Zone in the western Brooks Range, South Slope.

1. A typical expanse of tundra on the Arctic Coastal Plain of Alaska, just west of Point Barrow. Characteristically, the landscape is flat and dotted with numerous lakes as far as the eye can see. Aerial photograph taken at about 2,000 feet.

2. Closeup view of Arctic Coastal Plain tundra south of Point Barrow with a continuous grass-sedge heath. The typical low, hummocky microrelief of arctic tundra is evident. Here, in early July 1959, flowering had hardly begun.

1. Aerial view of low-center soil polygons on the Alaskan Arctic Coastal Plain west of Point Barrow. Their basins are water-filled (dark), but some of the ponds are nearly or quite choked off by vegetation (light). In foreground are parallel tracks of a winter "cat" trail, made by tracked vehicles like the "Weasel." Taken from altitude of about 100–200 feet.



2. Frost boils on alpine rock-desert along the Steese Highway at about 3,000 feet on Eagle Summit, east-central Alaska. Vegetation patches are mainly mountain avens (*Dryas*) and a dwarf willow (*Salix phlebophylla*). Taken in late June 1957.

1. The very early purple saxifrage (*Saxifraga oppositifolia*), an extremely wide-ranging arctic-alpine species. Observe the highly telescoped stems and consequently much-compacted leaves. Plants slightly larger than natural size. Photograph by James Warren.

2. A common dwarf arctic willow, *Salix phlebophylla*, which projects only a few inches above the ground and tends to form large mats. Here the mature catkins, scarcely larger than a man's thumb, can be seen beginning to shed their cotton-tufted seeds (Eagle Summit, late June 1957; see pl. 4, fig. 2). Notice the scalloped leaves of *Dryas octopetala* in the background.

1. Deep snow still covers timberline meadows in Logan Pass, Glacier National Park, Montana, on June 1, 1957 (altitude about 6,000 feet). The dead limbs and trees are likely the result of perennial wind and snow damage.

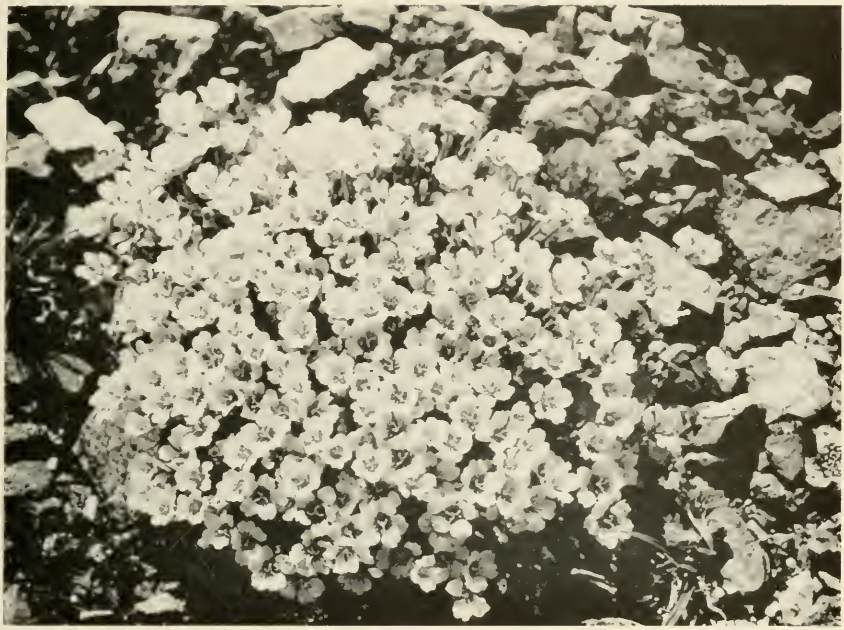
2. Alpine snowbeds on August 1, 1960, near highest point (ca. 12,000 feet) along highway through Rocky Mountain National Park, Colorado.

1. Worthington Glacier in the Pacific Coast Range just north of Valdez, Alaska. Notice how close to the terminus of the glacier patches of vegetation have invaded the new end moraine.

2. Alpine flowers on Eagle Summit, Alaska, nearly smothered while in full bloom by light snow on June 21, 1957. Most prominent species here: Arctic poppy (*Papaver radicatum* Rottb.) and louseworts (*Pedicularis lanata* C. & S., *P. oederi* Vahl). Photograph by Gene Whitaker.

1. A tortured spruce sentinel near the upper limit of trees on Snowy Range Pass (10,800 feet) in the Medicine Bow Mountains of southcentral Wyoming, tellingly pointing all its branches in the direction of the prevailing winds. Here can be seen the interdigitating of forest and alpine and a tendency toward the development of typical timberline *Krummholz.*

2. The Arctic blueberry, *Vaccinium uliginosum* L., is an abundant low shrub of the Tundra in all quarters of the Arctic. The fruits are often quite oblong as in this picture (about one-half life size).

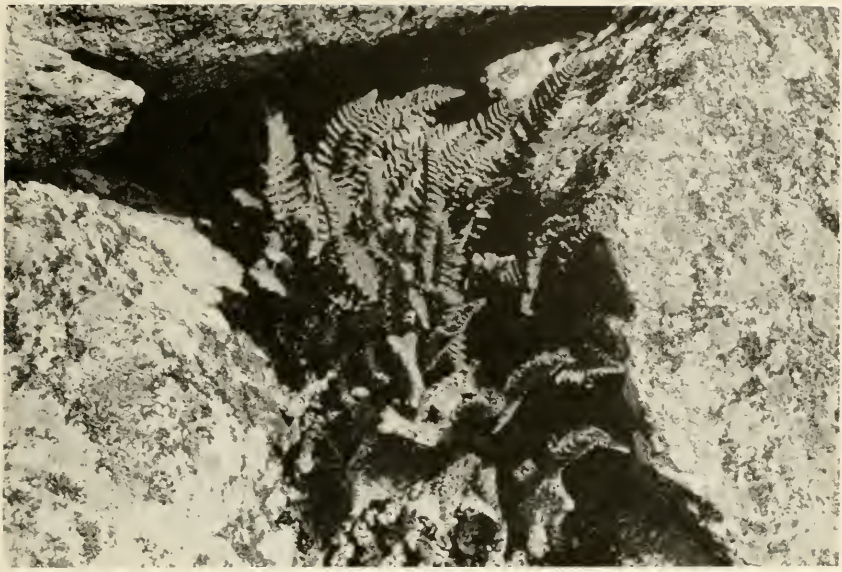


1. The white-flowered Arctic sandwort (*Arenaria arctica* Stev.), belonging to the chickweed family (Caryophyllaceae), is a very showy species of arctic and alpine rock-deserts. Above-ground vegetative parts are minimal.

2. Mountain avens (*Dryas octopetala* L.), a dwarf mat-forming shrub (chamaephyte), is one of the most widespread arctic-alpine species. A member of the rose family (Rosaceae), it inhabits dry heaths, herbslopes, talus, barrens, etc., and has large showy white flowers and almost no upright stems.

1. An alpine rock desert on Eagle Summit, Alaska, during the peak of flowering (late June 1957). Here in this veritable rock garden, the author is seen collecting Arctic sandwort and mountain avens (see pl. 9), the dominant species. Observe the hummocky solifluction slope in the background.

2. A typical arctic tundra meadow of cottongrass tussocks ("niggerhead meadow") on rolling foothill slopes along the lower Noatak River in the western Brooks Range, Alaska. Late in June 1963, the tufts of the mature white bristles ("cotton") of the fruiting spikes are dominating this landscape like fresh-fallen snow. Note the persisting old snowbeds in the background.



1. The hardy, coarse-textured fragrant shield-fern, *Dryopteris fragrans* (L.) Schott., is a nearly ubiquitous inhabitant of sheltered ledges and crevices of rock outcrops in some sectors of the Arctic and Subarctic, as for example Alaska. Characteristically, the sheltering rocks are covered with crustose and flattened foliose lichens.

2. The creamy white *Cetraria cucullata* (Bell.) Ach., an antler like fruticose lichen, is one of the many species of lichens that everywhere help to make up arctic tundra heaths. (Slightly under natural size.)

1. Labrador tea (*Ledum palustre* L.), a low shrub with white flowers of the heather family (Ericaceae), is one of the best known and most characteristic species of bogs, muskegs, and tundra in boreal and arctic regions. This particular race (subspecies *groenlandicum* (Oeder) Hult.) is confined primarily to bogs and muskegs south of the continental forest limits. A highly dwarfed race occurs on the Tundra. Note the leathery, revolute (incurved) leaves. (About one-half natural size.)

2. The pink-flowered bog rosemany (*Andromeda polifolia* L.) is another circumpolar species of the heather family that ranges widely in bogs, muskegs, and tundra across boreal and arctic regions. Its leaves are also prominently revolute and leathery. (About life-size.)

that the rosette habit is at least in part brought about by the arctic type of light regime.

In the Alpine the light regime is quite different in temperate regions. Owing to the thinner high-altitude atmosphere, the light is both very intense and high in ultraviolet rays. The days are not abnormally long, of course, and the sun is more directly overhead.

THE PLANTS

Every time I step from a "bush" plane into a different part of the Arctic or climb to the Alpine of a new mountain, I am impressed anew with the basic uniformity of their habitats and vegetation. To the biologist, botanist and zoologist alike, it has come to be axiomatic that one encounters fewer and fewer species, which at the same time become more and more widespread, as he moves from tropical to temperate to polar regions or, on a smaller scale, from sea level to higher elevations. Thus, the botanist finds that the arctic-alpine flora is not nearly so diverse and rich in species as temperate and tropical floras, and it has a much smaller endemic element. Arctic-alpine species tend to be circumpolar. This uniformity of the flora clearly reflects the almost tedious uniformity of the environment, which is generally so harsh and hostile to plants that only a small percentage of the earth's flora has been able to invade it. Once successfully adapted, a species is then able to spread throughout the peculiar arctic-alpine environment, and many species have done just that.

In order that we might get a bird's-eye view of the plants in the arctic-alpine environment, I will attempt in the ensuing discussion to touch briefly on some ecological, morphological, floristic, taxonomic, and geographic aspects.

LIFE ZONES AND CLIMAX FORMATIONS

The correlation of certain plants and animals with altitude on the one hand and latitude on the other was first carefully examined by C. Hart Merriam, who, as the result of a biological survey in the San Francisco Mountains of Arizona in 1889, formulated his classic "Life Zone" concept and certain climatic laws to explain it. He was able to recognize rather distinct horizontal vegetation belts on the mountain slopes, which graded from one into another with increasing altitude. He postulated that this rather distinct zonation of the vegetation was due to a climatic zonation, and he went on the generalize that this was not a local phenomenon but that the same zones in the same unique sequence occurred on all high mountains. Depending on the latitude, the whole sequence was shifted up or down in altitude. Further, he proposed that some of these zones had latitudinal counterparts. His zones, from highest to lowest, were: Arctic-alpine, Hudsonian, Cana-

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dian, Transition, and Upper and Lower Sonoran. His latitudinal counterpart for the Arctic-alpine Zone was the Tundra. In this zone, presumably, the climate did not permit the permanent development of trees. He was particularly interested in explaining the distribution of birds and animals on the basis of these vegetation zones.

While Merriam greatly oversimplified the geographic relationship of plants and animals to their environment by focusing only on climate, he is to be credited, nonetheless, with making the first serious attempt to interpret *bio*geography climatically. He was a bit short sighted, however, when he wrote, "It appears, therefore, that in its broader aspects the study of the geographic distribution of life in North America is completed. The primary divisions and their subdivisions have been defined and mapped, the problems involved in the control of distribution have been solved, and the laws themselves have been formulated." His "laws" have never enjoyed wide acceptance, but his Life Zone concept and terminology are still quite useful for general descriptive ecology, especially in montane areas for which, after all, they were first formulated.

The well-known plant ecologist F. E. Clements was also greatly impressed by the correlation of vegetation and climate, and he developed a whole new school of ecology, founded on the now classic concepts of "succession" and "climax." These concepts had from the beginning a far wider application and validity than Merriam's Life Zone concept, and they are still widely held despite rather severe criticism in recent years by phytosociologists. In Clements' view, there was on any newly exposed land surface, such as a glacial moraine, a more or less orderly succession of vegetation types from the accidental first colonizers through to an ultimate mature type, which attained a dynamic equilibrium with the regional climatic regimen and was subject to no further important changes so long as the climate didn't change. This *succession* was regarded as a very long-term process that could only culminate after the climate had succeeded in bringing about general physiographic uniformity, including a mature soil. Persistent local variations in soils or topography, for example, could arrest the plant succession at any given stage and put off the the arrival of the final one indefinitely. The final stage was termed the *climax*, and it was postulated by Clements that those regions with the same climate ultimately developed the same vegetation climax. The major plant formations of the world, such as the coniferous Boreal Forest and the Tundra, were seen, then, as climax types. Thus, the so-called "Tundra Formation" represents a climax without trees, which presumably will always develop under the influence of the arctic-alpine climate.

THE TUNDRA FORMATION—AN ECOLOGICAL LOOK

Our attention is drawn first to the general *physiognomy* or structure of the vegetation—the "gross anatomy," if you will, of the tundra vegetation. Closer examination will bring us secondarily to the nature and composition of the individual plant communities.

Every mature plant has a particular habit or shape and mode of growth that we call its "growth-habit" or "growth-form." It may be woody or herbaceous, tall or short, erect or prostrate, bushy or fastigiate, annual or perennial, etc. Growth-form may vary greatly within the same species and habitat; yet there is a distinct tendency for the members of a given species, sometimes of a whole genus or family, to fluctuate around an *average* highly characteristic form. This more-or-less stabilized, presumably growth-form is called the "life-form" of the species. (Some species encompass more than one race, and the races may have different life-forms.) It represents a long-term genetic compromise with the environment. Raunkiaer called the life-form a "biological type."

Various systems have been devised for classifying plants according to their life-form. The ancient Greeks already used the obvious distinctions between trees, shrubs, and herbs to classify plants. In modern times, a more refined system has been proposed by the late Danish botanist Raunkiaer, based on the position of the "perennating" (renewing) bud. It has been variously modified by other authors, but the usual classes are essentially Raunkiaer's:

1. *Phanerophytes.*—Renewal buds on shoots at least 25 centimeters above the surface of the ground; mostly trees or shrubs.
2. *Chamaephytes.*—Renewal buds on shoots between ground-level and 25 centimeters high; perennial herbs and some undershrubs.
3. *Hemicryptophytes.*—Renewal buds at ground level or within the surface layer of the soil; perennial herbs.
4. *Geophytes.*—Renewal organs (bulbs, tubers, rhizomes) well buried in the soil; biennial or perennial herbs (subclass of Cryptophytes).
5. *Hydrophytes.*—Water plants, whether anchored to the bottom or not, except free-floating or swimming types; tends to cut across other types and is often omitted (subclass of Cryptophytes).
6. *Therophytes.*—Annuals, completing entire life cycle in a single growing season, surviving unfavorable periods as seeds or spores.

Raunkiaer used this system to derive life-form "spectra" for various floras, as a whole, converting the number of species in each of the life-form classes into a percentage of the total sample. As a standard, he developed a so-called "normal spectrum," based on 400 species chosen more or less at random from the world's flora. Then he was able to deduce, for example, whether a tropical flora had more or less therophytes than an arctic flora, etc. Some general observations were: (1)

Phanerophytes and hemicryptophytes are the two largest classes in the world's flora as a whole; (2) warm humid regions have a preponderance of phanerophytes; (3) warm arid regions are overly represented by therophytes; and (4) chamaephytes predominate in arctic and alpine regions. This last generalization is significant to our discussion here.

Cautiously applied, Raunkiaer's scheme provides *one* means of quantifying the physiognomy of vegetation. It also serves in this case to focus our attention on several adaptive features of arctic-alpine plants in general. Perennating buds simply could not survive the freezing and desiccating arctic and alpine winds without heavy protection; and one would expect the environment to select in favor of those species and biotypes that have their renewing buds at or near the surface of the ground—in other words, low chamaephytes and hemicryptophytes. Maximum protection from the environment, harsh both above and below ground, is provided at the surface by the litter and snow. These are precisely the classes, of course, that Raunkiaer's scheme shows to be most abundant in the Arctic. Good examples of very low chamaephytes are the dwarf willows, purple saxifrage, and mountain avens (pls. 5, 9); their perennating buds are scarcely over an inch or two above the ground in winter. The bilberry or arctic blueberry (pl. 8) can be either a tall chamaephyte or short phanerophyte. Numerous herbs that die back to the ground completely each year or form basal rosettes fit the category of hemicryptophyte, although the distinction between this class and chamaephytes is in cases debatable as indeed between all the classes. The lines are arbitrary and for convenience only. A large flora of geophytes is precluded in the Arctic by permafrost.

It is common knowledge that the floras of high latitudes and high altitudes are comprised predominantly of *perennial* species. Owing to the extremely vigorous and selective environment, establishment by seed or other propagule is a very difficult and fortuitous event at best. Consequently, it is of supreme advantage to a species or biotype if once it gets a foothold it is able to colonize rapidly and endure for more than a single season. Perennials clearly have the edge on annuals, and the northernmost floras have few if any annual species. The abundance of grasses and sedges in tundra vegetation is particularly noteworthy in this respect. A species may not always have the same duration in every habitat, however. The European *Linaria alpina* Mill. (toadflax), for example, is annual in the lowlands, biennial in the lower mountains, and perennial at high altitudes. Low temperatures seem to reduce the annual duration of vegetative growth while increasing the life-span of the individual (Combes, p. 100).

There is a vast literature on the subject of plant communities in the Arctic-Alpine environment, and it would be foolish for me to attempt either summary or synthesis here. Particularly noteworthy, insofar as North America is concerned, are the works of Polunin, Porsild, and Raup. I should like, however, to make a few summary comments about plant communities.

If we take only an overview of the Tundra, we find that its plant communities can be grouped in three major groups: (1) rock desert communities, (2) heath and grass-sedge communities, and (3) aquatic communities.

Under rock desert communities, I include barrens, screes, rubble slopes, boulder fields, pavements, and river or coastal strands and dunes—any conmmunity where the vegetation is discontinuous and sparsely scattered in patches or polsters (pls. 1, fig. 2; 2; 4, fig. 2; 8, fig. 1; 10, fig. 1). In winter, these habitats are covered by little if any snow. Rock deserts may be veritable flower gardens during the short flowering season (pl. 10, fig. 1), and some of the Arctic-Alpine's most attractive members thrive here amidst the rocks (pl. 9). Rock crevices shelter a variety of species at the higher elevations, including several species of ferns (pl. 11). The rocks on these rock deserts may look completely barren from a distance, but all is not desert between the patches of ferns and flowering plants. Lichens, especially crustose lichens, cover large areas of rock surface, sometimes almost completely (pl. 11, fig. 1).

Within the continuous-vegetation group of communities, the heaths and grass-sedge prairies, individual types and subtypes are almost legion, and all generalizations must be treated cautiously. Mosses and lichens are ubiquitous in the Arctic, forming an almost continuous heath over vast areas, often as an understory to other vegetation. The creamy white *Cetraria cucullata* (Bell.) Ach. (pl. 11, fig. 2) is a very common heath lichen of the Tundra, and certain of these cetrarias (*Cetraria* spp.) and some cladonias (*Cladonia* spp.) are called "reindeer moss" by some, alluding to their food role for caribou and reindeer. Dwarf-shrub heaths cover enormous areas in total, and they are often dominated by species of the heather family, Ericaceae. Good examples are the arctic blueberry (pl. 8) and Labrador tea (pl. 12), both very widespread constituents of tundra heaths in the Arctic. These heaths are very like bog heaths of temperate latitudes, which probably are but glacial relicts of a once more widespread arctic type of vegetation. Some of the same species, such as bog rosemary (*Andromeda polifolia* L., pl. 12), are found both in tundra heaths and temperate bog heaths.

The prairie communities vary from marsh or wet meadow to very dry upland meadow, depending on the general terrain and microrelief. In localized spots, snowflush and alder-willow thicket communities, mentioned before, occur. Usually, grasses and sedges of one or more species predominate in the prairie communities, but from place to place large patches of herbmat will be in evidence, particularly in snowflushes and snowpatch areas. Typical examples of tundra prairie are illustrated by the pictures in plates 3 and 10, taken in the Alaskan Arctic. One was taken before most species had begun to flower and the other at the peak of flowering. The cottongrass tussock meadow (pl. 10), often called "niggerhead" meadow, is one of the most characteristic plant communities of the Arctic. The principal tussock-forming species is the sedge *Eriophorum vaginatum* L. (cottongrass), a strongly cespitose (clump-forming) species. By a combination process of their own growing habit and the perennial forces of freeze and thaw, these sedges build up over a period of years more or less conical mounds, composed primarily of organic remains of previous growth. The new year's growth is always at the apex of the tussock. Other plants, not able to thrive in the wetter depressions, can often gain a foothold on these relatively dry tussocks. The top of the mound, excluding the new stems, may be a foot or more above the surrounding depressions. Only those who have tried to hike for miles across these niggerhead meadows can fully appreciate just what sort of landscape the tussocks create. In total aspect, these meadows are very attractive when the "cotton" (fruiting-head bristles) is ripe; from the air one sees this cotton dominating the landscape for hundreds of miles along the Alaskan Arctic Slope for several weeks, looking just like a light fresh snow.

Arctic freshwater habitats are generally quite sterile because of the frigid water temperatures, even in summer, and the presence of ice through much of the year. Shallower lakes and streams freeze to the bottom in winter, and the deepest lakes may be so cold year-round that they scarcely lose their surface layer of ice before a new layer begins to form. Nonetheless, a fair number of aquatic species do recur across the Tundra in lakes, ponds, and streams. Pondweeds (*Potamogeton* spp.), several species of buttercups (*Ranunculus* spp. and *Caltha* spp.), and marestail (*Hippuris vulgaris* L.) are some of the most widely occurring ones.

MORPHOLOGICAL CHARACTERISTICS OF ARCTIC-ALPINE PLANTS

One could accumulate from the literature a fairly long catalog of specific correlations of morphological features with environmental factors, demonstrated for this or that species or taxonomic group, but precious few generalizations can be made about arctic-alpine plants as a whole. For example, I can demonstrate statistical correlations between height of plant or diameter of corolla and altitude in *Campanula rotundifolia* L., the harebells, an extremely polymorphic complex on which I have done considerable research. Height *decreases* as altitude increases, a negative correlation, and corolla diameter *increases* while altitude increases, a positive correlation. To a degree, but harder to show statistically, these same correlations exist with latitude. In themselves, altitude or latitude are not significant of course, but only as indices of a changing environment.

These two examples illustrate the biologist's perennial dilemma when he tries to translate correlation, in this case statistically significant, into something of biological significance. The negative height correlation is quite general and well known in plants; we expect plants to get shorter as we go toward arctic or alpine areas, because of the more rigorous environmental conditions, already discussed. I am simply saying statistically here what we have already stated earlier—arctic-alpine plants tend to be dwarfed. On the other hand, the tendency for the harebell flowers to get *larger* with increasing altitude or latitude is not as general a tendency, and the biological significance of this trend is more equivocal. *Perhaps* the larger flowers compensate for the fewer insects in this environment; their greater size might have greater attracting power. Certainly, insect-pollinated species, such as the harebell, must attract insects to reproduce successfully, and a reduced insect density is a handicap. Not all the insect-pollinated species have large flowers, however, and it would be misleading to conclude that pollination relationships explain the larger flowers in the arctic-alpine environment satisfactorily. Whatever the reasons, nevertheless, the correlation is often noted that arctic-alpine species tend to have large showy flowers (pl. 9, fig. 2).

The well-known tendency of arctic-alpine plants to become dwarfed suggests to us what might be the only important generalization that can be made, namely, that there is in the arctic-alpine environment an overall trend among the plants toward the *reduction of surface area*. Dwarfing has the effect of reducing the amount of exposed shoot, including stem, branches, leaves, and inflorescence. The aboveground stem may be virtually nonexistent, or if present it may creep along the surface of the ground. Grasses and sedges, both very successful in the arctic-alpine environment, have subterranean or partially superficial creeping stems; the same can be said for the willows. Dwarf willows, for example *Salix phlebophylla* Anders. (pl. 5), provide superb examples of this tendency. In all their reproductive features they are perfectly orthodox willows, yet their vegetative parts are so reduced that those familiar with only temperate willows are prone to be taken aback by their first experience with these arctic-alpine dwarfs. They have in effect done away with every vegetative flourish that the life cycle could spare, retaining little more than the inflorescence above ground. Such is true of arctic-alpine plants generally, which fact impresses one time and again as he moves about in tundra regions (pl. 9).

The reduction-of-surface-area trend can be observed in the very form and structure of the plant organs of many plants. The leaves are often more or less in-rolled (revolute), leathery, and hairy on one or both surfaces, as is well illustrated by some species of the heather family (pl. 12). These are all xeromorphic features, which presumably reduce water loss, that one is accustomed to seeing in plants of very arid environments. The inflorescence tends also to be reduced to one or a few flowers, which however may be quite large, as already discussed. As a result of much abbreviated stems, the stem leaves are often highly compacted, sometimes very distinctively so as in the purple saxifrage (pl. 5, fig. 1).

POLYPLOIDY AND APOMIXIS

Typically, the vegetative cells of plants, as the somatic cells of animals, have two sets of chromosomes, a paternal set and a maternal set. This is the well-known *diploid* condition. But plants, unlike animals, often have one or more additional sets (usually pairs of additional sets) per cell in a condition known as *polyploidy*. These plants are called *polyploids* in general, but they may be referred to more specifically as *triploids* (3 sets), *tetraploids* (4 sets), etc.

Early cytological studies of certain European and Scandinavian floras led to the generalization that polyploidy is more common at high latitudes, i.e., arctic latitudes, than at low latitudes. The corollary was quickly proposed that polyploids must therefore be more hardy and successful than diploids in the extreme arctic type of environment, hence more tolerant of extreme conditions in general. This conclusion is still generally accepted, but the evidence is not as unambiguous as first seemed. If polyploids were really more tolerant of extreme conditions, then one would expect to find high percentages of them also in alpine areas, arid regions, marine habitats, and disturbed situations, but this is not altogether true. However, much more research on this question is still needed.

If we subject the proposition that polyploidy is *relatively* more frequent in the northern latitudes to examination by case study, we find indeed that examples can be found of species pairs (one diploid and one polyploid species) in which the diploid member of the pair has the more southern range (e.g., in genera *Empetrum*, crowberry, and *Clethra*). However, the converse can also be found (*Vaccinium*, blueberries and cranberries, *Iris*, and *Campanula*, harebells and bellflowers). *Campanula rotundifolia* L. (harebell), for instance, is a widespread circumpolar species, comprised both of diploid and tetraploid biotypes, but almost all known diploid biotypes have been found in Greenland (Böcher). Valid general comparisons with tropical angiosperm floras really can't be made at present, owing to our sketchy cytological knowledge of these floras. Manton studied the fern flora of Ceylon and concluded that polyploidy among Ceylonese ferns must be at least as great as among British ferns.

Whatever the true *relative* frequency of polyploidy on the earth's surface, we must reckon with the fact that the number of species exhibiting some polyploidy within their ranks may reach as high as 80 percent of the total flora in certain arctic areas. Perhaps the explanation lies in an ability of polyploids to tolerate more extreme conditions, as has usually been suggested, but certain other facts tend in part to explain this high percentage quite apart from their ecological tolerance. These facts cannot be overlooked in any attempt at generalization. First, the families Gramineae (grasses) and Cyperaceae (sedges) are known to have an unusually high incidence of polyploidy among their species, and these particular families comprise a relatively large segment of the arctic flora, as already noted. Second, polyploidy is also particularly frequent among herbaceous perennials with efficient means of asexual reproduction, such as tend to dominate the arctic flora. Third, glaciated areas tend to be higher in polyploids than unglaciated areas, and a large segment of the present-day arctic flora occupies glaciated land. The presumption is that polyploids are better early colonizers. In summary, then, the explanation for the apparently high incidence of polyploidy in the Arctic may be far more indirect and complex than has been thought.

The second consideration above raises the question of *apomixis*, which in the strict sense refers to the production of viable seeds parthenogenetically (without fertilization by male), and in the broad sense includes all asexual means of reproduction. In either sense, apomictic species are uncommonly frequent in the Arctic. What's more, an apomictic species is very likely to be polyploid, and many polyploids are apomictic. This correlation is not necessarily unexpected. A polyploid species can escape all the cytological difficulties of normal seed production that usually attend polyploidy, *if* it reproduces by some asexual means instead. In other words, an apomictic "bypass" of sexual reproduction permits certain polyploid biotypes that would ordinarily be eliminated rather quickly to survive and even to thrive and spread. Clearly, apomixis is advantageous to arctic-alpine plants, and apomictic biotypes would tend to accumulate in these harsh environments over a long period of time. Thus, we can understand how apomixis would be an adaptation for arctic-alpine environments and how polyploidy can survive in apomictic households, but this still leaves open the real question of the selective advantage of polyploids in the Arctic, if any.

FLORISTIC AND GEOGRAPHICAL ASPECTS OF ARCTIC-ALPINE VEGETATION

If from an ecological viewpoint the vegetation of the arctic-alpine environment is unique, what about the individual species that comprise it? To what degree is the *flora* of the Arctic-Alpine unique?

Three principal classes of species are to be found in the arctic-alpine environment:

1. Widespread circumboreal species, meaning species with a world-wide distribution in North Temperate regions, having a large ecological tolerance (amplitude) that permits them to transgress two or more major climatic, hence environmental, zones and plant formations. In other words, this class includes species that might occur widely, for example, in both coniferous forests and tundra. Such species may thrive in arctic-alpine habitats simply by virtue of a wide physiological tolerance rather than any particular genetic adaptation. Certain species of the heather family, as bog rosemary (*Andromeda polifolia* L.; pl. 12), provide good examples.

2. Widespread circumboreal species represented in the Arctic-Alpine by specially adapted, hardy biotypes that have become established as separate physiological races, which may or may not be morphologically marked. These are sometimes called *ecotypes*—ecological races. An example here is the widespread species *Ledum palustre* L. (Labrador tea; pl. 12), which has differentiated a race, ssp. *decumbens* (Ait.) Hult., that is found *only* in the Arctic.

3. Endemic species found only in some part of the Arctic-Alpine either with or without more than one race. These species may be extremely localized or virtually circumpolar; confined to the Arctic or some part of the Alpine or common to both. There are of course minor overlaps into the next vegetation zones at the lower limits of the Arctic and Alpine. Several of the saxifrages, like *Saxifraga flagellaris* Willd. and *S. oppositifolia* L. (pl. 5), and *Diapensia lapponica* L. are good examples of widespread arctic-alpine species, endemic in the sense used here.

These must of course be arbitrary categories, and their sole function is to point up the major patterns of distribution. It is very difficult to categorize many species found growing in the Arctic-Alpine, for the simple reason that we lack rudimentary data about their ecological requirements and ofttimes have a poor picture of their distribution. The classic transplant studies of Turesson, the team of Clausen, Keck and Hiesey, Böcher, and others have provided ample evidence to convince us that widespread species do differentiate ecological races in alpine and arctic regions. They grew plants, transplanted from an arctic or alpine habitat, under uniform conditions at lower latitudes and elevations to determine whether their characteristic growth-form was due to environment or heredity. The Clausen team added the refinement of taking pieces from the same clone (same genetic individual) of certain plants, as grasses, and planting them at different altitudes to see what the same genetic stuff could produce under different environments. All of these studies leave no doubt that in the cases studied, at least, both environment and heredity have a strong hand in the development of certain characteristic arctic-alpine features, but also that the arctic-apline race is a real thing. Ideally, we need transplant studies in every last species before we can decide whether it is a widespread tolerant species, a physiologically differentiated race of some widespread species, which may or may not also be morphologically differentiated, or a fully isolated endemic species, incapable of thriving under other than arctic-alpine conditions. We will have to wait many years, however, before this sort of information will be available. Meanwhile, we must continue as in the past to infer what the real situation is from descriptive data.

Using the transplant work that has already been done as a guideline, we are now able to infer much more safely from morphological and phytogeographical data and methods just what the answers to the questions posed here really are from group to group. As our knowledge of distributions increases, for example, we approach a fairly complete picture of the species that are found *only* in the Arctic-Alpine, the endemics, and it seems safe to assume that their very restriction to this environment speaks to peculiar physiological adaptation. We have a wealth of descriptive information available on arctic-alpine plants, especially on the distribution of the species and their morphological varieties, thanks in large measure to the pioneering work of Hultén (1937, 1962) and Polunin (1959). These papers and others of Hultén's are truly monumental in the scope of the task they attempt and in large measure already have achieved. They have set a comprehensive groundwork for all future studies of arctic-alpine plants, particularly arctic plants.

Let us come finally to the present status of botanical research in the Arctic-Alpine. Most of the known flora of this region throughout the world was described before the advent of experimental and cytological methods, which have turned our minds to the problems of polyploidy and ecological (physiological) races. Furthermore, this descriptive work was done in widely separated quarters of the world by botanists who not only held sometimes divergent views but were able to communicate infrequently at best with each other. For one reason or another, many of the efforts were strictly national efforts, stopping at the limits of national boundaries. The plants, on the other hand, know no national boundaries, and, as we have already seen, many are essentially circumpolar. (Consequently, time and again the same species has got described from different areas by new and different names. One could recapitulate numerous case histories, hardly necessary here. As a result, however, we have come to have many more names than species in the arctic-alpine flora. The situation is confounded even more by the fact that we have lacked not only *inter*national, but *intra*national coordination. In North America, for example, the students of the Arctic have been largely different from the students of the Alpine, and we are often at a loss to know whether certain species in the Rocky Mountains, for instance, are conspecific with similar arctic species or are merely close relatives.

Fortunately, the recent trend among students of the arctic-alpine flora everywhere is to study only a very small group of closely related species, but on a very broad geographical basis taking in, if possible, the entire worldwide range. Only after this has been done for all the major problem groups can we begin to sift out the numerous superfluous names and come to a real understanding of the origins and affinities of arctic-alpine species. Of especial personal interest is the question of the overall affinities of the Alaskan arctic-alpine flora to the Rocky Mountain alpine flora and to the Eurasian arctic-alpine flora. Rydberg studied the Rocky Mountain flora, Hultén has been studying the Alaskan flora, and the Russians have largely reserved to themselves the study of the arctic-alpine flora of the vast Siberian region, which comes to within a matter of miles of the Alaskan Arctic. We have hardly begun to integrate our knowledge of these regions, to say nothing of attempting to study their floras through the same eyes. When the latter becomes possible, I am convinced that we will find an even greater unity among these regions than is presently suspected. The signal contributions of Hultén and Polunin have pointed the way, we hope, to a new era of international cooperation in arctic-alpine botanical research. Let us also hope that we have begun to see the end of *national* species and that more *international* species are just around the corner, speaking biologically of course and not politically.

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Concerning Whales and Museums[1]

By A. E. Parr

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[With 8 plates]

Whales have always been a problem and a challenge to exhibitors. Gargantuan size provides a readymade source of excitement. But optical uniformity of environment offers little opportunity for visual enrichment of setting.

Stranded whales have probably drawn crowds of curious or hungry spectators before written history began. When somebody first got the idea of claiming ownership and charging admission to the spectacle is not recorded. But it undoubtedly happened a long time ago.

In the early days, problems of size and decay confined the show to the spot where the whale had reached its doom under its own power. When we learned to delay the state of repulsiveness by icing and embalming, it became possible to take time to move the disconsolate carcass to more favorable locations for mass attendance. The wake of the whale might cover long distances and much time before dust returned to dust. The traveling corpse of a minor behemoth of the seas could be admired in New York as late as in 1954, upon payment of a proper tribute to the dead.

Much as one may now criticize the tedium of endless rows of stuffed specimens on shelves, even the earliest museums of the 18th century obeyed the cardinal principle that a living species must be restored to the posture of life before it is shown. This was even true of the thousands of birds on the tiresome T-perches we now despise so much. When whales in the round finally followed their skeletons into the museums, their dejected appearance of death and imminent decay was properly deemed to offer a completely unacceptable image of the elegant bodies that glide so easily through the waters.

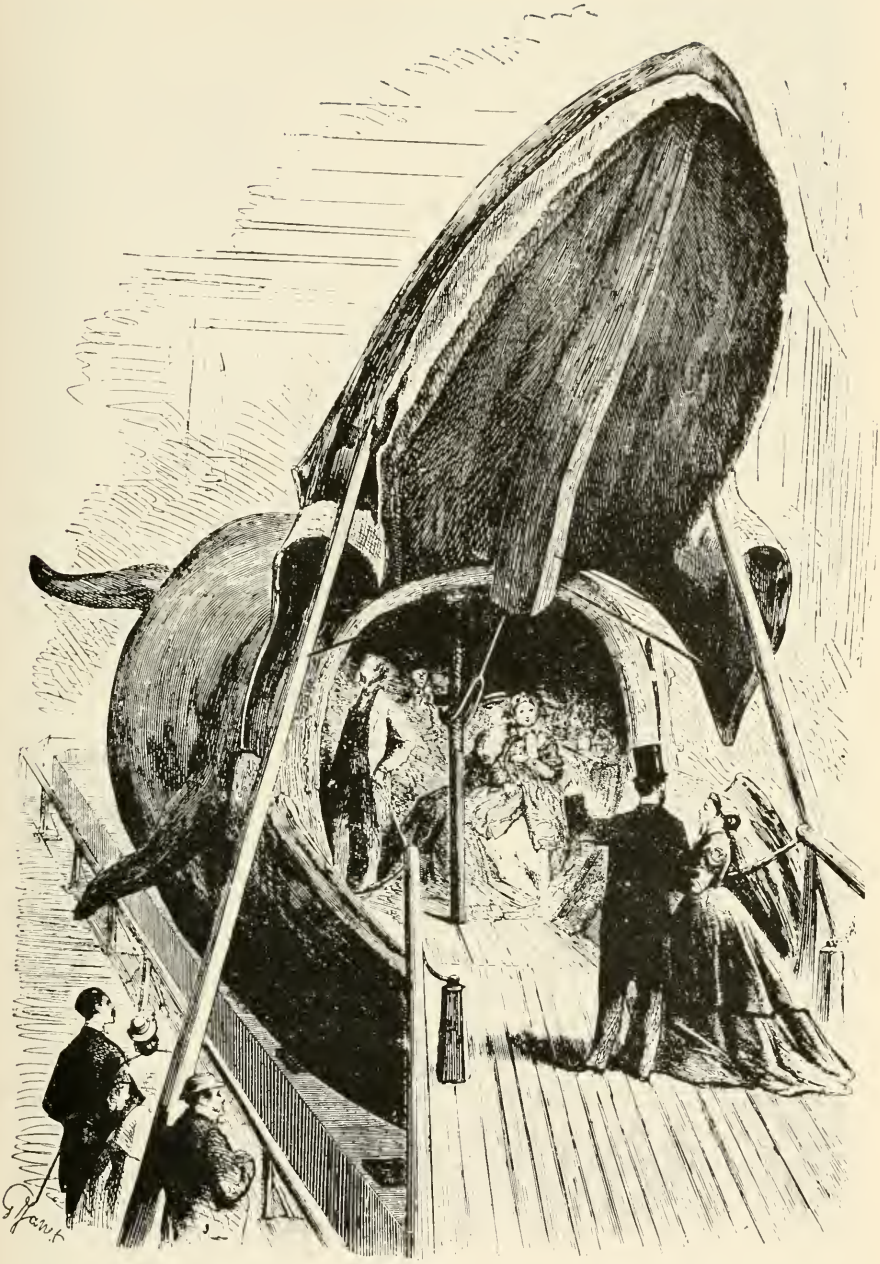
Since whales do not perch, the problem of presenting them in their living form was a good deal more complicated than the difficulties of bird taxidermy. In consideration of their normal environment, it was recognized that the specimens should have as little contact with other

[1] Reprinted by permission from *Curator* (the American Museum of Natural History), vol. 6, No. 1, 1963.

solids as possible. The question was whether to suspend or support. Supports are mechanically simpler and also carry an illusion of greater safety. The first museum whales could therefore be seen placidly floating across the tops of three or four newel posts or similar devices, after the manner of museum sharks. With more experience and confidence in the structural use of steel, suspension became the preferred method of installation.

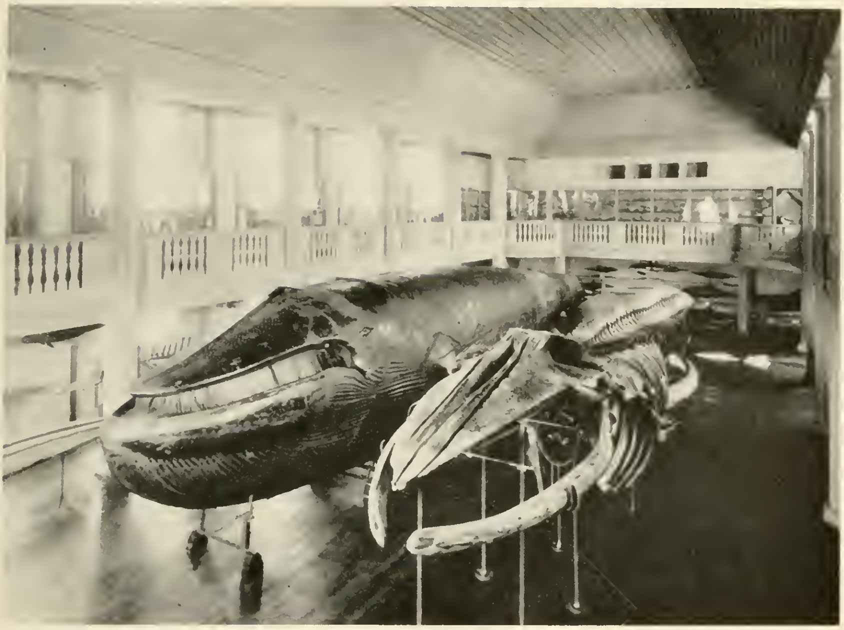
In the meantime, the influence of some of the best, illustrated works on nature favored the resting over the hanging whale. In any kind of graphic rendering a whale in the water becomes a whale in a void. Plate 3, figure 2 illustrates the dilemma very clearly. Whether the void is blue or blank makes little difference. No wonder, therefore, that artists sought satisfaction for their sense of design by the use of imaginary forces that nature could never duplicate. Giant whales are tenderly deposited, without a scratch, high among rocks and other picturesque objects on shore, as gracefully draped as Paisley shawls. The whimsical tableau that pleased the artists and art lovers most could not have been more embarrassing, humiliating, and disastrous for the poor whales. But they did provide handsome pictures that anyone can be glad to own, and it seems reasonable to assume that they may have helped to bring about such a pleasingly casual exhibit as that shown in plate 5, figure 2.

The method used in Malmö to show a small porpoise is, unfortunately, not equally applicable to larger whales. The reason for this is in itself a demonstration of a biophysical principle of considerable interest, which was first called to our attention by Galileo himself. Other things being equal, the weight of a body is approximately commensurate with its three-dimensional volume, while the strength of its supporting tissues such as bone and muscle is related only to their two-dimensional cross sections. If a body grows to eight (i.e., 2^3) times its original volume and weight, and all its parts remain in the same proportion to one another as before, then the strength of the supporting organs will have been multiplied only by four (i.e., 2^2) and will not be strong enough to sustain the increased load. This is the basic reason why the skeleton of a large land animal is so much heavier in proportion to its body than that of a small species. The difference becomes very striking when two such skeletons are shown in illustrations of the same size. Galileo quite logically felt that the mathematical relationship between overall dimensions and the dimensions of supporting parts imposes a maximum limit on the size that can be reached by any animal having to resist the forces of gravity by the strength of its own structure. The whales have partly circumvented the problem by letting the buoyancy of the water carry most of the load and have thereby become dependent upon the watery uplift to maintain the streamlined shape of even the most athletic members of their tribe.



The Malmö whale in Stockholm, 1866, mounted skin. After Löwegren (1961).

The Haröy whale in New York, 1954, embalmed.

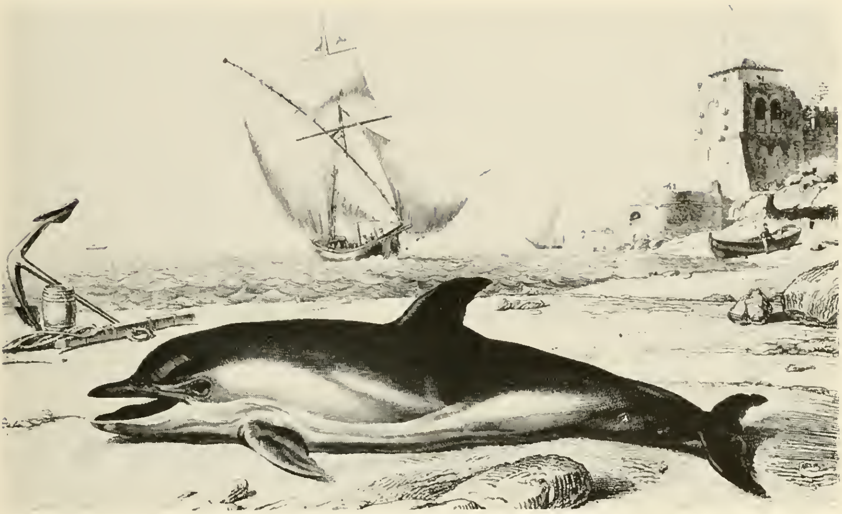


1. The Malmö whale, Naturhistoriska Museet, Götebord. After Löwegren (1961).

2. A whale in the water is a whale in a void. American Museum of Natural History.

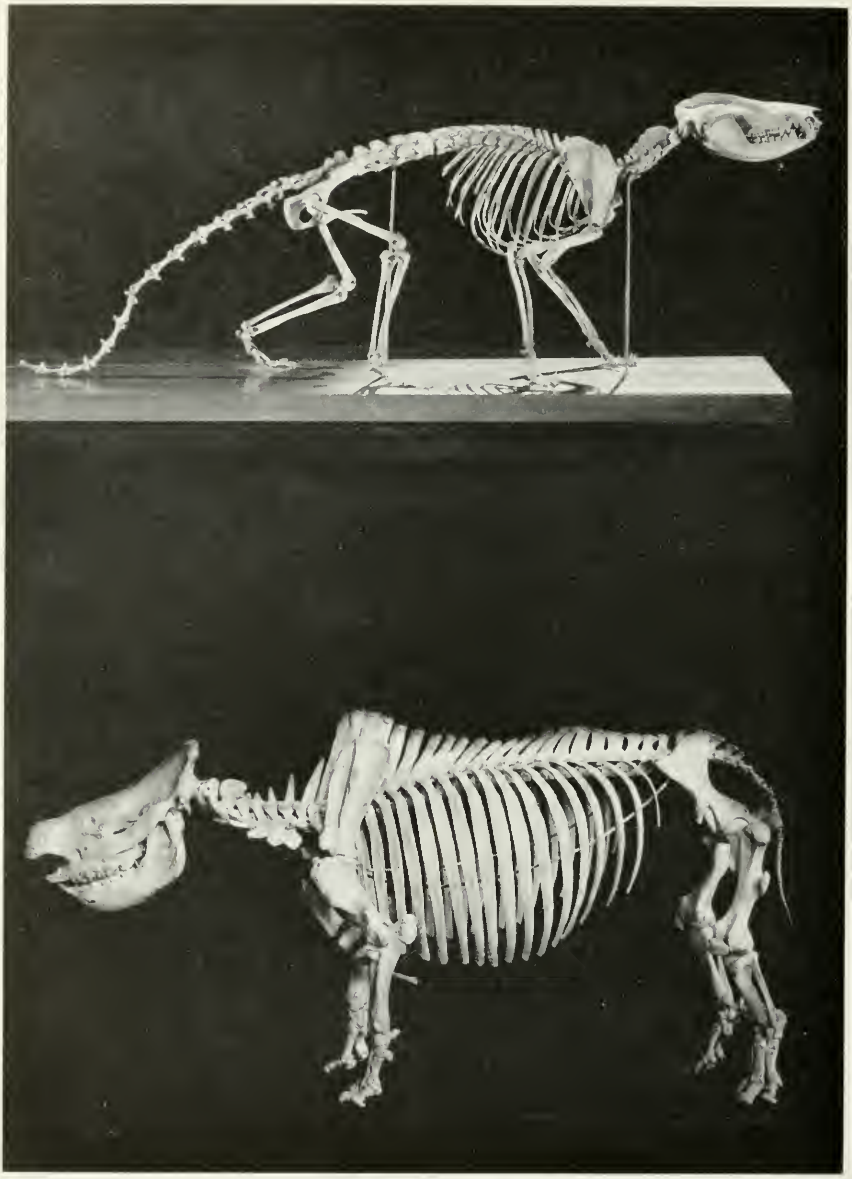
1. Rorqual as shown by Jardine (1837).

2. Rorqual as shown by d'Orbigny (1849).



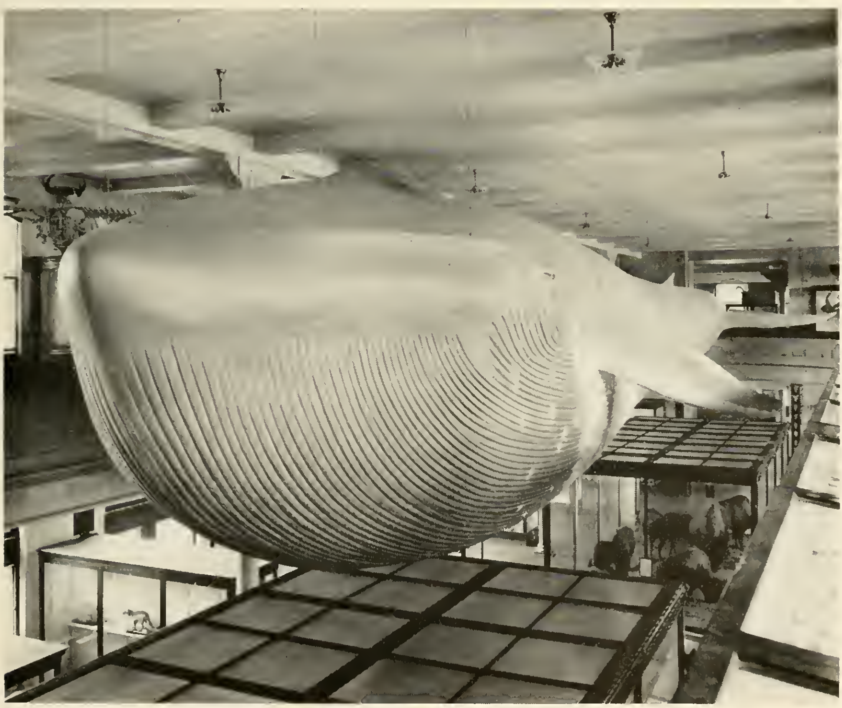
1. Dolphin according to d'Orbigny (1849).

2. Porpoise in the Malmö Museum. From Löwegren (1961).



Galileo's principle. Skeletons of opossum and of hippopotamus reduced to the same size.

1. Images of gross obesity. Scale models of beached whales, from Jacobi (1914).



2. Suspended like a big boat in a barn. American Museum of Natural History.

1. Rear view of new whale in Museum of Natural History, Smithsonian Institution.

2. Frontal view of same.

When it comes to the larger whales, the museums would therefore seem to have realized from the start that the body of one of the monsters resting on the ground could not convey any of the grace and power of the swift leviathans of the sea, but rather an image of gross and feeble obesity, unless the evidence of a biologically important and historically interesting principle were falsely denied.

Jacobi, in his discussion of whale models, actually felt that even such a small and firm species as the porpoise would be too distorted to make a good exhibit, if a mold was made from a specimen resting on a dry surface. Jacobi went to considerable trouble to obtain a cast showing the true shape that this little whale holds in the water. But, without opportunity to display life-sized models of the large whalebone whales, Jacobi found it necessary to show miniatures of two of the beasts resting on shore, in order to establish the scale of reduction by the juxtaposition of human figures, which could not very well have been introduced in circumstances that would be more natural for the whales. Since the modeling of the miniatures was done with complete honesty, they also show the shortcomings of whales on land, suffering the effects of Galileo's principle from which they had found surcease at sea.

The museums that wanted to exhibit life-sized models of the giants therefore realized the necessity of showing them in their hydrodynamically suspended and not in their mechanically supported shape, letting the air take on the role of the water in the visual image. But pedestals holding an object up from below are not particularly helpful to the conceit of a body floating in space, and suspension from above therefore became the accepted method of installation as soon as it could be safely used.

Since unencumbered space large enough to suggest even the limited freedom of an aquarium for beasts of such size is rare, the total impression of a whale in the museum is one of conflicting images like those created by a large boat stored in a barn. The space might fit the dimensions of the carcass, but it did nothing to suggest a marine environment. It is one of the merits of the fine new installation of a "sounding" whale in the United States National Museum that it has finally broken this deadlock between unyielding architecture and unwieldy contents.

To create the illusion of having joined the whale in its own domain, or even of looking in upon it in its natural habitat, would obviously be impossible. Any attempt to suggest environment by treatment of the background would become a distracting and objectionable strain upon the imagination. But, instead of giving in and simply presenting us with another whale in a museum hall, as others have done before them, the designers, in this instance, turned their attention from the impossibilities of the exhibit itself to the previously unexplored possibilities of its framing in space.

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The hall itself has been remodeled into bold asymmetry. Along one side of its length the solid bulk of double-decked display housing rises and recedes, to counterbalance the plunging volume of the whale in the clear, rectangular space opposite. The gently curved shape of the second-tier balcony and its railing evokes memories of ships, without straining credulity by actual imitation of form and structure. The stairs leading from main floor to balcony, and from balcony up and out of the room, are unobtrusively reminiscent of companionways. By these, and other, gently suggestive devices the designers have very cleverly managed to imbue the space itself with a subtly nautical air that makes the whale, in defiance of all logic, seem a far more reasonable and attractive sight than it ever did before under a roof.

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Tropical Subsistence Agriculture in Latin America: Some Neglected Aspects and Implications

By RAYMOND E. CRIST [1]

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[With 8 plates]

MUCH HAS BEEN written about the adverse physical factors in the less-developed lands of the tropics: The hot, steaming, depressing climate; the "tropical" diseases; the infertile, leached-out soils; the impenetrable forests with their "varmints" and venomous snakes—to mention but the most formidable in the whole capacious grabbag of horror factors, real or imagined, that are widely reported to cut productive capacity and potential to zero, or very near it. But less paper and ink and cerebration have been devoted to some of the more subtle, but perhaps more significant, or even sinister, cultural brakes, or roadblocks, operative for man in the tropics.

TROPICAL SUBSISTENCE AGRICULTURE, A WAY OF LIFE FOR MILLIONS

It is estimated that some 200 millions of people in the tropical areas of Latin America, Africa, and Asia—even in areas usually thought of as densely populated, such as the Indian subcontinent—make their living by practicing some form of "shifting agriculture," "slash-and-burn farming," "forest fallow," "nomadic agriculture," or whatever the local name for it. Thus perhaps 1 person out of every 12 or 15 in the world, a population roughly equal to the population of the United States, is engaged in this hand-to-mouth agriculture.

This remarkable system of agriculture, developed on a trial-and-error basis millennia before the principles of modern science were dreamed of, consists of clearing land of tropical forest or bush, except for huge trees which are left standing but killed by girdling; burning the trash when dry; and planting to crops for from 1 to 5 years. As

[1] The author has over the years carried out field investigations in Latin America under a continuing grant of the John Simon Guggenheim Memorial Foundation.

yields decline owing to the leaching out of soluble salts and plant nutrients, as weeds take possession, and as rodent, bird, and insect populations build up, this land is abandoned for another nearby plot. The jungle takes over for anywhere from 3 to 20 or 30 years, and the cycle is repeated. Since under this system of soil management it requires some 15 hectares of land to support one person, subsistence farmers are exploiting some 3 to 6 billion hectares of land, depending on the length of the fallow period. Over the millennia, hundreds of millions of hectares of forest and brushland have been cut over in this cycle, the forest-fallow phases of which may become longer and longer, especially on easily eroded mountain slopes. One has but to observe the beautiful leaves of a typical second-growth tree, the *Cecropia* sp., as their silvery undersides are turned up in the afternoon breeze to reflect the rays of the tropical sun over vast stretches of what might appear to the uninitiated observer to be virgin forest, to realize the extent of deforestation, and subsequent natural afforestation, due to the activities of countless generations of slash-and-burn farmers. Such subsistence farmers operate in a kind of shatter zone, where first the forest and then man has the upper hand, a temporary no-man's land of charred trees and stumps, fallen logs, and piles of unburned brush; Lilliputian man gradually causes to emerge from this seeming chaos a successful system of land management from which he is able to make his living as well as to achieve a degree of harmony between himself and his physical environment.

SIGNIFICANT FACETS IN THE LIFE OF THE SUBSISTENCE CULTIVATOR

First, a visit to a home in the forest: All the materials for house construction are cut in the surrounding forest; the six to eight upright posts, often of the extremely hard center of a palm tree, and the crossbeams and rafters, of 3- or 4-inch saplings of the hardwood trees locally available, are all bound together with the long, ropelike lianas, or *bejucos*, so pliable they can be tied when green or wet in a knot like a rope; the thatch for the roof is made of palm leaves, also deftly tied to the rafters with lianas; not a nail is used in tying the whole structure together so securely that it will withstand windstorms as well as torrential downpours in spite of its somewhat frail appearance; yet it is ideal for a tropical climate, giving ample air circulation while being a shelter from the rain. Such a house can be constructed in a few days; it is socially acceptable, as well as being ideal for the climate, and there are no mortgage payments to be made. The cooking is done over a wood fire in one corner of the house. Most kitchen utensils, water jars, spoons, bowls, plates, and so on, are made of wood or of hollowed-out gourds.

A cotton shrub or so grows near the house from which tufts or bolls of the raw fiber are gathered, then seeded or ginned by hand, to be sold as raw cotton or spun by hand by the womenfolk into coarse thread. Some coarse cloth may be woven by an old woman on a primitive handmade loom, or the simple cotton clothing of the adults may be purchased; children wear no clothing until they are 6 or 8 years old.

The family all sleep in hammocks, often made at home of palm fibers. If they can afford it and are accultured to that extent, they sleep under mosquito netting, but more often they do not, the smoke of the kitchen fire helping to keep insects at bay. It can get coolish and damp at night, especially noticeable if one sleeps in soiled, sweat-soaked clothing. The first thing the woman of the house does as she crawls out of her hammock in the morning is to put firewood on the embers that have smoldered all night to get the fire going for heating the water to make coffee, which she pours into cups made of a half shell of a coconut. Both she and her husband put in more brown sugar than the beverage will dissolve, but the coffee-flavored sugar in the bottom of the cup is carefully licked out; sugar gives them quick energy. If coffee is unavailable, they will probably have hot water sweetened with brown sugar—*agua de panela.* The woman continues with her household chores as her husband follows the path to his clearing (roza, conuco, milpa). The heavy drops of dew seem cold to his legs as they brush against the plants along the path; he is carrying his long, well-sharpened machete, and, if in the process of clearing land, he may be carrying his most prized, most costly tool, his axe. After working a few hours his wife or children will bring him his breakfast—a bowl of black beans, or cooking bananas (plantains) or yuca, boiled, baked, roasted or fried; or he may have corn cooked in various ways, or rice—the type of food will depend on the season and on how well off or on how lucky he has been. At all events, it will be relieved of its monotony only by occasional fruits, game or fish, and herbs.

Over millennia this primitive farmer has evolved a sure-fire crop complex: Corn, yuca, beans, and pumpkins or squash. To this list has been added, since the Spanish Conquest, the cooking banana. The techniques of this kind of primitive farming look simpler than they are. The great toe of the farmer's bare foot is used—or a dibble stick if one is fancy—to make a hole in the soft earth of the burnt-over plot, preferably after the first rain; two or three grains of corn and a few beans and squash or pumpkin seeds are put in, and the hole is covered up by a swipe of the foot and the earth is tamped down by being stepped on. The corn comes up rapidly and shoots up fast, its green stalk forming a living pole for the beans to climb up on; it will be harvested in about 90 days, the beans a month or so later. The squash or pumpkins are ideal for this kind of farming, for their vines spread all over the ground and over the fallen logs and heaps of brush that have not been burned. Thus every bit of land is actually in use, and each crop gets its quota of sunshine. Near the house, especially where the slops are thrown, will usually be the patch of cooking bananas, one of the first plants to be planted and a great producer of food for all. One of the most significant food plants is yuca, a patch of which is usually found near most huts. It grows from cuttings in about any kind of soil—sandy, rocky, moist, dry, etc.—seems to have few pests, always makes a crop of some kind, and has the advantage of keeping well in the ground after it has matured; thus there is no storage problem, as the roots can be dug up whenever needed from the time they are small, the size of young carrots, to when they are full grown, weighing many pounds.

It is difficult for the author to draw a clear line between garden agriculture and fire agriculture. Undoubtedly, even the most primitive farmers had, and have today, dooryard gardens. As seeds of fruits and vegetables were thrown out on refuse heaps, some of them sprouted, grew up as "volunteers," and began themselves to produce fruits and vegetables right there, handy to the house dwellers. As this process continued, more ground would be cleared for them, first by fire alone perhaps, then later on by the felling of brush and small trees, the girdling of larger trees, and the firing of the whole complex when it is dry—the slash-and-burn agriculture of today. It is a short step from the dooryard gardens created accidently or casually, to the well-kept gardens achieved by design, in which rare plants, such as exotics and spices, would be grown. As has been seen, the diet of the subsistence farmer is apt to be monotonous, at least for certain parts of the year when only one food item is available. When one has lived for weeks or months on cooking bananas, sweet yuca, or farina, it is small wonder that powerful herbs such as small green onions, chives, coriander, hot peppers, and so on, may be resorted to, both for variety as well as for purgatives.

The subsistence farmer is in a closed, almost hermetically sealed, economic unit or cocoon that he spins around himself; he may try to work his way out of this cell by taking to market a bag of raw cotton, or perhaps an extra bunch of cooking bananas, or even a few kilos of yuca, but these small surpluses usually are not produced by design. The load of firewood or charcoal, however, carried by mule or canoe or even on one's back, is expressly cut or made for sale and is often the only and seemingly very tenuous economic thread that gives the slash-and-burn cultivator contact with his fellows on the regional scene. It also serves the purpose of getting him and his family to the village or market town, where they gorge themselves on items often lacking in their daily diet, and in general participate in the social life around them, that is by no means a passive form of entertainment. Any listlessness they may show may be due more to the ravages of intestinal parasites than to the erosion of the spirit so common in our society, where millions of people try to "get through the day" by resorting to the use of tranquilizers or stimulants.

INSECURITY OF TENURE: INFLUENCE OF CULTURAL CONTROL

A basic factor in the development of any country or area is who owns or controls how much and what kind of land, for the use made of it is so often determined by those who control it. One naturally wonders who owns this land in forest fallow, and the answer is that it may belong to the Government, to individuals, or to large corporations, foreign or domestic—but almost never to the slash-and-burn farmer. Even those who claim it often have only the vaguest notion of where the actual boundary lines of their holdings are. Most of the less-developed areas of the world are innocent of land surveys; properties and national boundaries are marked by a system of metes and bounds; even national boundaries are in dispute, wide zones between nations being a kind of no-man's land, claimed by both nations—Guatemala and British Honduras, Peru and Ecuador, Venezuela and Colombia are cases in point. If even international boundaries are vague and often unmarked, it is small wonder that the property of persons and corporations within the several countries themselves should be poorly delimited, if at all. The result is that *de facto* landholding may be even more important than *de jure* landholding: i.e., powerful persons or groups own or control vast areas and are in a position to put the squeeze on anyone squatting on their land; hence anyone who does squat on and work obviously unused land gets far away from those in the seats of the mighty and produces just enough for subsistence, for if his activities are called to the attention of those who own or claim the land he can the more easily slip away, higher up the mountain side or deeper into the forest. The words "own" or "control" or "claim" are used because a powerful person can do about as he pleases in setting the boundary to his property, for he almost invariably has on his side the police force and the army, as well as the religious authorities.

Thus the primitive farmer is, so to speak, between the devil and the dark green forest. But the forest is his home, as it has usually been for all of his ancestors. It has no terrors for him because he and his ancestors have wrested their living from it; he is really terrified, and with good reason, of the landlord, or local cacique, or boss, with his bespectacled lawyer whose briefcase is full of lengthy documents that are backed up by the police. He knows all too well that he will lose in any fight with them, for he and his kind have always lost when confronted with those representing urban power—*asi es la vida.*

Millions of human beings, poorly qualified and equipped to cope with modern agricultural problems, are relegated by cultural controls precisely to those areas where the problems of soil management are most difficult. Often those with wealth and training have control over large land tracts physically good and within easy reach of markets. Such people can apply the techniques of modern scientific management to produce crops for the market, domestic or foreign, and thus achieve a high profit per hectare. Further, they are powerful enough to acquire control of still larger expanses of good land to hold for speculative purposes, that is, to hold it at prices which the land *would* have if it were already settled and being farmed; in other words the cost would be so high as to price the land out of the market for any small farmer. When access roads are built into sparsely settled areas, politicians and speculators often control the very land that the road was to make accessible, with the result that what was meant to be an access road may even drain out of the territory the few subsistence farmers already living there! Western Canada, the Middle West of the United States, New Zealand, and Australia were opened up by an influx of people who followed the new transportation lines and were able to acquire lands near them. This has all too often not been possible for potential settlers in the less-developed tropical areas today. These divers cultural and economic roadblocks spin around each individual subsistence farmer a cocoon of individual autarchy; and the national economy, unable to go forward dynamically, either stays on a dead center or retrogresses.

OTHER FACTORS FAVORING THE STATUS QUO

As the outsider looks at Latin America he is aware of the fact that there is a lack of continuity in many spheres. Political groups shoot their way into and are shot out of office with sickening regularity. A man may be a newspaper editor one day, a college professor another, only to be a salesman for a large importing firm the next day, or his country's representative abroad, traveling for his health. And so on. But the institution of the subsistence farmer is one that is centuries old, and shows very little chance of losing continuity; it may bend, to be sure, but the possibility of a complete break with the past seems remote. Where the price or market mechanism is practically inoperative, change of any kind seems most difficult indeed.

But other peoples in other times have experienced population explosions and a rural exodus. How did France manage to feed its population that grew from some 18 million to 25 or 26 millions during the century *before* the French Revolution? A large part of this expanding population migrated into the growing towns and cities. But in France as the population grew, roads were improved, canals were built, and maritime trade increased; these developments were good for the towns, but they also served to pull the peasantry along with them, as it were, toward increased production. More up-to-date examples are not lacking: Canada, the United States, New Zealand, and so on, are cases in point. Tropical Latin America shows in many respects the reverse of the coin: The average small-scale subsistence farmer is not surplus or market-minded, and, even if he should be, the road or river tends to be a one-way street—i.e., the products that move over them tend to lose most of their value en route, as they must pay high transportation costs, or high taxes, or suffer outright confiscation at the hands of one who claims to own the land on which the produce was grown. Further, native peoples, ignorant of the official language, who occasionally try to enter the market economy are frequently, and sometimes even openly and flagrantly, robbed by the small village shopkeepers, who consider themselves civilized. As long as these things go on, it will be difficult to make the subsistence farmer market-oriented. Roads and rivers should be two-way streets, along which produce flows to market to be exchanged for cash or goods of sufficient value to make the trip worthwhile and to motivate further rewarding trips on the part of the producer of raw materials.

NATURAL AND SUPERNATURAL FORCES

The subsistence agriculturalist lives in a world pervaded by fears. His life is hemmed about by taboos, for evil spirits are at work everywhere. He may not be able to enter, much less to clear and grow crops on certain pieces of forest because of the spirit or spirits that live there. He may have to work on an infertile hillside instead of a piece of fertile alluvial riverbottom land, over which hovers the ghost of his old friend and compadre, Juan López—for Juan, late one night and full of aguardiente, fell face down in the little pond there and breathed his last. In Haiti the peasant may have to spend much time keeping the voodoo of his enemies off his own plantings and at the same time harnessing those occult forces of black magic for his own ends of bringing discomfiture and bad luck to those who wish him ill; he may have to bury the head of a white rooster in his neighbor's dooryard, or hang the right wing of a guinea hen in the palm tree closest his door, and so on. Thus, phantoms, demons, and horrible apparitions will be called forth to haunt his neighbor. Long and learned papers have been written about such practices and their implications, in many parts of the world; social anthropologists are doing outstanding work in this field. Suffice it to say that when a large part of one's daily life is taken up with propitiating the gods, or trying to, or wishing one could propitiate them; when the evil eye is a constant menace; when every wind, every heavy rain, every drought, every phase of the moon—in short every natural force—has its religious significance and must be interpreted; when indeed almost every act is portentous, then, although the individual's disciplined, hemmed-about, and inhibited life might seem to him—and thinking makes it so, remember—fulfilled, the fact is inescapable that his productive capacity and potential are, in the modern sense and to say the least, not at their maximum. These factors are mentioned merely to emphasize the truth that what is true of the world's better developed lands is equally true of the hand-to-mouth agriculturalist of the less developed areas, namely, that increased production, progress if you will, everywhere in the world is more profoundly affected by the motivations, attitudes, and capabilities of its people than by all other factors.

[A few paragraphs in brackets are indicated here in which to emphasize the fact that fear is a great brake on production among groups and individuals in many walks of life. The rancher in many regions—less often now than formerly, to be sure—sees little sense in increasing his herds and in breeding them up if a revolutionary band may come along at any time and drive them off, without ceremony and without compensation of course, only to barbecue them over the campfires of their peripatetic messhall.

[Latin American writers have used such incidents as the raw material upon which to base their novels. Gonzalo Picón-Febres dedicated *El Sargento Felipe* "to the honorable and industrious people of Venezuela—the real victim of our civil wars," and then goes on to describe in vivid prose the material and moral ruin of Felipe's home and family. Felipe was rounded up for army service by a 'government' recruiting patrol. While he was away, his livestock was driven off, his coffee was stolen, and his daughter became the mistress of Don Jacinto, a wealthy landowner. The novel is a series of pictures of country life, and particularly of the havoc of war. The soldiery, "pushed into war by hunger and misery, had as their highest ideal the booty to be stolen from those conquered in battle. . . . As they passed, the landowner trembled for the fate of his hacienda, the village church for the jewels of the virgin, the businessman for his tiny savings, the working man for his life, and the women for their honor."

[The foreign corporation with vast tracts in bananas or sugarcane, or whatever, may become so fearful of confiscation without compensation as to allow production to decrease, sometimes even to zero. And of course the fear of "*el quedirán*," of public opinion, may effectively keep people from introducing a new crop, no matter how productive, and a hostile political climate is often sufficient to nip production in the bud or cut it once it has started. The fear of unstable prices in any agricultural activity that is completely market-oriented is also a significant factor in inducing caution, or even inaction, in the production of crops.]

PROTEIN-CALORIE MALNUTRITION

To return to the subsistence farmers: The diet of such hand-to-mouth farmers is extremely monotonous for months at a time; protective foods such as meat, eggs, and milk products are in short supply; the protein intake of these families is often inadequate and many of the members show signs of undernourishment or malnutrition—a bad skin condition, depigmentation of the hair, the so-called "Dutch hair" in Brazil, and so on. One of the consequences of inadequacy in protein intake (kwashiorkor) is cirrhosis of the liver, which is extremely common even among children in many tropical countries; such people are extremely susceptible to infections and infestations to which better-fed people would either be immune or highly resistant. Although it may be medical heresy to say so, there may be things of the spirit that in some measure overcome some of these nutritional deficiencies. Once these simple people have propitiated the gods, in whatever is the customary way, they are resigned to their fate; instead of being a prey to tensions they are relaxed, kindly, hospitable, and fatalistic: whatever is to be, will be—it is the will of God; a certain amount of fasting, even when involuntary, may perhaps provide an opportunity for the operation of certain emergency mechanisms built by nature into the human body. Manmade institutions also have evolved that increase survival advantage; every effort is made by the whole family to get to the nearest *caserío*, or village, on those days of the week or month that are market days, even though the trip requires a whole day, or even longer; going to market serves many needs besides the need to buy merchandise and to sell produce, and one of the important benefits for the entire family of attending market is that everyone has a chance to consume quantities of protein and fats in the form of roast pig, guinea-pig, toasted nuts, and so on, as well as fermented beverages, such as chicha, pulque, palm wine, and the like, that contain all the factors of the juices from which they are made as well as those generated by the microorganisms involved in the process of fermentation.

Comparative studies of dietary regimes carried out recently have shown that teenagers in Michigan who practically live on soft drinks and snacks may have a diet less in balance than their Mexican counterparts who consume substantial amounts of black beans, tortillas, chile peppers, and pulque. Malnutrition may be a reality even in the midst of plenty. "They are as sick that surfeit with too much," says Nerissa in *The Merchant of Venice*, "as they that starve with nothing." Ancestral habits and cultural influences greatly limit the type of foods that are acceptable and often impose the use of others which are actually deleterious.[2]

It is not enough to tell people that certain foods are good, and good for them, and that they can easily produce them, for no amount of urging will get them to produce—or even to consume—foodstuffs that they do not, for whatever reason, *want* to eat. A case in point: A few years ago on a 10-day jeep trip from Bogotá to Cartagena, Colombia, our party stopped overnight at a little village surrounded by a vast area inhabited by self-sufficient agriculturalists, where we were welcomed by the local priest who gave us lodging in his home. We were extremely hungry and ate heartily of the excellent meal the kind padre set before us, indeed down to the last crumb. Seeing this devastation, our host excused himself from the table, left the room, and came back with a 10-pound can of cheese spread, marked in Spanish, "Gift of the People of the United States to the people of Colombia." This can had been opened, but very little of it had been used; when asked if we would like this, we answered in the affirmative, and we began a kind of second round of eating. Our generous host beamed his delight at this cheese finding such a good market, for he pointed out that even his most poverty-stricken parishioners were not interested in it, that, although it tasted and smelled like cheese, and he had assured them that it was cheese, it was soft and lacking in resistance. In Spanish, cheese is *macho*, that is, it is a male food, the opposite of soft and malleable; it must be one that offers resistance to the teeth, that must be bitten off in hard chunks, and must be chewed on with vigor if one is to make headway with it. Since this cheese spread did not correspond to the local concept of what a cheese should be, few people were interested in it, including himself; he had used some of it to mix with chicken feed and the fowls had rather enjoyed it, but he was happy to find people who ate it with such relish, and he presented us with an unopened can to carry along with us the next day!

THE PRIMITIVE FARMER: CULTURALLY AND TECHNOLOGICALLY ILL-FAVORED

The millions of subsistence farmers have for the most part lived out their obscure lives beyond the impact of almost all those factors that we associate with modern life. Education has not penetrated their world, which means that, among other things, the fundamentals of modern hygiene and asepsis are not known—even the boiling of water to kill noxious, waterborne bacteria is not knowingly practiced. Fortunately for the visitor to the little thatch-roofed hut in the forest, water has first to be boiled to make the coffee or the sweetened water that is so hospitably proffered by one's host. These primitive farmers

[2] Frederick J. Simoons, "Eat Not This Flesh," University of Wisconsin Press, Madison, 1961.

are not only illiterate, they know next to nothing about balanced diets, soil science, seed selection, technology, mechanics, and so on. It is little short of a miracle that these *milperos*, *conuqueros*, *rozeros*, or whatever the local words for self-sufficient farmers, living largely apart from other human beings, are still the carriers, albeit to be sure only in the most simplified forms, of elements of nonmaterial culture, such as language, religion, and social organization. Time and again these people, living what seems marginal, obscure lives, will be found to have the manners and the *savoir faire* of people who have had cultural advantages. They are by no means examples of *Homo ferus*, the abandoned forest children of the Middle Ages; they do not perhaps have the sense of fulfillment that comes from the intimate participation in the creative activities of a group, but they have not become dulled by automation and dial watching; they are not bored; their lives may seem monotonous to the casual observer, but they are a challenge compared to those of the ordinary factory workers of today; life is hard and uncertain but their will to live is great; suicides are unknown; they are so intent on keeping body and soul together that they have no time for brooding over the difficult lives they are leading.

Self-sufficiency at the family level means lack of interest in innovations, such as the introduction of new techniques, new crops, and so on. The head of the household at present depends on the outside world practically not at all; hence why should he effect changes suggested by those from outside? A change in the age-old routine has in the past often meant disaster. It took centuries for the European peasant to adopt corn and potatoes, the great food crops brought from the New World. The first to accept such innovations are usually those who have enough food supplies from other crops to keep them from being dependent upon the new crop for *survival.* A farmer naturally will follow the routine that has meant survival for his forefathers as well as for himself. But this routine, this self-sufficient agricultural system, means that practically everyone must engage in the same kind of activity to produce sufficient food—there is no chance for a large surplus, for capital accumulation. As the population increases, the cropping phase must be lengthened and the period of forest fallow is decreased, with a consequent drop in production; then the people must reduce their numbers or migrate, as must have happened often throughout history.

Those who begin as subsistence farmers, but who ultimately produce a surplus may even be able to support advanced civilizations. The pre-Columbian Mayans lived almost exclusively on corn, grown on small plots, the soils of which were neither worked, nor fertilized, nor irrigated. The surplus they produced was used to support an urban elite. As the population increased, the period of time a given plot could be in second-growth brush or forest was shortened as the pressure of population on the land resource increased. Hence it became necessary to establish *milpas* farther and farther away from the urban centers where the farmers had their homes and to which they had to carry their crop on their backs, often as much as 50 miles, or even more. Besides, they had to pay heavy taxes in kind to the political and religious authorities. It is possible that the cost in time, of transportation, *plus* heavy taxation, ultimately made the system unworkable, and the population, like swarms of bees, migrated in all directions to establish new centers closer to their farms; thus new cities were being founded in Yucatán at the same time that older ones were being abandoned to the encroaching second-growth brush and forest.

And in another century or so the cycle was completed again—from subsistence farmer, to populated urban agglomeration, to disintegrating urban center, back to the subsistence farmer on his small plot far from any organized settlement.

After exhaustive studies of present-day soil fertility in the Petén, Dr. Cowgill concludes that "with present agricultural methods the central Petén is capable of permanently supplying food needs of perhaps 200 people per square mile and certainly not less than 100 people per square mile (compared to 1.5 people per square mile for the entire department at present). . . . In other words, half the adult population could be full time, non-food producing specialists supported by the other half of the population."[3]

Most of the less-developed nations, with their huge contingents of subsistence farmers, have heads too small for their bodies, as it were. The rural areas, unorganized and poorly coordinated, are like the lumbering bodies of gargantuan dinosaurs, capriciously lunging about, with little or no direction from the central nerve centers, i.e., the regional and national capitals, themselves in imbalance because of the influx of rural dwellers and the consequent accretion of slums. The concept of the hollow frontier does not fit into this picture at all. The vast, sparsely populated areas are largely in forest fallow; where subsistence agriculture is the way of life of practically all rural dwellers, the maximum human carrying capacity is a function of the amount of forest land available for clearing at any given time, which in turn depends on the amount of time required for afforestation, or the regrowth of forest on the cutover sections, and for the soil-formation thereby implied. Wherever subsistence agriculture is a reality, the concept of the hollow frontier is inapplicable, for such a frontier cannot exist there; the terms are territorially mutually exclusive.

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[3] Ursula M. Cowgill, "Soil Fertility and the Ancient Maya," Transactions, Connecticut Academy of Arts and Sciences, vol. 42, Oct. 1961, p. 40.

A SELF-SUFFICIENT FARMER PRO TEM.

Political upheavals and violence of any kind may bring about a marked increase in the number of subsistence, or near-subsistence, farmers. The violence—*la violencia*—in Colombia during the past decade or more has had the effect of breaking up many formerly settled communities, some of whose inhabitants migrated to the cities in search of a livelihood and protection, while others fled to the unsettled areas in the mountains or in the eastern plains of the country. One such refugee, living some 10 miles up the Meta River from Puerto López, was from the mountains of Tolima, where he had been able barely to scratch out a living from his tiny plot. Murders of farmers in his vicinity became so common that he feared for his life and moved to town, but he had no skills and could find no way of making a living. He was finally able to get a ride in a cattle truck returning to Puerto López from Bogotá. From there he went upriver in a dugout canoe with his wife and children, and began to grow a crop of corn at the edge of the river. He is at present a subsistence farmer, to be sure, but one that might correctly be referred to as a subsistence farmer in transition, because as soon as there is a market and he can produce a surplus he will be interested in entering a money economy by supplying that market with surplus corn, a fattened hog, a few chickens, papayas, or a bunch of cooking bananas. M. Rodriguez had as helper a Huitoto Indian girl, who was learning Spanish and in general taking on the ways of the sedentary agriculturist. Thus this was a case of a subsistence farmer in transition using the labor of an Indian girl in process of acculturation. Her children will probably be better adapted to hot country farming than either she or the Rodriguez family are at present.

BETTER RURAL LIVING CONDITIONS OR CITY SLUMS?

At present the self-sufficient farmer operates in a kind of social, economic, and political no-man's land that officially belongs to a nation or political entity, yet the area under cultivation, or forest fallow, is not an "effective" part of the nation. The Jesuits early saw the necessity of having the seminomadic Indians of many parts of the Americas assembled in villages, or *misiones*, if they were to have effective control over their charges. Modern governments may perhaps have to act in a similar manner, for it would seem that their leaders can hardly afford to allow their unskilled farmers to swell the slum sectors of cities where their labor cannot be utilized. It would seem more rational to keep them on the land by having them engaged in tasks they *can* perform, such as the building of roads and dams, drainage ditches and canals, and even crude schools, houses, and community centers, and so on, rather than to be allowed to agglomerate into an amorphous mass in shanty towns, without streets, lights, water, or doctors, thus creating a kind of cancerous growth, a subproletariat, a class of pariahs or untouchables. Once they have enjoyed just a few of the amenities associated with the bright city lights, the modern Lorelei, once they have lived in modern times, even if just barely on the margin of modernity, getting literally fringe or crumb benefits, they will never willingly return to isolation and a way of life that has not changed in thousands of years—their eyes will continue to be on the stars, rather than on the pitfalls of slumdwellers. Even illiterates can enjoy electric lights, moviehouses, radios, television, music, asphalt streets, running water, and sanitation, and they can dream of the time when they might enter the Promised Land of decent houses, schools, libraries, and supermarkets; one of the ways then to build up uninhabited or sparsely settled rural areas is to make some of these amenities available in the county as well as in town.

A kind of national service on the land might be instituted, since the only investment most self-sufficient rural dwellers can make toward the development of their country is their labor; and in future there is going to be less and less employment for the unskilled worker, either manual or clerical. In many of the less-developed areas where self-sufficient agriculture is the norm for a large part of the population, authoritarian regimes are well-entrenched and represent the political status quo and continuum. *Barriga llena, corazón contento* (a full belly, a contented heart) is an old Spanish proverb; people used to authoritarian regimes would find little to complain of regarding national service on the land if performing that service meant receiving three square meals a day, along with even a few of the amenities usually available in a modern urban community.

CONCLUSIONS

The small-scale independent farmer simply cannot bring the full weight of modern technology to bear on the problem of producing food, fats, oils, fibers, rubber, medicine, and lumber, which is modern agriculture's job. Wherever the new methods of scientific technology are being applied to farming, there are huge surpluses, a veritable cornucopia of tropical plenty, of bananas, palm products, coffee, cacao, pineapples, and so on.

Agricultural surpluses are a major source of the investment capital necessary to finance the development of the less-developed countries, but small holdings do not seem to attract the enlightened management or the capital required for the modern equipment, fertilizers, pesticides, marketing, and so on, necessary to produce agricultural surpluses; hence, if governments adopt policies of land fragmentation that make agriculture less rather than more efficient, they invite economic stagnation, or worse. The subsistence farmer is in many

1. Squatter's clearing and hut on good alluvial soil at Tamazunchale, Mexico. The corn crop has been harvested. The patch of cooking bananas and yuca is to the left, beyond which is an abandoned clearing. Note beehives in front of the house; papaya tree in, foreground.

2. A subsistence farmer's hut on the natural levee of the lower Calima River, Chocó Colombia. The main items in his diet of corn and bananas are supplemented by the fruit of the native Chontaduro palm (Pejibaye), seen surrounding the house, and fish from the river.

1. Subsistence plots south of Lake Valencia, Venezuela, near the hamlet of Güigue. The plot of corn in the foreground will soon ripen; the second, in the middle ground, is about a month old. The farmer has planted yuca on the rocky slope in the background.

2. A canefield on the hacienda Tacrigua, Lake Valencia Basin, covers all the good alluvial soil, and the only land available for subsistence is on the hillsides; these farmers almost every year enter the money economy of the country by working as cane cutters.

1. An isolated hut on a hillside south of Valencia, Venezuela, with plants of cooking bananas near the house and a cornfield on the steep hillside to the left, a prey to erosion.

2. View from the back of the hut in plate 2, figure 1, showing a cornfield to the left, a former clearing to the right in "forest fallow" (rastrojo), with virgin forest in the background.

1. The subsistence farmer changes very little from decade to decade and from country to country. Pictures on this and the facing page are of Mr. Sánchez, a subsistence squatter (called *parásito* in Costa Rica), and his home and plot, taken near San Vito, in southwestern Costa Rica, February 18, 1964.

'Mr. Sánchez stands beside his house. From the huge trees he fells he saws up by hand the planks seen in the foreground, which he sells to market-oriented coffee growers in the vicinity.

He had planted bushes of chile peppers and other herbs as well as a few stalks of tobacco for his own use; unhulled beans and unshucked corn were drying on the roof of the house, made entirely, roof and walls, of the trunks of slender palms split in half.

2. Mr. Sánchez looks out over a landscape of fallen logs; the soil is fairly intensively used: stalks of mature corn are seen to the right, while the patch of land to the left, this side of the lean-to, is just being planted to corn. Beans are planted with the corn, whose stalks grow up just in time to act as poles for the climbing beans. To the right of the lean-to is a patch of yuca, a staple root crop that hardly ever fails. In the background to the right the cutting edge of the cultural frontier meets the uncut virgin forest.

1. Closeup of Mr. Sánchez's house, with a pepper plant in the right-hand foreground, and a plant of cooking bananas (plantains) behind our host. Corn and beans are to be seen drying on the roof.

The primitive hand press, just to our right of Mr. Sánchez, which consists of a pole stuck through a hole in a post, is used to squeeze the juice out of a stalk of cane; the juice is used straight, or to sweeten coffee; when fermented, it is a refreshing drink.

2. Mr. Sánchez standing beside his lean-to at the far end of the clearing from his house, with the mass of fallen trees in the middle ground and virgin forest still standing in the background.

The 70 million Sánchezes in Latin America, even on the small plots they do not own, are a conservative group; they are indeed a prey to fears of the forces unleashed by both man and nature; but they are imbued with the spirit of pioneers, not easily swayed by the winds of revolutionary change advocated by a floating, landless proletariat, or willing meekly to submit to the whims of a power elite intent upon preserving the status quo.

1. In the Western Cordillera, west of Popayán Colombia, a rancher has grubstaked landless laborers to clear the forest, with the first crop of corn as their payment; then they plant the cleared land to grass, turn it over to the landlord, and clear more forest land. The white, black-eared cattle grazing in the foreground are a hardy triple-purpose (used as work animals, as well as for meat and milk) breed that seems to have evolved in Antioquia.

2. A settler on the banks of the Meta River, who fled the poverty and political violence endemic to his mountain province of Huila. His wife and daughter and the Indian girl, to the right, help him to grown corn, beans, yuca, and squash on the natural levee of the river. It is a hand-to-mouth existence now, but Mr. R. looks forward to the time when he can produce a surplus—corn, cooking bananas, a fattened hog perhaps—that will tie him to the market at Puerto López.

The small, thatch-roofed hut of a subsistence farmer along a stretch of new road from Bolivar (Valle) to Buenaventura, in Colombia; the photograph was taken from the back of another hut, with its banana plants and a papaya tree in the foreground.

A clearing in the forest near Yapacani, eastern Bolivia; ears of corn, tied together in pairs by their shucks, form the clump in the center of the picture. The woman of the house is coming forward with some delicious papayas, for which she was very loath to accept any payment. The men were working in the forest.

respects a museum piece, an anachronism. The future of agriculture certainly belongs to the large-scale operator, whether an individual, a corporation, or the state, but for today and for the immediate future the subsistence farmer is forced to survive by following his time-honored regime on the land or to become a completely uprooted slum-dweller.

More and more, young people obstinately refuse to follow in the footsteps of their elders, to lead lives of drudgery, penury, and isolation. The psychological factors that have already been so effective everywhere in achieving the rural exodus are operative even among the remotest subsistence farmers. These factors will continue to exert their powerful influence until that day when the life of the subsistence farmer will be transformed, when his home will be provided with those amenities that make for at least a semblance of ease and well-being, when his village will have become a genuine social and cultural center, full of life and gaiety, no longer isolated, backward, and wretched.

And that day will come only when there is widespread education in farming methods and techniques, when agriculture will be as assiduously served by educational institutions as are modern industry and the liberal professions, when soils scientists, agricultural engineers, and county agents will have no more feelings of inferiority than do biochemists or nuclear physicists. To achieve this transformation is a tremendous task for the leaders of nations with vast undeveloped tropical regions. These leaders already have the means and the ability to carry forward this great campaign; they should now show the determination to effect this revolution, peacefully. Their survival depends on it.

The subsistence farmer lacks a formal education, but is by no means unintelligent; he is a cautious operator whose activities conform to age-old practices on land that does not belong to him. He is where he is, geographically and from the point of view of development, for various reasons: his own tradition and the power position of the elite favor the status quo. He often suffers from malnutrition as well as intestinal and blood parasites, so that he has just enough energy to cope with his life as it is. He is either too far from market to think in terms of sizable marketable surpluses, or, if he does chance to do so, some one turns up with a document proving himself to be the "owner of all this land," and from experience the squatter knows that it is "healthier" for him to move farther into the forest without a struggle. He has no capital, few tools, and only those skills that have enabled him to survive with the most primitive of farming techniques. Armed only with a cutting tool—apparently the Mayans used the blunt stone axe—millions of subsistence farmers over the millennia have cut over billions of hectares of tropical forest. He has done what the Scottish

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crofter, the New England farmer, the "Okies" of the 30's, the Chinese and the Indian peasant, and many others, have often been unable to do, that is, he has survived on farming alone. He has on a trial-and-error basis devised a system of agriculture valid for his cultural equipment in his physical milieu—by planting the right crop or crops at the right time, the subsistence farmers of the world have achieved survival advantage for themselves and their descendants; those who failed to follow the routine were weeded out as impartially as a sieve retains those particles larger than its mesh. Hence, the problem is not one of survival—they *have* survived—but rather one of whether they are to play the role of the Trojan Horse in the Harlems, Notting Hills, and their equivalents in the less-developed areas of the world, or whether they will be economically, socially, and politically integrated into our modern scientific, technological society. According as this integration is or is not effective, millions of subsistence farmers will achieve levels of living to which human beings in this modern world are justified in aspiring, or they will continue to lead obscure, poorly rewarded lives—either in the almost trackless forests or in the growing slums of great cities—that are marginal to the powerful currents of modern technology.

I have, for more than three decades, observed the way of life of humble, primitive agriculturalists, from Mexico to Patagonia; it seems fitting to close with a quotation from Rene Dubos in which he uses part of a sentence from Lucretius's *De Rerum Natura:*

> Men come and go, but however limited their individual strength, small their contribution, and short their life span, their efforts are never in vain because, like runners in a race, they hand on the torch of life.[4]

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An Archeological Reconnaissance in Hadhramaut, South Arabia—A Preliminary Report

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[With 8 plates]

Our knowledge of culture history in the Old World is surprisingly uneven after more than a century of archeological research. For some areas and for certain time periods, such as Dynastic Egypt, Bronze and Iron Age Palestine, and Classical Greece, the outline of culture history has been firmly fixed, and the future task is largely one of refining and filling in details. But for other areas, and for such related studies as interregional contacts, only sketches of the culture history—in varying degrees of completeness—are available, and only within the last decade or so have archeologists devoted themselves to fixing the bare outline.

Southern Arabia is one of these latter areas. Located on the fringe of lands of great archeological interest, and burdened with a reputation for inhospitality and insalubrity, this region did not receive its first professional archeological mission until 1937. At that time, Gertrude Caton Thompson excavated several structures dating from the fifth to the second centuries B.C. at Hureidha in Hadhramaut (Caton Thompson, 1944). The next field research was carried on by the American Foundation for the Study of Man Arabian Expeditions led by Wendell Phillips and under the successive archeological direction of W. F. Albright, F. P. Albright, and R. L. Cleveland in

Wadi Beihan, at Marib, in Dhofar, and at Sohar (Bowen and Albright, 1958; Cleveland, 1959, 1960; Van Beek 1952, 1961). The results of these expeditions were considerable. Chronology for the period from about the 10th century B.C. to the 7th century A.D. was largely fixed and much information on the culture history was discovered, e.g., data on irrigation techniques and installations, and on successive waves of cultural influence from other parts of the ancient world.

But enormous gaps in our knowledge remained. Little systematic work had been done on prehistory, with the result that the development and affinities of the early cultures of the region were largely unknown. Further, no systematically collected evidence had come to light of human occupation between the Middle Paleolithic stage—represented by artifacts picked up by Miss Caton Thompson's team and others—and the 10th century B.C. in Wadi Beihan, or the 5th century B.C. in Wadi Hadhramaut. There were also many unanswered questions regarding the role of southern Arabia—if indeed it played a role—in the diffusion of cultural traits, the development of trade, the migration of man, and the interchange of cultivated plants and domestic animals between Africa and Asia.

To obtain data that would contribute to the solution of these problems, an intensive archeological reconnaissance in one of the major drainage systems of southern Arabia was organized and directed by Van Beek. After much consideration, Wadi Hadhramaut was selected as the survey area, because it is one of the two or three most fertile and intensively cultivated valley systems in southern Arabia today, and presumably was throughout antiquity also. Such an area is likely to have been continuously inhabited, and thus to contain evidence for a complete culture sequence from earliest times to the present.

Wadi Hadhramaut is located in the East Aden Protectorate, approximately 165 kilometers north of the southern coast of the Arabian Peninsula (pl. 1:1). It runs roughly parallel to this coast for a distance of about 200 kilometers (fig. 1), and then gradually turns southeastward to empty into the Gulf of Aden. On the west, near Qarn Qaimah, the wadi is approximately 15 kilometers wide, but eastward its width gradually diminishes to little more than 2 kilometers just beyond Tarim. Except for the last few kilometers of its course where it is perennial, the upper reaches of the wadi are dry. Occasionally a *seil* (Arabic for flash flood), formed of the runoff from the plateau, covers part—rarely all—of the wadi floor. At present, some areas of the main wadi and virtually all silt-covered tributaries are cultivated by means of *seil* (flash-flood) irrigation. Elsewhere, and especially in the main wadi where the water table ranges from about 15 to 20 meters deep, well irrigation is extensively

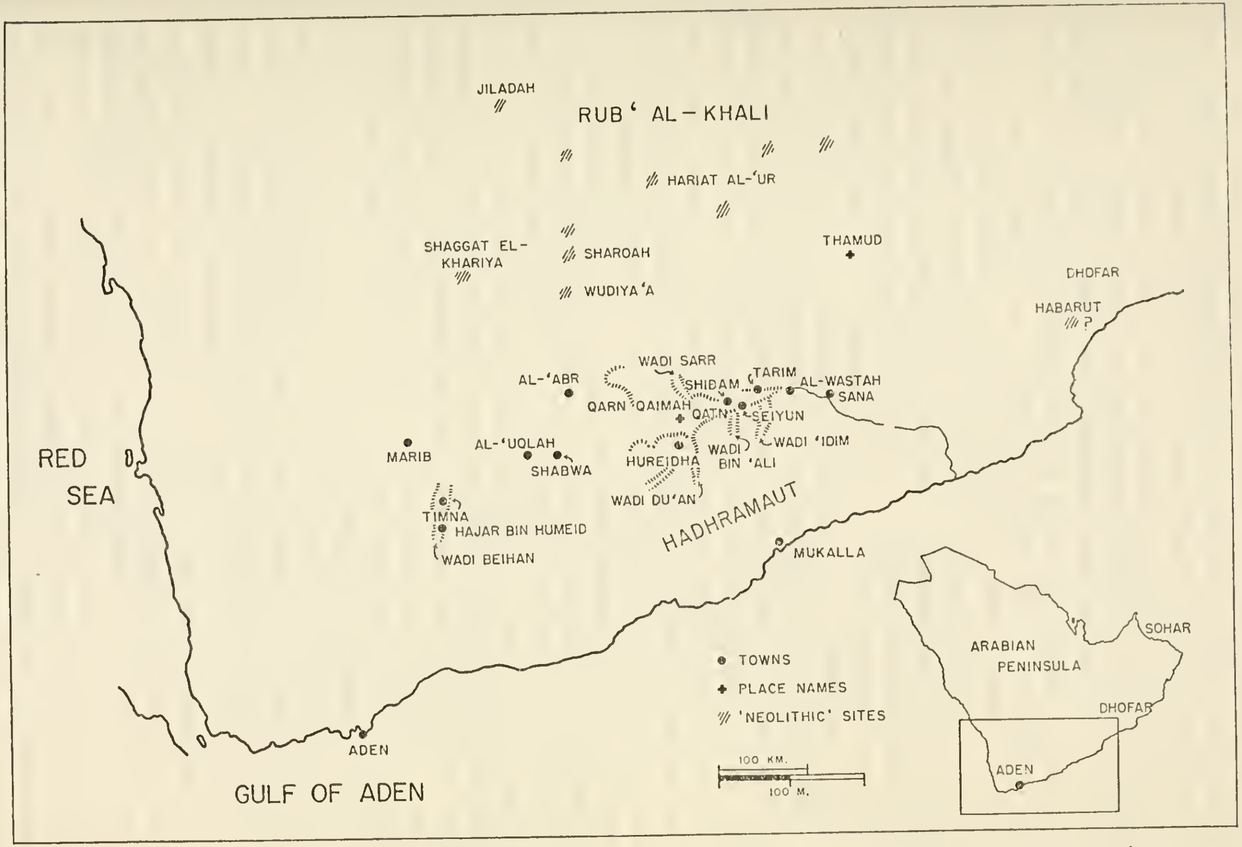


Figure 1.—Map of southern Arabia and Wadi Hadhramaut. Locations of known "Neolithic" sites are approximate.

used and is the basis of agriculture in the area. Rainfall averages less than 20 centimeters per year. Wheat and dates are the chief agricultural products, but tomatoes, onions, eggplant, and carrots are also grown. The principal livestock are goats and sheep, oxen used in working the fields, and camels used in both transport and agricultural activities. Since Wadi Hadhramaut is an inland area, virtually all of its commercial contacts are with the coast at the present time, and although camel caravans still carry commodities they are rapidly being replaced by motortrucks and airplanes. The present population of the wadi is estimated at 100,000 people, mostly settled in three cities, Tarim, Seiyun, and Shibam, and a host of villages and small towns. The most distinguished feature of Hadhramaut is its magnificent mud-brick architecture, in which some buildings attain a height of eight stories and are decorated with elaborate geometric relief. This information on the Hadhramaut today is necessary for an understanding of the area in antiquity.

The expedition, conducted under the auspices of the Smithsonian Institution with additional financial support from the National Science Foundation, had a staff of one part-time and three full-time scientists. Van Beek was responsible for all ceramic-phase sites from earliest times to the present, but was primarily concerned with sites of the pre-Islamic period, i.e., before the seventh century A.D.; he also studied the megalithic sites which apparently belong to a preceramic phase. Glen H. Cole investigated prehistoric, i.e., preceramic, lithic sites, and assisted Van Beek with megalithic sites. Albert Jamme recorded ancient South Arabic graffiti and formal inscriptions, and also undertook the important task of accurately recording place names for future map additions and corrections. For 1 month, Henry W. Setzer collected modern mammals for the study of the present fauna of the area and to facilitate identification of bones from future archeological excavations.

During the 3½ months of fieldwork, from November 15, 1961, to February 25, 1962, the expedition surveyed approximately 130 kilometers of the main wadi and portions of all tributary wadies. From just beyond Tarim to the vicinity of Shibam—a distance of about 65 kilometers—the area was intensively investigated for 2½ months; during the remaining month, only known sites and certain selected areas in the region from Shibam to Qarn Qaimah were studied. This procedure enabled us to achieve a balance between detailed examination and broad coverage of the terrain. Most of the survey was conducted on foot, but local vehicles were hired to facilitate the examination of larger tributaries and more distant sites. Each site was plotted on a topographic map; detailed notes, photographs, and when possible sketch plans were made; and large samplings of surface artifacts were collected. At one site, test pits were dug which clarified the nature of the disturbance of debris and the process of erosion; at another, soil samples were taken from the exposed silt beneath one of the earliest towns to provide data on the environmental situation at the time the silt was deposited. Graffiti and inscriptions were recorded by means of scale drawings and by both black-and-white and colored photographs.

For this interim report, each archeologist prepared a paper describing his area of research; these papers were edited and assembled by the senior author to form this article.

PREHISTORY

Stone artifacts are widespread and abundant in the Hadhramaut. Except on the broad alluvial flat in the main wadies, sporadic flakes and other artifacts can be picked up anywhere from the limestone rubble and gravel flanking the flat, up to and including the plateau surface over 300 meters above. Collections of artifacts were made from 110 localities extending from the Tarim area on the east to Qarn Qaimah, some 130 kilometers to the west. All artifacts were collected from the surface. Apart from pre-Islamic village sites, no place was seen which would appear promising for archeological excavation. Any Pleistocene deposits which exist must be buried in the deep silt fill of the wadi system.[1]

The geology of that portion of the Hadhramaut investigated is strikingly similar throughout. One is everywhere confronted with Eocene limestones, which form precipitous cliffs. These overlay Cretaceous sands and silts, forming low spurs and outliers which protrude into the wadies. These lower deposits usually are capped with rather thick breccias (cemented talus, up to 10 meters thick in one measured section) apparently graded to a level well below that of the present wadi floors. Traces of an earlier phase of wadi erosion seem to be found in the relatively slight inclination of the breccia-capped tops of some of the spurs and outliers. These "flat" tops, commonly strewn with stone artifacts, evidently relate to a wadi floor at a higher level than that of the present. The generalized section given in figure 2 is everywhere applicable except that in the smaller tributaries, where the alluvial silt flat is not present, the wadies are floored by more or less irregular gravel and rubble spreads, alluvial fans, talus material, and channel gravels which are locally incised and terraced. Also, the occurrence of spurs and outliers is more exceptional than characteristic; a section taken at random is more likely to have a breccia-capped or talus slope extending from below the lower cliff-forming limestone directly to the wadi floor (dotted line, fig. 2), fringed at its foot by talus and outwash material.

[1] Caton Thompson and Gardner (1939) regard certain terrace deposits along the modern channel cut in Wadi 'Amd near Hureidha as being of Pleistocene age.

Although an occasional isolated artifact of particular interest was collected, the vast majority of material was taken from sites which, in nearly all cases, appear to be localities of human activity. In a few instances, it is possible that the collected artifacts had been transported—probably no very great distance—by running water. The sites can be grouped according to the morphological features upon which they occur: On the plateau where artifacts are often found in great abundance over considerable areas; on talus slopes where artifacts—presumably workshop and mining debris—are retained more or less in place by the coarse, angular limestone cobbles; on benches formed by the lower cliff-forming limestone; on the "flat" topped spurs; and on low-lying, terraced, alluvial remnants, gravel and rubble spreads, and mounds of Cretaceous sediments.

Sites on the upper plateau remnants (fig. 2–A).—A good quality chert occurs at the top of some of these buttes and was very extensively worked; the heaviest artifact concentrations are found on these surfaces. In some cases, the artifacts are so abundant that they form a solid pavement (pl. 1:2). At one such locality southwest of Ghurfah, near the confluence of Wadi Jibb with the main wadi, a crescent-shaped butte contains two areas of dense artifact concentration separated by some 200 meters of relatively sterile ground. The area covered by artifacts is roughly 50,000 square meters. Within this area, a 2-meter square was plotted at a randomly selected point and 529 artifacts were collected from it. The majority of these artifacts are small, relatively fresh, and characterized by a pink or light reddish-brown patina. This is in sharp contrast to the larger artifacts with dark brown-to-black glossy surfaces which are generally found on the main plateau surface. A few of these larger, dark-colored artifacts are, in fact, to be found on the upper plateau remnants as well. This suggests that at a period much later than that of the main human activity on the plateau, the isolated chert resources of these old plateau remnants were exploited.

Sites on the main plateau surface (fig. 2–B).—Because of the difficulty of gaining access to the plateau surface in certain areas, this feature was investigated less intensively than those more easily reached from the wadi floor. Access to the plateau is most readily gained via certain tributary wadies which cut through the upper cliffs. Such wadies are not abundant; most of the small wadies cutting into the plateau (see Caton Thompson and Gardner, 1939, plate 1) hang well up on these cliffs (pl. 2:1). The fact that artifacts occur abundantly around the upper portions of these access wadies suggests that the same routes were available during Upper Pleistocene times (to which the artifacts concerned must date). At one locality near Tarim where the plateau was reached by employing cliff-hanging tactics, artifacts were scattered over a wide area and found only occasionally.

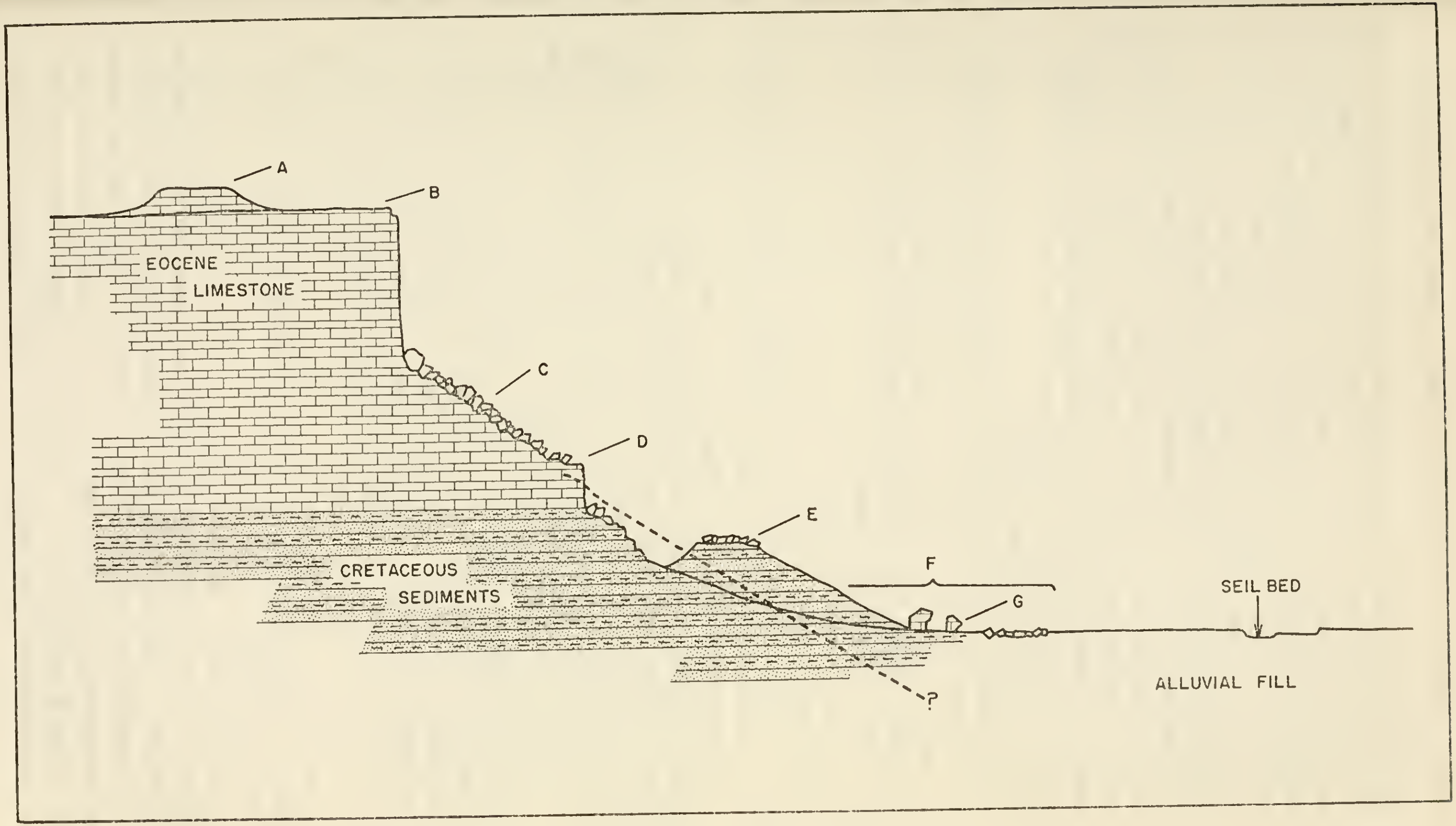


FIGURE 2.—Generalized profile of Wadi Hadhramaut.

It is likely that the impression of heavy artifact concentration on the plateau gained by restricting investigation to the area along and near the wadi edge, especially near access routes to the wadi bottom, would not hold true for the *Jol* (as this dissected limestone plateau is known) generally. Caton Thompson's experience would tend to lend weight to this supposition. On making the journey from the coast to Tarim, virtually no "paleoliths" were found until the edge of the Wadi Hadhramaut above Tarim was reached (Caton Thompson, 1953, p. 191). On this trip, intensive search was not possible. It is quite likely that scattered implements would have been discovered if she had been able to make an intensive search, but such heavy artifact concentrations as those that occur along the wadi edges could not have been overlooked easily, even from a moving vehicle.

Trimming and workshop debris is largely wanting on the plateau. The tools and flakes occurring there are characterized by a dark brown to nearly black glossy patina. Sometimes in the vicinity of those small buttes which bear a supply of chert, small numbers of the lightly patinated artifacts which are common on the tops of the buttes are found on this lower surface as well.

Flint and chert are usually not far away; they are found in the underlying limestone and are exposed in places along the access wadies, or in the cliffs and fallen rock easily reached from them.

Talus sites (fig. 2–C).—Artifacts do not seem to occur in any abundance on the upper talus slopes. Unlike most of the lower-lying sites whose locations can often be predicted, the upper talus is everywhere similar and presents no clues as to where artifacts might be found. When artifacts were chanced upon, they generally consisted of a few core trimming flakes and perhaps an occasional core. In a few cases, however, presumably where the flint or chert was of good quality and/or particularly plentiful, such workshop debris occurs in considerable abundance. This mostly seems to have undergone much less patination than the material exposed on the plateau above and on the limestone bench below. This may indicate that this material was worked later in time, or, more likely, that since it occurs between blocks of limestone on the talus slope it is much more sheltered from the sun, is possibly more protected from frequent wetting by dew, and perhaps from whatever other factors might contribute to forming the dark desert patination.

One talus site of particular interest deserves mention. This is a flint mining site on a high ridge in the Qatn area (pl. 2:1). Nodules of flint up to 10 or 15 centimeters in diameter were exposed; these had been flaked off flush with the limestone surface. The limestone proved to be very tough; Cole was unable to extract any of the nodules with the aid of a geologist's pick. From the relatively fresh, somewhat concave surface of the limestone, it appeared that a surface layer of weathered material had been chipped away and the flint nodules recovered, but as fresh limestone was reached, the flint miners had to content themselves with flaking what they could from the embedded nodules. Trimming debris could be found for a considerable distance down the slope below the site of mining operations.

Flint or chert was similarly trimmed from detached blocks of limestone. In some cases where the block was sufficiently small, the matrix was apparently flaked away to bare the desired nodule. In any event, it is not uncommon to find large trimming flakes that are part chert and part limestone.

Limestone bench sites (fig. 2–D).—Stone implements, flakes, and debris commonly occur on the bench at the top of the lower cliff-forming limestone. In places, especially at wadi junctions, this bench becomes quite wide forming a large, very flat area. These features, which provide a flat surface free of limestone rubble, a good view into both wadies, and easy access to the wadi floor, seem to have been a favorite camping situation for certain of the prehistoric inhabitants of the Hadhramaut. They usually contain artifacts in sufficient abundance to warrant collection. Occasionally broad, flat, bench localities were found which had few or no artifacts, but generally this seems to have been the result of a local deficiency of raw material for toolmaking.

The artifacts found on the bench sites appeared—superficially at least—to be similar to those collected from the plateau, although occasionally material reminiscent of that found on low-lying features was encountered. The artifacts are usually darkly patinated. It was noted, however, that more trimming debris is to be found on these sites than on the plateau, presumably reflecting easy accessibility of raw material from the talus which is always close by.

Although the bench sometimes narrows to a mere ledge or disappears altogether, it often provided the best means of access to lower-lying features. It was easier to walk along this bench and descend to possible sites than to negotiate the talus slopes and rubble fields situated at their foot. It was from this practice that most of the talus sites were discovered.

Sites on spurs and outliers (fig. 2–E).—Artifacts are generally found atop these features, and often occur in abundance (pl. 2:2). On the higher, breccia-capped spurs and outliers, the material seems to be indistinguishable from that of the bench sites. In fact, the intervening cliff is sometimes quite insignificant, being only a few meters in height, and a single spread of artifactual material covers both bench and the upper portion of a spur. Flint or chert is often locally available (from the breccias), and workshop debris is generally found mixed with the "finished" artifacts. These spurs frequently protrude into the wadies in such a manner as to command an excellent view of the surrounding terrain, and for this reason they were commonly used as sites of watchtowers and forts of recent date. Others, which do not offer a commanding view, were presumably used because of the presence of raw material, their more sheltered locations, and possibly other advantages, such as availability of water, which cannot be assessed today. Often spurs are found in close proximity to other spurs and outliers, suggesting the possibility that these features are remnants of what was once a large continuous surface which held a greater spread of artifacts. If this is the case, these artifact concentrations may not represent isolated campsites.

Sites on low-lying features (fig. 2–F).—These sites, which are often no more than 10 or 15 meters above wadi level, occur on top of mounds and spurs of Cretaceous sediments, on abandoned portions of alluvial fans, and on rubble and gravel spreads (pl. 3:1). These surfaces presumably had not yet come into existence when people were leaving artifacts about on the plateau, benches, spurs, and outliers. The darkly patinated artifacts characteristic of sites on the latter features rarely occur on these low-lying surfaces. Until there has been time to study this material, little can be said about it except that it is only slightly or not at all patinated. In certain situations where artifacts are subject to occasional inundation, this patination is thin and white. The average artifact size is much smaller than that of the higher-lying material, and typologically late implements—tanged projectile points, bifacial foliate (leaf-shaped) points, etc.—sometimes occur in these contexts. It is possible that analysis will permit this material to be referred to two industries: The one just mentioned which sometimes approaches microlithic proportions, and a second, interestingly enough, which is often associated with pre-Islamic and perhaps even preceramic architectural features. This might be described as a crude, nondescript flake industry, generally of rather small average flake size. Unpatinated or slightly patinated artifacts were, in several cases, found in and about curious stone structures, often without ceramic associations. These structures were most commonly stone circles, although rectangular alignments of stone, and complexes of circles, or of circles and rectangles also occur. As these stone structures are commonly found on the low-lying rubble and gravel spreads where artifacts of this kind are apt to occur, it is possible that the association is fortuitous.

Rock shelters (fig. 2–G).—Large fall blocks from the limestone cliffs are strewn about on the lower slopes and on the gravel and rubble spreads (pl. 3:2). Some of the more favorably situated blocks are used today by Bedouin as shelters, and are the primary source of pre-Islamic South Arabic graffiti and rock paintings. In a few instances, flaked stone artifacts were found around the shelters in sufficient quantity to suggest that they are associated with occupation. Judging from the random chipping in evidence, it is possible that flint or chert artifacts were picked up and brought to a shelter for purposes of fire-making. (The present-day Bedouin employ them in this fashion.)

Shallow shelters sometimes occur in the limestone cliffs but, with a single exception, no surface evidence of human occupation was found in any of them. The exception is a rather large shelter beneath the lower cliff-forming limestone near Henin. This will be mentioned again below.

A few hand axes or hand axlike tools were found during the course of the survey. In several cases, these were associated with assortments of surface material characterized by a Levallois technique of flake preparation. Two specimens, however, were isolated finds on talus slopes, and one of these appears quite acceptable as an Acheulian-type implement. In fact, several of these tools would not be out of place in various East African Acheulian assemblages although, with the exception noted, they could not be regarded as typical. The suspected Acheulian hand ax (pl. 4:1) was found near Qarn Qaimah. It is of a material distinct from the ubiquitous grey limestone of the Hadhramaut, displaying a reddish, heavily weathered surface. It may prove to be of the same material as the second isolated find mentioned above. The second implement was found in Kathiri territory, and as all material collected there had been packed before entering the Qu ʿaiti state there was no possibility of comparing the two specimens.

The scarcity of these possible Acheulian bifaces, together with the apparent lack of cleavers, picks, large flake scrapers, and other Acheulian artifact types, and the fact that nothing even vaguely reminiscent of Acheulian workshop debris was seen, suggests that Acheulian occupation of the Hadhramaut was very sparse, if it occurred at all. The possibility that evidence of such occupation has been buried beneath thick silt deposits must not be dismissed. Although chert is abundant, suitable raw material above the level of the present wadi floors appears to be virtually nonexistent. Judging from the size of slightly worked cores and core-trimming flakes, it would seem that the nodules were too small to be used for the manufacture of characteristic large-sized Acheulian implements. If suitable material were available below the present level of wadi fill—and there is some reason to think this may have been the case [2]—certainly workshop debris would not be found far removed from the source, and finished artifacts are not apt to have been taken very far up the slopes.

The industry most abundantly represented in the area covered by the survey is based on a Levallois technique of flake preparation. The basic flake type is the quadrilateral flake derived from longitudinally

[2] In the upper reaches of that part of the Wadi Hadhramaut that was investigated, occasional pieces of a hard siliceous sandstone were seen and a few artifacts made of it were noted. The exposed thickness of Cretaceous sediment is greater here, and it may be that this material comprises a lower member of the series, although no outcrops were seen.

prepared cores. Triangular flakes produced from convergent preparation of the core, and oval or discoidal to irregular shaped flakes derived from radially prepared cores are also in evidence. Irregular flakes derived from biconical, discoidal, and formless cores, as well as from other kinds of nonprepared cores are an important component, and in some cases, these were the dominant flake type. Any of these flake types may be retouched to form a variety of scrapers as well as points and other tool types. As was true of the flakes collected by Caton Thompson (1953, p. 209) near Tarim, the prepared flakes sometimes bear remnants of a faceted striking platform, but they were more commonly struck from a plain platform. In addition to these flakes, the various kinds of cores from which they were produced were found.

In spite of the fact that artifacts occur on surfaces which have been exposed since they were first left on them, it seems in some cases that they represent a single, short period of occupation rather than an accumulation over a long period of time. In places, for instance, where a good supply of flint or chert is available, artifacts have doubtless accumulated over a long period. In such localities, artifacts with widely differing patination are found, and wide ranges in flake dimensions are apparent. Here also, one sometimes finds cores or other pieces of material that display two or more degrees of patination. A core which had been discarded after having yielded the larger flakes desired at an early period became serviceable again at a later time when much smaller flake sizes were required.

However, a number of sites with relatively small concentrations of artifacts were found, sometimes in places that have no obvious attraction as campsites. At such sites, workshop debris is usually absent because flint and chert are not immediately available. Often these sites occur on the plateau where there would have been no water, and in places where such advantages as shelter or an unrestricted view of areas where game might have been expected would not have been obtained. Further, uniformity of such characteristics as flake size, tool types, and patination suggests that the artifacts are, in fact, in archeological context, and that these contexts represent temporary campsites, or possibly killsites. Once detailed analysis of the collections is completed, it is thought that it will be possible to demonstrate that statistically significant differences in such characteristics as mean flake size, and flake and tool typology, exist between certain of the assortments, and that these differences can be correlated with degree of patination. On the basis of these analyses and correlations, it may be that a crude seriation can be developed to accommodate some of this material.

Thanks to the activities of the Desert Locust Survey personnel and, more recently, of Aramco geologists and surveyors, something is known of the archeology of the southwestern extreme of the Rub‘ al-Khali

1. General view of Wadi Hadhramaut, looking southwest.

2. Artifact pavement on an upper plateau remnant near Qatn.

1. Flint mining took place around the large block on the skyline near the ridge crest. Not hanging valleys in the cliffs across the wadi.

2. A typical flat-topped spur; the flat top of the spur was a prolific source of artifacts.

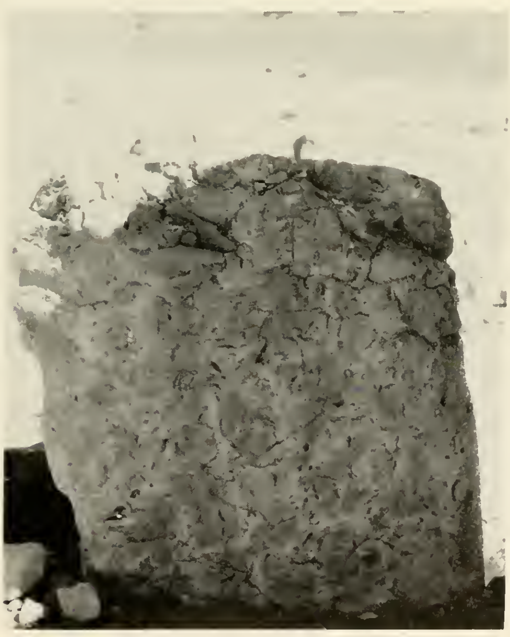
1. A low spur at the junction of two wadies near Qatn. Small, relatively unpatinated artifacts, including several of the Habarut type were found on the lower, flattened portion of the spur. A site occurs on the bench of the lower cliff-forming limestone across the wadi.

2. Large limestone fall blocks near Seiyun. Artifacts were found in fair abundance around these blocks. Modern Bedouin encampments also occur here.

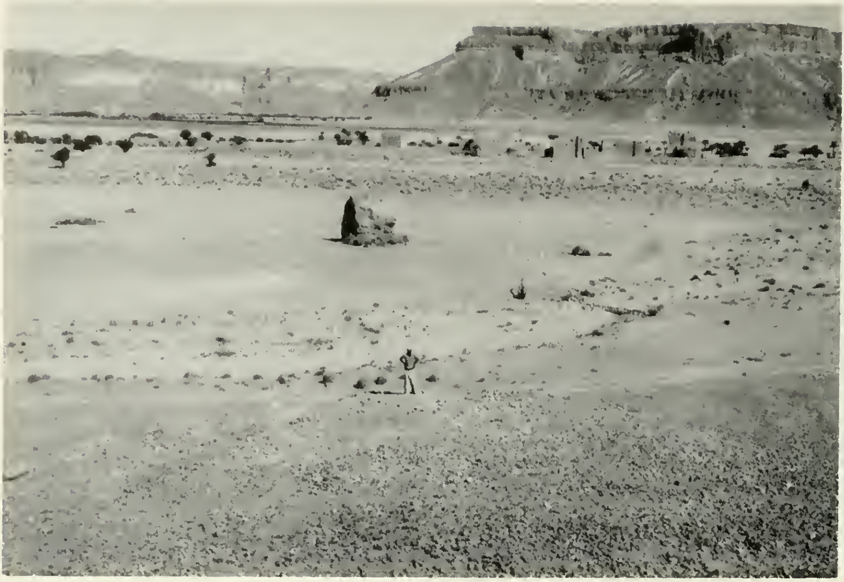
1. Hand ax from near Qarn Qaimah.

2. Rock shelter west of Henin.

1. Megalithic complex in Wadi Sarr. The square enclosure is on the right, the fallen dolmen on the left, and behind the dolmen is the row of standing stones and one of the stone circles.



2. Typical pecked crenelated design on the inner face of a slab in the square enclosure.



1. Remains of pre-Islamic structure, probably a customs post or caravansary near Qatn.

2. Eroded pre-Islamic town site in Wadi 'Idim. Note remains of stone buildings in upper left quarter of photograph.

1. Exposed building in site shown on plate 6, fig. 2, showing different masonry styles and well-preserved mud-brick walls.

2. Section of exposed pre-Islamic irrigation canal in Wadi Du'an. The stone piles in the upper right corner are remnants of other installations in this system.

1. Remains of an early Islamic village built on an outlier east of Seiyun.

2. Ruins of a recently abandoned Islamic village.

and its fringes (Zeuner, 1954; Field, 1955, 1956, 1958, 1960; Smith and Maranjian, 1962). Industries referred to as "Neolithic" are represented by a number of sites located from 200 to 400 kilometers north and northwest of the Hadhramaut (fig. 1). Bifacial leaf-shaped and triangular points, barbed and tanged arrowheads, rhomboidal bifacial points, and a variety of scrapers have been described. Curiously, no evidence of similar industries was found in the Hadhramaut, although some of the individual tool types occur infrequently. One rock shelter near Henin (pl. 4:2) yielded a small assortment of tanged and barbed projectile points, a few of which are made of obsidian. Obsidian otherwise seems to occur only on pre-Islamic sites where microlithic artifacts were fashioned from it (Caton Thompson, 1944, p. 134). A few small tanged points came from scattered localities, usually low-lying spurs or outliers. But one site in Wadi Bin ʿAli, on top of the lower cliff-forming limestone, yielded a very few of these artifacts. A single, relatively large tanged point (5.2 cm.), virtually identical in shape with the one figured in Zeuner (1954, pl. 1, b), was found on the plateau near Qatn. Bifacially worked foliate points were even less frequently encountered, and no rhomboidal bifacial points are recalled. It is possible that comparable scraper types will appear on detailed examination of the collections.

A place known as Habarut, some 350 kilometers to the east of Tarim near the Dhofar border, has also produced some material similar to that of the Rubʿ al-Khali fringe sites, but more characteristically yields an abundance of trihedral rods (tools, triangular in section, with pressure flaking on entire surface of each side), points, and other implements fashioned on triangular-sectioned pieces carefully worked, sometimes on two but usually on all three faces.[3] Relatively large (10 cm. and more) crudely trimmed bifacial foliates and limaces also occur, and these appear to be most similar to artifacts in certain "Late Stone Age" contexts. Such artifacts, for example, occur in a Somaliland Doian industry, and are referred to a "Neolithic" aspect (Clark, 1954, p. 258), but overall similarities to the Doian are not close. The Fayum "Neolithic" (Caton Thompson, 1934) would seem to offer rather closer parallels, although numerous points of difference exist. For example, the hollow (concave) based arrowhead—present in the Doian as well as this industry—seems to be lacking in South Arabia. A few pieces similar to material from Habarut have also been found on the coast near Mukalla (Caton Thompson, 1953, fig. 7, Nos. 59–62).

As with material from the Rubʿ al-Khali fringe sites, occasional artifacts of the kind found at Habarut appear in the Wadi Hadhramaut, but nothing even remotely similar to the total assortment—or to

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[3] Material from Habarut has been collected by various British political officers and is, in large part, housed at the Aden Museum. These collections were kindly made available to Cole by Brian Doe, Director of Antiquities of the Government of Aden.

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any of the separate collections examined—was seen there. A few of the trihedral rods were found in scattered localities. One low-lying spur in Wadi Bin Selman had these associated with several bifacial foliate points. Crudely trimmed large bifacial foliates were rarely found.

At one of the Rub' al-Khali sites, arrowheads were found associated with a hearth. Charcoal recovered from it has given a Carbon 14 date of 3,131±200 B.C. (Field, 1960 b). Caton Thompson (1934, p. 93) has advanced a slightly earlier date (*ca.* 5,000–4,000 B.C.) for those Fayum industries which are comparable with that of Habarut. Thus it would seem that hunting groups, if they were not actually living in the Hadhramaut, at least visited it on occasion during the first few millennia B.C. and doubtless were still doing so at the time of the appearance of potterymaking town dwellers.

Apart from the possibility of people employing Acheulian techniques of implement manufacture having lived in the Hadhramaut, the typological affiliations of the older industry so abundantly represented in this area would seem to be to that complex of industries in the Near East and North Africa referred to as the "Middle Paleolithic." In Africa, the similarities are with the "Middle Stone Age" (more is involved than mere Anglicizations, see Malan, 1957). Insofar as can be told from the Hadhramaut material, "Upper Paleolithic" industries do not occur. It has been suggested that a similar situation exists in North Africa (Forde-Johnston, 1959, p. 15). Assuming continuous occupation of the area during Upper Pleistocene and Post Pleistocene time, it would appear that a "Levalloiso-Mousterian" industry persisted until quite late. Industries of "Bedoin Microlithic" and "Desert Neolithic" type seem to appear on the scene, rather than develop from the earlier tradition. No Aterian-type industries are known here. Even should subsequent analysis reveal a possible transitional industry, the fact that all material is from the surface will always allow for the possibility, or probability that mixed assortments are involved.

The above remarks, it should be remembered, are based on a casual examination of only a small part of the material collected from the Hadhramaut, although more careful study of material from certain Rub' al-Khali fringe sites and from Habarut has been possible. A detailed account of the collected material awaits careful study, after which it may be possible to suggest more precise affiliations of the early Hadhramaut cultures with those of the Near East and Africa.

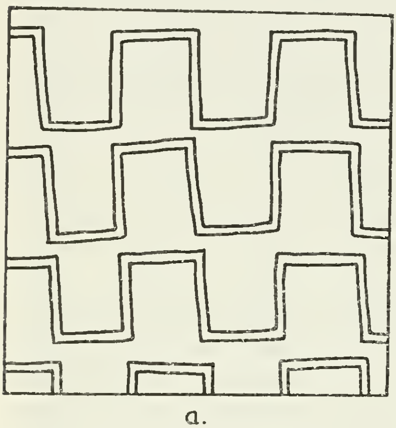
PRE-ISLAMIC PERIOD

In the absence of a fixed nomenclature for the archeological periods in South Arabia, the term "pre-Islamic" is used here to denote the period from the end of the Prehistoric period to the coming of Islam in the 7th century A.D. It overlaps the Prehistoric period at the stage represented by megalithic structures, and it includes the long period of settled town life both before and after the introduction of writing, an event which cannot yet be precisely dated. Thus, the term is vague and should remain so until the cultural development of this area can be described in terms of cultural achievements, technological levels, or historical periods as are commonly used elsewhere in the Near East—a description which must await additional excavation and interpretation of archeological data.

A total of 23 sites belonging to the pre-Islamic period were recorded in Hadhramaut. Of these, seven sites were already known, and our chief contribution at these sites will be in the analyses of the large collections of pottery. The remaining 16 sites, so far as we have been able to learn, were recorded for the first time. These 23 sites include several different types: (1) Megalithic structures; (2) guard or customs posts, some of which probably served as caravansaries; (3) townsites; and (4) irrigation installations. In this brief report, obviously not all sites can be discussed; only those of special interest and with features common to a number of sites will be mentioned.

Three sites with megalithic structures and several other sites with similar structures but built with smaller stones were discovered during the survey. All of these structures are located on the low-lying benches or gravel-covered terrace usually near the base of the cliff. Two of the three megalithic sites consisted of large circles of standing stones, and on one stone, a palimpsest of South Arabic graffiti was found, which had been carved after the stone was set up. To the best of our knowledge, this is the first unequivocal evidence that structures of this type antedate Islamic times in this region. The most interesting of these sites is a complex of structures in Wadi Sarr, one of the northern tributaries (pl. 5:1). This complex, which occupies a gravel-covered terrace along the west side of the wadi, consists of several structures. The central structure is a square enclosure formed of standing limestone slabs and surrounded on all sides by large horizontal sandstone blocks, which apparently serve as a foundation or a curbing for the square enclosure. Within the enclosure is a dolmenlike chamber in the southwest corner, the cover slab of which is supported on two sides by the standing slabs of the enclosure and on the other two sides by slabs inside the square. There are also other standing slabs within the enclosure which, at first sight, appear to have been placed at random, but on further examination were almost certainly arranged to support cover slabs in the other three corners of the square; this suggests that originally there were dolmenlike chambers in each corner of the structure.

An important feature of this complex is the decoration on the inner face of most of the slabs of the square (pl. 5:2); in all probability, it originally appeared on all of the slabs forming a continuous design inside the enclosure. The motif consists of at least three broad lines, each forming a crenelated design (fig. 3: a). These lines are usually pecked with a hammerstone, but on at least one slab, they are incised. Also noteworthy is a group of graffiti carved on the outer face of one of the enclosure slabs, which shows that the slab was in situ when the graffiti were engraved, and that the structure dates no later than the date of the graffiti. Other features of this complex include a separate dolmen which is also surrounded by large horizontal blocks, a row of 10 large stones, and 2 stone circles, one of which is formed of tall standing slabs. Numerous chert artifacts were collected around this complex; a few sherds and glass fragments of recent date were also found which attest to recent Bedouin encampments.



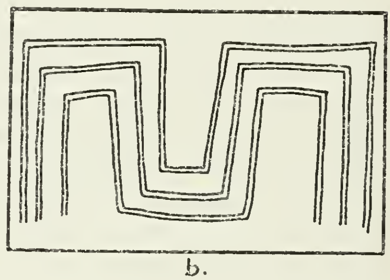


FIGURE 3.—*a*, Crenelated design on the inner face of most slabs in the Wadi Sarr megalithic structure; *b*, Natufian B design on a bone plaque from Mugharet el-Wad in Palestine (after Garrod and Bate, 1937 pl. 13:2:17).

What is the purpose, the cultural affinities, and date of this complex? Perhaps none of the questions can be answered with certainty. Clearly the elaborate construction and the carefully worked design inside the structure point to a special function. If dolmens are indeed tombs as is commonly held, then this may have served as a burial complex for a distinguished family, the leading members of a tribe, or other important persons. So far as cultural relationships are concerned, we know of no similar complex anywhere in Arabia or in the entire Near East. The nearest dolmen fields known to the senior author are in the Jordan River valley, where several hundred dolmens survive on the terraces to the east of the river. There, they are usually considered to belong to the Neolithic period. The closest parallel that we have been able to find thus far to the crenelated decorative motif is a Lower Natufian (Mesolithic) design that appears on a bone plaque from Mugharet el-Wad (fig. 3: b), one of the Mount Carmel caves, and on a basalt bowl from Eynan, Israel; the design of these parallels is more elaborate—and perhaps more advanced—than the Wadi Sarr example, in view of the adjustments in the width of the crenels required by the compression of the crenelated lines which form the basic element of the motif. Whether the similarities between these structures and designs in Palestine and Hadhramaut are coincidental or are evidence of cultural relationship cannot be determined at this time. If a relationship exists—and this is by no means impossible—it may indicate that the Wadi Sarr complex represents a Mesolithic or Neolithic horizon in southern Arabia which may belong somewhere between the eighth and second millennia B.C.

Another type of site discovered during the reconnaissance usually consists of no more than one building, and is always located near one of the camel tracks leading to the southern coast of Arabia. These sites are invariably situated on the west side of the southern tributaries near their junctions with the main wadi. They occur in every wadi in which there is a caravan track to the plateau; none was found in wadies which do not provide access to the plateau for camel traffic. The size and strategic location of these sites suggest that they served as customs or guard posts, where import and transit taxes were levied on products consigned to the main wadi and to regions to the north and west of Hadhramaut. One site (pl. 6: 1), located in the Qatn area, was built of stone and finished with smooth-dressed stone wall panels. In front of it was a rectangular enclosure formed of large undressed stones, which may have been a corral for caravans in transit, suggesting that the site may have served as a caravansary as well as a customs-guard post. Another site, a small stone fort, was situated on the ledge of the lower cliff-forming limestone a few meters from a track which runs along the ledge in its ascent to the plateau. The only artifacts found at such sites are sherds and, in one instance, fragments of dressed wall panels.

In Hadhramaut, the largest and most impressive pre-Islamic remains are those of town sites. These sites usually are located either in the middle of the wadi on the silt or close to the cliff wall near the junction of the gravel talus and the silt. In the southern tributary wadies, such as Wadies Du‘an and ‘Idim, some of these sites attain considerable size; one measures about 600 meters long by 300 meters wide, and the occupation debris reaches a depth of at least 9 meters (pl. 6: 2). Because of their location on the silt, all sites are badly eroded from the action of flash floods, with the result that each site consists of a series of small mounds separated by gullies of varying depth. Each of these mounds preserves the remains of one or two buildings. At some sites—in addition to natural erosion—*seil* farming is being carried on in the eroded gullies, exposed dressed blocks are carried away for use in modern construction, debris soil is being removed by farmers for their fields, and in some instances, the site has been leveled, plowed, and incorporated into a modern field system. It is worth noting in passing that these forces of destruction have made it impossible in many parts of the sites to determine the stratigraphic relationship between buildings, since the intervening layers of debris have been removed.

Because of erosion and other agents of destruction, many details of the ancient sites can be seen on the surface. Most of the buildings were constructed with foundations and lower courses of stone, and a variety of masonry types and dressing techniques appear in each site and occasionally in the same building, suggesting different periods of construction. The superstructure is usually represented by a pile of disintegrated mud brick, but often mud-brick walls and even individual bricks can be distinguished (pl. 7:1). On the larger and earlier sites, the surface is strewn with literally hundreds of thousands of sherds which have eroded out of the debris. Architectural fragments, incense burners, an occasional fragment of sculpture, inscribed pieces, and obsidian points and sickle blades are also found.

Perhaps the most surprising discovery of the survey is the lack of townsites in the main wadi. Today the main wadi contains perhaps 90 percent of the entire population of the Hadhramaut drainage. Because of its present large population, it is reasonable to expect a proportionately heavy population in antiquity and to find a heavy concentration of sites in the main wadi. Yet only one townsite and a trace of a second were found; the former is located on the gravel-strewn talus, while the skimpy remains of the latter are situated on the silt floor of the valley. How can this apparent lack of ancient settlements be explained? While the collected data have not yet been thoroughly evaluated, it seems likely that there may have been many sites in the main wadi in antiquity which were destroyed within the last thousand years or so by (1) the construction of irrigation installations, and (2) the erosion of the valley floor. With regard to the former, it should be noted that large sections of the main wadi have been cultivated using *seil* irrigation techniques. This method of irrigation, which has been used throughout the Islamic period, requires the leveling of fields, the cutting of canals in the silt floor, and the erection of earthen dykes around each field plot. Thus everything, including ancient building remains, was leveled. From many of the dykes still in use and from others long abandoned, pre-Islamic pottery is eroding out, while in the immediate vicinity, there is not a trace of a pre-Islamic structure. It was from such a dyke that the only trace of pre-Islamic pottery on the silt of the main wadi was found. It should also be noted that the silt beneath this dyke now stands 2 meters above the present wadi floor. Yet, at one time, the wadi floor must have been level with the present surface of this block of silt, and perhaps both were even higher. It seems probable that this block of silt has been preserved by chance, while the remainder of the surrounding valley floor has eroded 2 meters to its present level. If this is the case—and there appears to be supporting evidence elsewhere—any sites that may have stood on the silt have been washed away without leaving a trace. At the same time, the height of the silt floor seems to have increased at the eastern end of the wadi, near its confluence with Wadi 'Idim; when wells are dug in this area, pre-Islamic artifacts are often found a meter or so *below* the present surface. In other words, a gradual grading of the western two-thirds of the valley floor may have destroyed all evidence of pre-Islamic towns in that area, while deposition of this graded material together with silt from Wadi 'Idim has buried pre-Islamic towns below the surface in the eastern part of the main wadi. Although this explanation may not be correct in all details, it seems likely that some such phenomenon is responsible for the disappearance of what must have been many townsites in the main wadi.

Some pre-Islamic towns in Wadies 'Idim and Du'an go back to at least the 9th or 10th century B.C. and possibly a century or so earlier, judging from similarities between the pottery from these sites and that of Hajar Bin Humeid in Wadi Beihan. Many also come down in time to the early post-Christian centuries, and possibly to the Islamic period. Altogether it is probable that the entire pre-Islamic period is represented in the collections made at townsites during the reconnaissance.

One extremely important site of this period is a large field of ruins of a pre-Islamic irrigation system in Wadi Du'an. Within an area of about 2 square kilometers, there are several hundred—and perhaps as many as a thousand—partially exposed mounds revealing sections of canals and sluices, some of which are in an excellent state of preservation (pl. 7:2). All were constructed of stone and mortar. That these ruins belong to the pre-Islamic period is certain from an examination of the installations themselves and associated artifacts. This type of construction was not used in the Islamic period anywhere in the Hadhramaut drainage; as noted above, Islamic period installations are entirely of earthen construction. Further, all the sherds found on the silt surface surrounding these canals and sluices are weathered, heavily patinated pre-Islamic sherds; not one Islamic sherd was found in this area. By contrast, the field plots of the Islamic irrigation systems have only Islamic sherds, except for those instances described above where pre-Islamic sites were ploughed up and incorporated in the field system.

ISLAMIC PERIOD

While the expedition focused its fieldwork on the Prehistoric and pre-Islamic periods, it seemed worthwhile to record and to make collections at a few sites of the Islamic period, from the seventh century A.D. to the present. It was hoped that such an investigation would (1) provide the later material necessary to complete the development of a ceramic sequence for Hadhramaut, (2) determine whether a number of sites described in the literature and marked on maps as "ancient" and "pre-Islamic" are as represented or are Islamic and of comparatively recent date, and (3) yield evidence that could be used to distinguish pre-Islamic from Islamic irrigation installations.

A total of 27 Islamic sites were selected for study from hundreds in the wadi. Three types of sites are represented among those recorded: Guard posts or fortresses, isolated villas, and townsites. Guard posts abound in the main wadi and tributaries. In general, they consist of one or two very small rooms, and are constructed of dry laid slabs or undressed stones. They are always strategically located near a camel or foot track and in a good defensive position whether on the plateau, the lower cliff-forming limestone ledge, or the benches and outliers. As might be expected, artifacts are scarce at such sites, but enough are found to enable us to distinguish between early and late Islamic posts.

Also occupying benches and outliers are a number of large isolated houses or villas. These structures presumably were built on high ground to provide better defense against attack, and this, together with the many remains of guard posts, suggest that much of the Islamic period was characterized by strife and insecurity. Some of the early villas were constructed entirely of well-dressed stone (pl. 8:1), others of roughly dressed stone with mud-brick superstructures. Later houses are invariably built of mud brick on a foundation of only a few courses of undressed stone. A house plan common in more recent ruins consists of a virtually square building with a roughly cylindrical tower attached to each corner. A few buildings of this type are still occupied—the best example is the Sultan's palace in Seiyun—but no new buildings using this plan are being constructed now. This style of building is a good time marker for the Islamic period; it was not used in the early Islamic period, but was common in late Islamic times, and has only recently been abandoned.

Most Islamic towns, including present-day towns and cities, are built of mud brick on the talus near the base of the cliff and sometimes incorporate natural features such as benches or outliers in their built-up area (pl. 8:2); a few small villages and clusters of houses are located on the silt in the middle of the wadi, but these quickly dissolve when flash floods fill the wadi, leaving only a course or two of stone foundations and a few artifacts. Except in the larger towns and cities, little or no repair work is done to houses that begin to disintegrate; instead, houses are abandoned, and the inhabitants build an entirely new town nearby. Because of this practice, high mounds are not being formed now, and if this tradition began in antiquity it would explain the lack of depth in most pre-Islamic sites. Artifacts from early Islamic structures include plain buff pottery, glass, and occasional sherds of imported ceramics, such as celadon. In recent Islamic sites, red slip pottery and painted pottery are common; glass, wooden, and metal artifacts, and imported European and Asian porcelain also appear; many similar objects are still available in local shops and represent a continuum between the recent past and the present.

EPIGRAPHY

About 1,300 South Arabic graffiti and rock inscriptions were copied in the main wadi and tributaries between Tarim and Qarn Qaimah during the 3½ months of fieldwork. These graffiti and inscriptions are either engraved or pecked, in all probability with hammerstones or similar tools. They are chiefly found on boulders which broke away from the limestone cliffs and tumbled to their present locations on the talus or silt. A few inscriptions are preserved on the vertical cliff surfaces, and originally there may have been many more in such positions which weathered away. The decipherment of most of the texts is unusually difficult because of the rough surface of the boulders, and the light incision and pecking of letters on the limestone. These difficulties are compounded by the fact that many graffiti and inscriptions are located in chamberlike places where the light is exceptionally poor.

These texts contain only personal names, but a great number of them are new and represent an important addition to the corpus of South Arabian names. Rarely are they accompanied by names indicating filiation or the clan or family to which the person belonged, as is more commonly found in the western part of southern Arabia. Several very important forms of letters were also found which shed new light on Semitic paleography. For example, some forms of *'alif* are practically identical to some found in Protosinaitic and early Phoenician (Canaanite) inscriptions. *Wasm* or tribal signs also appear in the Hadhramaut inscriptions.

While searching for graffiti and inscriptions, Jamme also sought to obtain information on the toponymy of the area. In order to achieve maximum accuracy in the spelling of local geographic names, literate local guides were hired to write place names in Arabic in our notebooks; whenever possible, their spellings were checked by other native informants. This material was turned over to the U.S. Army Map Service and to the Directorate of Military Survey in England for their use in improving the maps of this region.

During the course of the survey, Jamme was privileged to make several major epigraphic excursions to places outside the reconnaissance area. Near the town of al-Wastah, which is located about 20 kilometers northeast of Tarim, a small collection of graffiti was found high on a cliff just below the plateau. This group consists of 6 South Arabic and 18 Thamudic graffiti. This is the southernmost find of Thamudic graffiti which are most commonly found in northwestern Arabia.

On the occasion of the annual pilgrimage to Nabi Allah Hud, Jamme visited the small village of Sana, which is located about 45 kilometers southeast of al-Wastah. About 2.5 kilometers northwest of Sana are the ruins of a pre-Islamic temple which was dedicated to Sin, the lunar god of ancient Hadhramaut. At this site photographs were made of 27 fragmentary South Arabic inscriptions.

In the vicinity of al-ʻAbr, a Protectorate military post located about 150 kilometers west-northwest of Shibam, about 300 photographs of graffiti and rock inscriptions were made. Most of these are located about 11 miles north of the military post. The initial study of these photographs shows that the general characteristics of the texts are similar to those of texts from Wadi Hadhramaut, but that *wasm* or tribal signs are more numerous and diverse. Several forms of letters used in these inscriptions are also important for the study of South Arabic paleography.

About 100 kilometers southwest of al-ʻAbr are three large boulders covered with inscriptions at a place known as al-ʻUqlah. Jamme spent 5 hours studying 86 texts on the main boulder and 3 texts on each of 2 other boulders. These texts mention several consecutive Hadhrami kings as well as a Sabean provincial king who ruled toward the end of the third century A.D. Many of these texts were copied in 1936 by the well-known Arabian explorer, H. St. J. B. Philby. It is now clear that his copies of these inscriptions require major additions and corrections, and it will now be possible to correct these errors. Twenty-eight of these inscriptions were copied for the first time (Jamme, 1963a).

Thus the epigraphic work of this expedition is of considerable importance to the study of language, literature, and culture history of South Arabia. The texts discovered will make a valuable contribution to the South Arabian onomasticon, and especially to the study of paleography; the latter, in turn, sheds light on the origin and evolution of the South Arabian alphabet. It is probable that important data on migrations and trade will be forthcoming once the personal names have been studied (Jamme, 1963a).

SUMMARY

From the foregoing discussion, it is clear that when the data collected by the expedition have been analyzed and interpreted, they will fill some of the gaps in our knowledge of the culture history of southern Arabia. With regard to prehistory, this first systematic reconnaissance for evidence of the earliest cultures has given us a broad framework of the culture sequence of the area. Until the area was systematically surveyed, it was impossible to determine if the occasional collections which had been made were representative. It now appears that the earliest widespread industry belongs to a "Levalloiso-Mousterian" tradition and is most closely related to the group of industries labeled "Middle Paleolithic." This industry, which must have persisted a long time, apparently was followed by a "Desert Neolithic" industry, of which few sites were found in Wadi Hadhramaut. Perhaps to this period belong the megalithic structures, the most important complex of which may reflect a northern tradition of design, construction, and decoration.

It seems probable at this stage in our investigation, that this area remained at a "stone age" level of culture until late in the second millennium B.C., lagging far behind contemporary developments in the Fertile Crescent. At least no remains were found that could be assigned to the period between the hunters and gatherers of the lithic cultures and the earliest towns, which belong to the beginning of the first millennium B.C. or slightly earlier. It appears at this time that people with an advanced culture, probably from the northwestern fringes of the Fertile Crescent, migrated to Hadhramaut, driving out, killing off, or assimilating the inhabitants of the area, late in the second millennium B.C. They brought a tradition of urban living, a knowledge of ceramics, metallurgy, irrigation agriculture, and perhaps writing, and developed the extremely lucrative frankincense and myrrh trade. Based on a preliminary examination of the pottery and other artifacts, it appears that while Hadhramaut shared in the main stream of the culture that prevailed over all of southern Arabia, it also developed provincial or local features that in part make its culture clearly distinguishable.

This summary, based on 3½ months' work in Hadhramaut, but without the benefit of analyses of the collections, is necessarily tentative. Minor adjustments and revisions will certainly be required and probably some radical alterations will have to be made, but the broad outline is likely to remain. For filling in the details and for answering many important questions, the excavation of several pre-Islamic sites will be required. This is our next task.

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The Corrosion Products of Metal Antiquities[1]

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[With 10 plates]

Archeologists who find the remains of metal antiquities in the earth or in the sea have observed the wide variety of products that encrust their surfaces. These encrustments are caused by the chemical interaction of the metal with the corroding agencies of earth, air, and water. Many generations of museum curators and collectors have been concerned with the nature of these products, especially when they want to show a corroded object close to its original condition. A few chemists have investigated metal corrosion crusts, and have been impressed by their diversity and complexity. Mineralogists have observed in the corrosion crusts crystalline compounds identical with some of the minerals of the earth's crust. Information about these inorganic mineral products in corrosion crusts is scattered far and wide in the scientific literature and in unpublished notes in museum files and laboratory notebooks. It is important that it be collected, classified, and made readily available to the collector, curator, and the scientific investigator.

The term "mineral" is used to designate the chemical elements or compounds occurring in the earth's crust as a product of natural inorganic processes. Minerals have more or less constant chemical composition and characteristic atomic structure, and hence characteristic crystalline form and physical properties. Most minerals can have chemical formulas assigned to them. Metal corrosion products give X-ray diffraction patterns identical with their mineral prototypes, thus the same chemical formula can be assigned with confidence to the

[1] A preliminary report under the title "Mineral Alteration Products of Ancient Metal Antiquities" was read at the First Conference of the International Institute for Conservation of Historic and Artistic Works (IIC) in Rome, 1961. This report has since been published in the collected papers of the Rome Conference under the title "Recent Advances in Conservation." London: Buterworth and Company (1963), pp. 89–92; edited by G. Thomson.

corrosion product. A corrosion product that cannot be identified with a known mineral may be analyzed and described in chemical terminology until a corresponding earth mineral has been discovered. Some mineralogists insist that a true mineral can only be formed by geologic processes working on geologic material, yet there are no differences either physical or chemical between compounds created by purely natural processes and those formed on an artifact where man accidentally assisted in bringing the artifact and the proper environment together. Austin F. Rogers (1903), former professor of mineralogy at Stanford University, early in the century described the corrosion crusts on ancient Chinese coins and he named the mineral species he found among them such as malachite, cuprite, and others. F. W. Clarke (1924), in his classic work on geochemistry makes several allusions to minerals in artifacts; in Dana's System of Mineralogy (Palache, Berman, and Frondel, 1944, 1951), there is reference to a number of occurrences of minerals on man-made objects. Admittedly, this is an ambiguous area that has not been finally resolved by mineralogists.

The mineral crusts on ancient objects are important for a number of reasons. Under certain circumstances the mineral alteration product formed on a metal adds interest and even beauty to an object and increases its value in the eyes of collectors. The artistic term "patina" is applied by them to the colorful, thin, but continuous corrosion films that form on the surface of copper and its alloys giving evidence of age and long use. H. J. Plenderleith says (1938) ". . . patina is a form of incrustation which is stable under normal conditions of temperature and humidity, is protective in proportion as it is hard and non-porous, and has often an aesthetic appeal in accordance with its hue or the play of colours of the minerals of which it is composed." Green and red patina on ancient bronze is so admired that it is sometimes produced artificially on recently made objects to simulate appearance of age and authenticity. Even old leaden objects with thin crusts of cerussite and litharge are more interesting than lead in the raw. Unfortunately, however, most corrosion products on metals are ugly and disfiguring. Rust on iron and tarnish on silver have little appeal. Even copper and bronze is unattractive when covered with chloride-bearing corrosion crusts. Thick corrosion can obscure fine details of decoration and modeling and can completely hide gilding, inlays, and inscriptions. Sometimes corrosion crusts act as cementing agents for clay and earthy accretions. The term patina does not properly apply to corrosion crusts and earthy overlayers that conceal and disfigure.

Because ugly corrosion crusts so often detract from the appearance of metal artifacts, there is frequently an urge to clean them away immediately after recovery of the artifacts from soil or sea or after long storage to ready them for exhibition and display. Herein lie certain dangers and opportunities for oversight, not only because of possible damage to the object itself from enthusiastic but untrained hands, but because of inadvertent loss of valuable historical and scientific information which may be contained in or concealed under unwanted encrusting materials. In the mineral shell there may be evidence of metal composition, of age, and even of place of origin. The corrosion crust sometimes has a layered structure containing two or more distinct minerals in which the outer more stable minerals can serve as natural protective coatings for less stable compounds lying beneath. For these several reasons corrosion crusts should be carefully examined and identified by an expert before they are scraped away or dissolved off by a technician and thrown casually into waste jar or sink. An added reason for the careful examination of corrosion crusts is that they may contain rare minerals unknown or little known to science which add greatly to their interest and importance.

In industry the utilitarian terms "corrosion" and "corrosion products" are widely used to describe the chemical and electrochemical changes in which the metal passes from the elemental to the combined state, and those terms, for practical purposes, are retained here although some mineralogists seem to prefer the terms "mineral alteration products" and collectors still prefer to speak of any kind of alteration of the surface as patina. In the various modern textbooks on corrosion of metals the emphasis is almost entirely on causes of corrosion, corrosion mechanism, and corrosion prevention, but hardly any consideration is given to the products of corrosion. These appear to be unwanted materials that are scraped or brushed away or covered over.

In the early part of this century the microscopic identification of mineral alteration products using methods of optical crystallography was slow and laborious. The task was made difficult by the finely crystalline character of the alteration products and complexity of the mixtures. Today, using X-ray diffraction and X-ray fluorescence methods of analysis, identification of inorganic crystalline materials is much easier, and what was formerly wearisome and time consuming has become fast and routine.

This paper gathers together, classifies, and briefly describes the wide variety of mineral corrosion products that occur on ancient metal objects. It is an exercise in taxonomy within the widest meaning of that term. Precise criteria for recognizing mineral species will not be given because those are adequately dealt with in standard texts on mineralogy. No attempt will be made here to explain corrosion mechanism or corrosion theory. That has been treated by

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numerous investigators over many decades, and the results are summarized in monographs on metal corrosion like those of Evans (1960), Uhlig (1948), La Que and Copson (1963), and others.

COPPER

Of all the metals used in antiquity, copper forms the most colorful and interesting group of mineral alteration products.

In the older literature one occasionally encounters the word "aerugo" (from *L: aes*—brass or copper) which refers particularly to the "rust" of bronze, copper, or brass. Although now an archaism, aerugo is quite an appropriate term. Much less correct is the term "verdigris" which is sometimes used to describe the green on copper, but this name refers specifically to the green product formed by the action of acetic acid (vinegar and other organic products of fermentation) on copper and its alloys and hence is not a proper mineralogical term.

COPPER OXIDES

Probably the most widely occurring alteration product of ancient copper and its alloys is the red cuprous oxide, Cu_2O,[2] called *cuprite.* Usually most of the cuprite is concealed beneath overlying green and blue basic salts of copper and it seems to be an intermediate compound in the conversion of metal to those salts. A cuprite underlayer is often revealed when the outer green oxidation crusts are removed by mechanical or partial chemical cleaning. In cast bronzes cuprite sometimes forms along grain boundaries or in seams that penetrate deeply into the metal core, but more often it occurs in coarsely crystalline masses in which perfect crystals of cubic habit abound. A fractured or scaled surface of cuprite on bronze occasionally has a sugary or drusy appearance caused by reflection of light from numerous small crystal faces. This crystalline cuprite is usually cochineal red in color but sometimes fine-grained cuprite in inner or intermingled layers is quite orange-red or even yellow. In primitively smelted copper, cuprite is often disseminated in small globules among the copper crystal grains. This is not a corrosion product but is cuprite formed under inadequate reducing conditions at the time of smelting. Collins (1934) concluded from evidence of X-ray diffraction studies that the "mirror black" patina of certain Chinese bronzes consists of crystalline cuprite of unusual structure possibly having a thin film of tenorite on the surface.

Tenorite: Fink and Polushkin (1936), who studied the microstructure of patina, observed that cuprite and/or tenorite is always found as an intermediate layer between copper or bronze and malachite.

[2] The chemical formulae used here for minerals are those employed by Palache, Berman, and Frondel in their revision of Dana's "System of Mineralogy."

The black cupric oxide, CuO, is seldom reported; if present, it seems to be consistently overlooked. Tenorite was recently reported, however, by Périnet (1961) among the products found among the inner layers of a corroded copper nail recovered from a sunken second century B.C. Greek vessel found in 1952 off the islet of Grand Congloüe in the Mediterranean not far from Marseilles.

COPPER CARBONATES

Malachite and azurite, both basic carbonates of copper, are perhaps the most familiar natural alteration products on copper artifacts, and they are the most desirable constituents of bronze patina from the point of view of the collector.

Malachite, $Cu_2(OH)_2CO_3$, sometimes occurs as a smooth dark green compact layer on the surface of a bronze and gives it an enameled appearance, but more often it is seen in scattered rounded masses described as mammillary, or as botryoidal because of their resemblance to clusters of grapes. Occasionally, rounded nodules several millimeters in diameter are found on the interior of bronze vessels and also on objects of base silver. The banded structure characteristic of large malachite masses is sometimes seen on ancient bronze pieces that have been cleaned down and polished. Occasionally, malachite is observed on bronzes in delicate fibrous aggregates, sheaflike in form. Patches of bright green malachite can make an ordinary copper object look interesting and precious.

Azurite, $Cu_3(OH)_2(CO_3)_2$, although similar in composition to malachite, has about 3 percent less water of constitution, and its color ranges from bright blue to dark indigo. Like malachite it sometimes occurs on objects as a thin, compact, enamel-like layer; but it is observed ordinarily in fine blue crystal aggregates scattered among patches of malachite. In nature azurite is less abundant than malachite and on artifacts the same is true. Azurite is most often encountered on the interior surfaces of hollow vessels where less humid conditions may favor azurite formation. Occasionally, a bronze will appear to be completely transformed to crystalline azurite.

Presumably malachite and azurite are formed by contact of the object with soil water or even rain water charged with carbonic acid gas in the presence of atmospheric oxygen. Cuprite, as mentioned above, is sometimes observed in an intermediate zone between the carbonate surface layer and the metal core of an object, but it is not yet certain that cuprite formation is essential to the reaction.

Chalconatronite: A few years ago Gettens and Frondel (1955) discovered a bluish-green chalky crust on the hollow interior of an Egyptian bronze figurine of the deity Sekhmet in the Fogg Museum of Art. This product did not have the properties of any of the copper minerals commonly found on ancient buried bronze. After study, it was determined that it is a hydrous double carbonate of copper and sodium having the composition $Na_2Cu(CO_3)_2 \cdot 3H_2O$ and that it is a new mineral species not previously decribed. It has been given the name "chalconatronite." This mineral was also observed on an Egyptian bronze group, "Cat and Kittens," in the Gulbenkian Collection in Lisbon, and on a Coptic censer in the Freer Gallery of Art. Chalconatronite seems to be a product peculiar to the arid soils of Egypt where in certain districts alkali carbonates occur abundantly.

COPPER CHLORIDES

On ancient copper and bronze objects found after long contact with the saline soils of desert regions or buried in the sea, the green corrosion crusts are usually a mixture of the chlorides of copper. Surface crusts containing chlorides do not form a desirable patina on bronzes but are usually ugly and disfiguring. They give rise to a troublesome kind of alteration product which has long caused concern among collectors for the safety of bronze objects and have stimulated more scientific inquiries in museum laboratories than any other class of corrosion phenomena. A description of several of these copper chloride minerals follows.

Atacamite, $Cu_2(OH)_3Cl$, the most common copper chloride mineral, gets it name from the desert of Atacama in northern Chile where it occurs in secondary copper ore deposits. Since sodium chloride is highly reactive toward copper and its alloys, ancient artifacts of these metals exposed to it are often converted to fissured and nearly formless masses of atacamite. The color of the mineral ranges from emerald to blackish green. On the surface of many bronze objects from Egypt and Mesopotamia atacamite occurs as a continuous, sugar-like coating of dark green glistening crystals.

Atacamite is a fairly common product. Rooksby and Chirnside (1934), who were among the first to apply X-ray diffraction methods of analysis to metal corrosion products, observed that the green corrosion product on modern electrical copper wire exposed to sea water and also to artificial salt solutions is atacamite.

Often crystalline atacamite is associated with a paler green powdery product which gives the X-ray diffraction pattern of *paratacamite*, a mineral identical in chemical composition, but having hexagonal crystal form, whereas atacamite is orthorhombic. Such related minerals are called dimorphs. One form appears to occur about as abundantly as the other. Although both atacamite and paratacamite are observed most commonly on bronzes from arid areas, they may also be found on bronzes from regions of normal rainfall. Otto (1959) cites the occurrence of both minerals on bronze objects from Germany and other parts of Europe, and he adds that paratacamite occurs much more frequently than hitherto realized. It is also found on bronzes from Anyang and other parts of central and eastern China.

Paratacamite is the pulverulent green product of hydrolysis and oxidation of synthetic cuprous chloride in moist air. It is also the green powder that forms on chloride-corroded bronzes when the inner unstable nantokite (cuprous chloride) layer is exposed to air by cross sectioning or mechanical cleaning. It is not clearly stated in books on mineralogy which of the dimorphs is more stable; but on basis of museum experience it appears that paratacamite is the initial product of rapid nantokite transformation, but that atacamite (perhaps mixed with malachite) is the final one. The formation of paratacamite is the manifestation of what is called "bronze disease," a phenomenon which will be treated more fully under "nantokite" (*vide infra*).

Botallacite, $Cu_2(OH)_3Cl \cdot H_2O$, is another basic copper chloride. It was found originally at the Botallack mine, St. Just, Cornwall, England, and was first described by A. H. Church (1865). The type specimen was placed in the British Museum (Natural History), but for nearly a century no other occurrence of this mineral was reported until a specimen of greenish-blue alteration product taken from the interior of an Egyptian bronze figurine of the deity Bastet in the Fogg Museum of Art was identified by Professor Clifford Frondel of Harvard University as this same botallacite (1950). A second occurrence on an artifact was observed by the author on an Egyptian bronze censer in the Walters Art Gallery, Baltimore. Botallacite may occur on ancient bronzes more commonly than is suspected. Dr. Frondel has described other natural basic copper chlorides (1950) which someday may be found on an antiquity of brass or bronze.

Nantokite: Cross section studies on bronzes massively coated with atacamite and on others coated with cuprite sometimes reveal an inner layer of a pale gray waxy-looking substance which has been shown to be cuprous chloride, CuCl. It conforms to the unstable mineral called *nantokite* named from the first noted occurrence at Nantoko, Copiapo, Chile. Because of its waxy appearance, Rosenberg (1917), who seems to have been the first to describe its occurrence on ancient bronzes, appropriately calls it "matiére stearineuse." Caley (1941) found that nantokite was one of the principal alteration minerals of the extensively corroded bronze and copper objects recovered from deep wells at the site of the Athenian Agora, and from the Fountain Peirene at Corinth. Various investigators have shown that nantokite is the parent substance of both paratacamite and atacamite which are described above and that it is the cause of "bronze disease." Gettens (1932, 1936) described the occurrence of nantokite in corroded copper nails from a second millennium B.C. Mesopotamian site called Nuzi

(Iraq). Later he proposed (1951) a series of chemical reactions to explain the complex processes that are involved in the transformation of nantokite to cuprite and alternately to atacamite. Essentially nantokite rapidly hydrolizes and oxidizes when exposed to moist air and forms simultaneously red cuprous oxide and basic cupric chlorides. R. M. Organ (1963) has recently given a new review of the chemical reactions involved in chloride corrosion of copper, and described various methods used at the British Museum Research Laboratory for arresting it. One of these is to keep the antiquity in a dry atmosphere; the second is to effect complete removal of cuprous chloride by cathodic reduction at hight current density followed by intensive washing; the third, which employs soaking for long periods of time in changes of aqueous sodium sesquicarbonate, aims to convert cuprous chloride to harmless cuprous oxide. The fourth method makes use of silver oxide powder to form an impermeable seal of silver chloride over exposed cuprous chloride. This method is applicable for arresting local areas of disease on objects which cannot be treated by total immersion methods.

The occurrence of chloride minerals on artifacts from areas of fairly heavy rainfall, such as Europe and eastern China as noted above, is interesting but puzzling. Captain Collins remarks in his discussion of one of Vernon and Whitby's reports (1930) that "Soluble chlorides seem to cling to bronzes, though there may often be little chloride in the surrounding region." This would be an interesting subject for further investigation by soil chemists.

COPPER SULFATES

The bright green basic sulfate of copper corresponding to the mineral *brochantite*, $Cu_4(SO_4)(OH)_6$, is seldom reported on artifacts although it might be expected on bronzes exposed to sulfate-bearing waters. H. Otto (1961), however, reports the occurrence of this mineral on bronze artifacts found in German graves. The author (1933) found evidence of basic copper sulfate in the green corrosion crusts of a bronze statute of Nathan Hale in Hartford, Conn. The refractive index of the green material indicated that the green was more like antlerite, $Cu_3(SO_4)(OH)_4[Cu_3(SO_4)(OH)_4]$, than brochantite but unfortunately, X-ray diffraction methods for mineral identification were not available at that early date to permit precise identification. Some years ago the author examined the thin green corrosion crusts on a number of bronze statues of the Garden Court of the Ringling Museum, Sarasota, Fla., and found that the alteration product gave an X-ray diffraction pattern corresponding to brochantite. The sulfate at Sarasota appears to originate in the hydrogen-sulfide-bearing water used in the irrigation system in the garden. Likewise, a sample of green removed from a weather-exposed bronze lamp post in front of the Freer Gallery of Art in Washington, D.C., gives a brochantite pattern. Kosting (1937) also found that the green on a 10-year-exposed copper roof in Washington, D.C., is brochantite over a layer of cuprite. He further notes that only antlerite was detected in the patina from copper that was formed by accelerated weathering in the laboratory. There is good evidence that the green on copper roofs and statutary bronze in urban areas is mostly basic copper sulfate, formed from sulfur compounds produced in the burning of coal and fuel oil. Vernon and Whitby (1930) in the late 1920's carried out extensive researches on the green of copper roofs in London and other parts of England. They concluded that the main constituent of the green alteration product is basic copper sulfate and that it corresponds to the mineral brochantite when it has been exposed long enough to attain full basicity (cupric hydroxide content). This may require upward of 70 years. Mixed with basic copper sulfate are lesser amounts of basic copper carbonate and of copper chloride whose compositions correspond to the minerals malachite and atacamite when they reach full basicity.

Connellite: Recently H. Otto (1963) reported on the basis of X-ray diffraction analysis the occurrence of the rare mineral *connellite*, [$Cu_{19}(SO_4)Cl_4(OH)_{32}\cdot 3H_2O$?], on rings made of bronze sheets from the only group of graves of the La Tène Period found in southwestern Germany. The bright blue needlelike crystals of connellite occur mixed with other copper minerals in the bronze corrosion crusts.

COPPER SULFIDES

Sulfides are not often reported as occurring on copper artifacts, but they might be expected where objects have been in contact with sulfur-bearing waters. Both Austin F. Rogers (1903) and F. W. Clarke (1924) mention the investigations of A. G. Daubrée (1875, 1881) and others who examined Roman coins and medals recovered years ago from French mineral springs and report occurrences of *chalcocite*, Cu_2S, *chalcopyrite*, $CuFeS_2$, *bornite*, Cu_5FeS_4, and *tetrahedrite*, $(Cu,Fe)_{12}Sb_4S_{13}$. Daubrée (1875) also noted the occurrence of indigo blue *covellite*, CuS, among the other sulfide minerals in the corrosion crusts of coins. He believed the sulfide in the thermal spring water came from the reduction of soluble sulfates by bacterial action on vegetable material. Quite recently Mendel Peterson of the Smithsonian Institution recovered several fragments of a much corroded copper gunpowder can from the wreck of the *l'Herminie*, wooden flagship of the French West Indies fleet, sunk off Bermuda in 1838. Examination showed that the copper metal was completely altered to a blue-black brittle mass, identified by X-ray diffraction analysis as covellite. The source of sulfide appears to be sulfate-reducing bacteria in the wood. Likewise, shapeless lumps found by Mr. Peterson in a 17th century Spanish shipwreck, also off Bermuda, were found to be nearly pure covellite and appear to have been derived from copper or bronze artifacts or fittings that came in contact with a source of sulfide ion. Peterson suggests that some of the sulfide may come from gunpowder stored in magazines of warships. Gunpowder is a mixture of charcoal, saltpeter, and elemental sulfur. Lacroix (1910) observed covellite mixed with chalcocite as an alteration product on copper nails in a Roman shipwreck off Mahdia, Tunis. Here again the sulfide probably originated from bacterial decomposition of organic debris.

Mr. R. M. Organ[3] of the British Museum Laboratory says that *chalcocite* was found on a bronze sword blade dated about 1,000 B.C., taken from the river at Kings Lynn, Norfolk. A. Lacroix (1909) in France over a half century ago described Roman bronze coins found in a thermal spring at Grisy-en Saint Symphonén-de-Margne (Saône-et-Loire) that had been transformed to black chalcocite which is sectile and locally crystalline. Daubrée (1881) also noted the occurrence of a black form of chalcocite with metallic lustre on old copper coins from thermal springs, which he called *cupréine.* A. Périnet (1961) found *chalcocite and digenite* (Cu_9S_5) among the alteration products on a copper nail recovered from the ancient sunken wooden ship in the Mediterranean off Grande Congloüe.

COPPER NITRATES

The occurrence of heavy metal nitrates in nature is rather rare because of their solubility in water, although the nitrates of the alkali metals, sodium and potassium, which are especially soluble, occur abundantly in certain desert regions. Aoyama (1960, 1961) has identified basic copper nitrate, $Cu(NO_3)_2 \cdot 3Cu(OH)_2$, among green corrosion products on copper electric powerlines in Japanese mountain areas. Although X-ray diffraction data is given, the exact mineralogical species is not named. The writer has had the privilege of taking samples of green crystalline corrosion products from bronze vessels found by University of Pennsylvania archeologists in a royal tomb at Gordion in Anatolia. Preliminary studies showed the crystals give X-ray diffraction patterns identical with patterns of monoclinic synthetic basic copper nitrates which have not yet been reported to occur naturally. There may be new minerals yet to be identified among the copper corrosion products of the numerous bronze vessels found at Gordion. It is feared, however, that most of them have been lost by premature cleaning.

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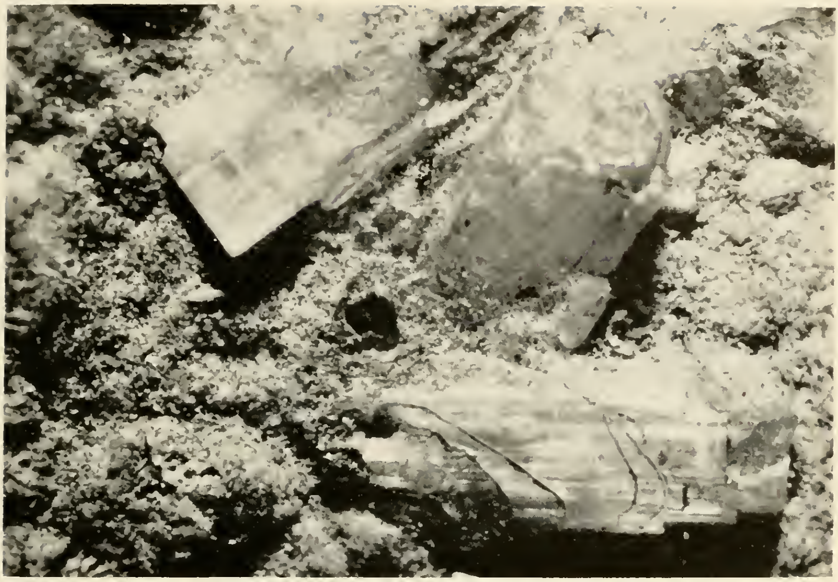
[3] Private communication.

Chinese bronze ceremonial vessel of the type *ting*. Shang Dynasty. From long burial this ancient bronze has been almost completely altered to mineral products of copper, tin and lead, similar to the ore minerals from which those metals were originally derived. Courtesy Royal Ontario Museum (Menzies Collection), Toronto.

Bronze statuette of the Egyptian deity Amen-ra; probably XXV–XXVI Dynasty. An inlaid inscription and a delicate inlaid checker pattern has been revealed completely hidden under a layer of atacamite, which is a mineral corrosion product of copper. It was formed during burial and contact with the salt-ridden soil of Egypt. Freer Gallery of Art 08.50.

Chinese bronze ceremonial vessel of the type *kuei*. Chou Dynasty. This view of the underside shows patches of whitihs crystalline cerussite (lead carbonate) mixed with bright green malachite (basic copper carbonate). Lead was often added by early Chinese metallurgists to copper-tin melts used in casting vessels of this kind. Freer Gallery of Art (No. 11.58).

The corrosion crusts on the stem of this old Persian lamp (25 cm. high) made of leaded bronze contain rare mineral salts of copper and lead. Some clusters of the distinct mineral crystal forms found in the crusts are shown in detail in plate 5 opposite. Freer Gallery of Art, SC. 541.



The detail, upper (magnification *c.* 15X), taken from the stem of the old Persian lamp (plate 4, opposite) shows colorless crystals of phosgenite which is a double salt of lead carbonate and lead chloride. The larger phosgenite crystals are intermingled with smaller dark blue crystals of the rare mineral cumengite shown in the detail, lower (*c.* 15X). Cumengite is a complex basic salt of lead and copper chlorides. Freer Gallery of Art.

Left: Chinese bronze ceremonial vessel of the type *kuei*. Shang Dynasty. Right: Chinese bronze ceremonial vessel of the type *huo*, elephant form. Early Chou Dynasty. During centuries of burial the copper constituent of the alloy has been leached away from the surface of both vessels and has been replaced by tin oxide with minimum distortion and volume change. Some of the finest patinas on ancient bronzes are formed in this way. Freer Gallery of Art (Nos. 41.8 and 36.6).

Cluster of silver cobs (hand struck Spanish one-quarter reales) found in the sea from the wreck of a ship from the Spanish treasure fleet lost off the Florida Keys in a storm in 1733. The cobs which are partially altered to black argentite (silver sulfide) are cemented togethered by coral sand. Courtesy Marvin Klein, Islamorada, Fla.

Ivory and bronze mounted iron knife. Graeco-Roman 3d-4th century A.D. The inherent stability of three different materials are shown in a single object. The iron blade is almost completely converted to rust; the bronze lion is only superficially corroded with malachite; the ivory figure is stained with copper green from the lion, and is cracked and fissured, but it has lost little of its original modeling. Courtesy Dumbarton Oaks Research Library and Collection. Washington, D.C. (No. 53.37.1).

Several 6-pound cast-iron cannon balls were recovered from the wreck site of the H.M.S. *Looe* sunk in 1744 off Looe Key in the Florida Straits. The upper illustration shows the condition of one ball after removal of calcareous incrustations. The lower shows a cross section of another ball in which a lead plug had been employed to fill a hole in the casting. The iron core is surrounded with a thick rind of iron oxide but the lead is relatively unaffected. Courtesy Department of Armed Forces History, Smithsonian Institution.

Chinese bronze ceremonial vessel of the type *yu*. Chou Dynasty. In the detail photograph of the inside lip of the vessel the imprint of a coarse fabric, probably straw matting, plainly shows. Fabrics of various kinds were used to wrap or lay over objects when they were placed in tombs. Even imprints of delicately woven fabrics like fine silk are sometimes encountered on ancient bronzes. Freer Gallery of Art No. 37.1.

COPPER PHOSPHATES

Bone and horn materials buried in direct contact with copper and bronze are often found stained blue-green with copper phosphate salts formed by action of copper salt solutions on calcium phosphate of the bone. Geilmann and Meisel (1942), on the basis of X-ray diffraction studies, identified as *libethenite* [$Cu_2(PO_4)(OH)$], a green-blue mass on a bronze spiral which had been in contact with bone in a German grave. H. Otto cites (1959) three occurrences of copper phosphate on artifacts. He does not call this alteration product libethenite, but gives the formula as $Cu_3(PO_4)_2 \cdot 3H_2O$, a compound which he claims is not known to occur in nature.

OTHER COPPER MINERALS

No occurrence of the natural silicate of copper *chrysocolla* seems to have been reported. Native or *redeposited copper* sometimes occurs among the inner layers of heavily chloride-encrusted bronzes. It is probably formed by reduction of cuprous chloride (nantokite) by the more electropositive high-tin phases of bronze alloys. Redeposited copper can occur in isolated pockets or patches or as a continuous inner layer. It is sometimes revealed in the form of little scales beneath the green corrosion crusts when they are stripped from the bronze surface with formic or other mild organic acids. Often the flakes are intermingled with cuprite.

In spite of the considerable amount of research already done, much remains to be learned about corrosion products and corrosion processes of copper and its alloys. Investigators for industry have been much concerned with corroding agencies and corrosion prevention, but they have given little attention to corrosion products themselves. These, unfortunately, are usually summarily discarded as worthless and uninteresting end products of corrosion reactions.

LEAD

Among ancient metals, lead, next to copper, forms the widest variety of corrosion products. It also forms some double salts with copper.

LEAD CARBONATES

The commonest alteration product on lead is *cerussite*, or lead carbonate, $PbCO_3$. This is the dense, adherent, warm-gray deposit usually seen on old lead seals, sarcophagi, statuary, and on all sorts of buried lead objects. Cerussite, fortunately, seems to form a protective layer on lead and prevents its progressive and complete disintegration. In 1959, during the restoration of the east front of the U.S. Capitol in Washington, sheet lead pads were found under the old marble columns.

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The columns and pads were set in place in 1825. When uncovered the lead was observed to be thinly coated with a white crust which was shown by X-ray diffraction analysis to be *hydrocerussite* [$Pb_3(CO_3)_2(OH)_2$], corresponding to artificial white lead, commonly used as a paint pigment. When exposed to open air it will probably further alter to cerussite as it often does in nature.

In the Freer Gallery collection of ancient Chinese bronze ceremonial vessels those with high lead content frequently have cerussite as a mineral alteration product among the corrosion constituents. On some of the vessels it covers large areas with rather ugly grayish crusts interspersed with patches of reddish lead oxide (litharge) and malachite. It is not uncommon to find cerussite as a distinct layer underlying malachite. In some occurrences, cerussite is found as well-formed crystals with glistening crystal faces; in others, it occurs as rounded excrescences much like malachite, and in one early bronze vessel cerussite took the form of the original bronze surface much as tin oxide does when it replaces copper pseudomorphically. Cerussite often reveals itself on ancient bronze by its pinkish yellow fluorescence in long wavelength ultraviolet light.

LEAD OXIDES

Next to the carbonates the several oxides of lead seem to be the most commonly occurring lead minerals. Caley (1955) identified *massicot* or yellow lead monoxide, PbO, on lead objects excavated at the Agora in Athens. He also found dark brown patches of lead dioxide or *plattnerite*, PbO_2, in a thin layer next to the lead metal. On the lead pads from the U.S. Capitol, already mentioned, patches of a hard salmon pink encrustation gave the X-ray diffraction pattern of *litharge*, another form of lead monoxide. The third common oxide of lead called minium (red lead) is found also in nature, but its occurrence on a lead artifact apparently has not been recorded.

LEAD SULFIDE

A. G. Daubrée (1875), reported the occurrence of *galena*, PbS, on a specimen of lead metal found in a thermal spring at Bourbonne-les-Bains in France. Strangely, no other occurrence of this naturally abundant mineral of lead has been noted.

LEAD CHLORIDES

The occurrence of the rather rare white lead mineral *cotunnite*, $PbCl_2$, was observed by A. Lacroix (1910) as an alteration product on lead plates of a sunken Roman ship found off Mahdia, Tunis, in 1907. Cotunnite was first found at Vesuvius as a product of sublimation. Lacroix also reported another white lead mineral, *phosgenite*

[$Pb_2(CO_3)Cl_2$], from the same source and on a lead pipe in hot springs from Bourbonne-les-Bains, France (1909). At the Laurion mines in Greece this double salt of lead was found with laurionite and other lead minerals formed by the action of sea water upon ancient slags produced from smelting lead ores. Lacroix notes that only the normal lead salts have been observed on the objects found in the reducing environment of deep sea water off Mahdia, while at the water's edge at Laurion the basic (oxy) salts predominate. A large crystal of phosgenite was found by A. A. Moss[4] inside a metal vessel, possibly pre-Roman in date, from the Great Cave, Wookey Hole, Somerset, England. The metal contained 60 percent lead and 40 percent tin.

In the Freer Gallery study collection there is a stem or column of an old Persian lamp which is made of highly leaded bronze. Most of the surface is covered with nondescript corrosion crusts of copper, but samples taken from scattered crystalline whitish patches give an X-ray diffraction pattern of *phosgenite.* Also, on this same lamp there were observed scattered small clusters of deep blue, highly refracting crystals which X-ray diffraction analysis showed were made of an even more rare mineral *cumengeite* [$Pb_4Cu_4Cl_8(OH)_8$], named after the French mining engineer, Edward Cumenge (1829–92). Only a single occurrence from Baja California, Mexico, is reported in Dana (1951). This is one more example of a rare mineral appearing on an artifact.

Other lead-copper minerals may occur, but they have not been observed or reported. Here is a possible opportunity which should not be overlooked by the archeological chemist or the rare mineral collector.

LEAD SULFATE

An occurrence of white crystalline *anglesite*, $PbSO_4$, mixed with galena on an ancient lead artifact from the thermal springs at Bourbonne-les-Bains in France was reported by A. Daubrée (1875). Small deposits of anglesite mixed with phosgenite were observed by G. Périnet (1961) on lead plates from the ancient sunken ship found off Grand Congloüe. Anglesite probably occurs on lead artifacts more commonly than is realized.

TIN

Tin is a metal of prime importance in archeology, not as an individual craft material but as a necessary adjunct to the making of bronze. Unfortunately, few objects of pure tin survive from antiquity even from centers of early bronze making such as Egypt, Mesopotamia, and China. If much pure tin was made in antiquity, it

[4] Private communication R. M. Organ.

has perished, perhaps for two reasons: First, it has been transformed by direct intercrystalline oxidation to mixed stannous and stannic oxides. Plenderleith and Organ (1953) have described tin oxidation in some detail, and Caley (1941) and Mantell (1949) have emphasized the important role of halides, especially of sodium chloride, in stimulating corrosion attack on tin. Secondly, it is sometimes transformed by allotropic modification to powdery gray tin (*vide infra*).

Although we have few objects of pure tin from remote antiquity to examine, an impressive bit of evidence of early commerce in tin was found preserved in the Bronze Age shipwreck found off Cape Gelidonya on the southwest coast of Turkey in 1960 by a University of Pennsylvania expedition lead by George F. Bass (1961). The wreck yielded the largest hoard of pre-Classical metal tools and "oxhide" ingots of copper ever found. In addition there were lumps of tin oxide, all that remained, it is presumed, of ingots of tin. Sea water had promoted the complete oxidation of the tin, but it had acted only superficially on the surface of the copper ingots. Samples of the powdery white tin residues from these ingots were supplied to the author by Mr. Bass. The powder gives the X-ray diffraction pattern of *cassiterite*, SnO_2, and the lines of the pattern are as sharp as those given by cassiterite ore specimens.

In one of the earliest published articles on applications of chemistry to archeology, Dr. Otto Olshausen (1884) of Berlin described three tin objects from early German graves which had been converted almost completely to tin oxide (*Zinnsäure*). These are further examples that show why so many early tin artifacts have completely disappeared.

Tin oxide, however, is an important alteration product on the surface of ancient high-tin bronze objects. Gettens (1949) found that stannic oxide is a major constituent of the smooth gray-green patina on Chinese bronze mirrors and ceremonial vessels sometimes called "water patina" by collectors. It also occurs on high-tin Etruscan and other European bronzes. This alteration product, which may penetrate into the bronze for a distance of 1 to 2 millimeters, may be a hydrous form of a stannic oxide. The pale greenish color is a stain caused by a small impurity of copper. It appears that, under certain conditions of soil contact, the copper is dissolved away from the surface of the bronze and replaced, atom by atom without volume change, by stannic oxide. This phenomenon is identical with pseudomorphic substitution of elements in mineralogy. The tin oxide encasing corroded high-tin bronzes is sometimes compact and translucent like ceramic glaze. Geilmann (1950, 1956) has published the analyses of a dozen Bronze Age artifacts from Europe in which tin oxide resulting from alteration is now the principal constituent. These were all originally bronze objects in which copper has been pseudomorphically replaced by a brownish colored hydrous tin oxide.

Copper is now only a minor constituent. This type of patina formation seems to occur principally on bronzes buried in sandy soils. Here, both carbonic and humic acids play an important role in dissolving out the copper of the alloy, leaving the tin constituent as stannic acid. In other occurrences the tin oxide is powdery and friable. The hydrous tin oxide patina alteration product is similar to cassiterite but the lines are broader and more diffuse, which suggests that it is cryptocrystalline and more finely divided than natural cassiterite.

It has recently developed that there is a close resemblance between the diffuse X-ray diffraction pattern of tin oxide alteration product on bronzes and that of the yellow tin mineral *varlamoffite* discovered in recent years in the Maniema region of the Belgian Congo by the mineralogist N. Varlamoff. It was named after the discoverer by S. Gastellier (1950) who made the first analyses. These show that the material is not a definite mineral species but a complex mixture containing: Metastannic acid, H_2SnO_3, average 59.22 percent; SnO_2 25.55; Fe_2O_3 9.45; SiO_2 1.68; and H_2O 2.12; total 98.02. The yellow color is caused by the ferric oxide. Another occurrence of varlamoffite from Cornwall, England, was subsequently described by Russel and Vincent (1950–52), who showed that the X-ray powder patterns of varlamoffite and of hydrated stannic oxide (metastannic acid) prepared in the laboratory are identical in spacing and intensity with cassiterite, but that they are broader and less well defined. In tests made in the Freer Gallery Laboratory, the diffuse cassiterite patterns given by several specimens of stannic oxide from ancient Chinese bronzes were found to match perfectly the diffuse lines and spacings given by a specimen of varlamoffite from Cornwall, England (specimen USNM R8886). A specimen of varlamoffite from the Belgian Congo (USNM 115558), however, gave lines only slightly less sharp than cassiterite. Although the investigators of varlamoffite mentioned above speak of hydrated stannic oxide or metastannic acid, H_2SnO_3, Weisser and Milligan (1932) many years ago showed conclusively by thermal differential analysis and by X-ray diffraction analysis that no true hydrates of stannic oxide exist. They maintain that the diffuseness of lines of the cassiterite pattern is caused by the small particle size of the stannic oxide crystals and that any water involved is adsorbed water.

F. Lihl (1962) as well as Plenderleith and Organ (1953) have reported evidence of stannous oxide as well as stannic oxide among corrosion crusts on tin objects, but there is no mineral of stannous oxide listed in the current edition of Dana's System of Mineralogy.

Much must be done before the mechanism of the solution of copper and its replacement by tin oxide on bronze surfaces is completely understood.

The second reason mentioned above for the rarity of metallic tin may be a physical change called "tin pest," whereby tetragonal metallic white β-tin is transformed to cubic powdery grey α-tin by allotropic modification at equilibrium temperature about 13.2° C. (55.8° F.). This behavior of tin is well described by Plenderleith and Organ (1953) and by F. Lihl (1962) who admit the existence of allotropic modification but minimize its importance in respect to the decay and disappearance of ancient tin objects. They agree that often what appears to be tin pest is nothing more than intergranular oxidation of tin with formation of mixed stannous and stannic oxides. This view is strongly supported by the X-ray diffraction analysis investigation carried out by Lihl on old corroded tin sarcophagi in Vienna.

SILVER

SILVER SULFIDES

Like tin, silver forms few alteration products. Black silver tarnish formed by action of hydrogen sulfide in the atmosphere is familiar to every householder. Strangely, the occurrence of the well-known silver mineral *argentite*, Ag_2S, has not been noted in the literature. Two occurrences of argentite, however, have been observed recently in the Freer Gallery Laboratory in the soft black corrosion crusts formed on silver coins found in wrecks of wooden Spanish treasure ships. One is a silver "piece of eight" from the Spanish ship *San Antonio*, which sank off Bermuda in 1621. Another is from a ship of the Spanish treasure fleet lost off Key Largo, Fla., July 13, 1733. It has been previously noted that copper objects retrieved from ships long sunk are commonly altered to sulfides (see under Copper). Source of the sulfide ion again may be sulfate-reducing bacteria harbored by the decayed wood. A. B. Albright of the Department of Armed Forces History, Smithsonian Institution, says that old wooden fragments brought to the surface from these marine wrecks often reek with hydrogen sulfide.

Perhaps the rare mineral, stromeyerite, CuAgS, should also occur where copper-silver alloys are subjected to similar environments; but, if so, it is one of those many interesting corrosion products that go down the workshop drain unrecognized, unadmired for color, and unappreciated for rarity.

Acanthite, Ag_2S, an orthorhombic dimorph of argentite was observed as shining faceted black crystals inside the hollow stem of a medieval silver chalice excavated at Mellifont, Eire. Identification was made by the Department of Mineralogy, British Museum (Natural History). It was also found as a black inlay (niello?) on a Sasanian dish made of base silver by the Research Laboratory of the British Museum.

SILVER CHLORIDES

Silver objects retrieved from desert soils are often encrusted with a gray-brown or dull lavender crust of cerargyrite or silver chloride, AgCl. Silver coins recovered from salt water are sometimes superficially altered to this mineral. There are instances, however, where silver chloride penetrates deeply into the metal structure. Many of the silver ewers and bowls now displayed in the University of Pennsylvania Museum, recovered by the late Sir Leonard Wooley from Ur of the Chaldees, were originally heavily encrusted with cerargyrite. After the crusts were removed by Kenneth A. Graham (1929) by means of electrolysis and formic acid, much of the original appearance of these precious antiquities was restored. A Persian silver plate dating from Sasanian times recently acquired by the Freer Gallery of Art has a continuous dull, purplish-gray color caused by alteration of the surface metal to cerargyrite. The color of the surface resembles the mauve color of the silver halides of an undeveloped photographic film exposed to full light. The appropriateness of the common name, horn silver, is apparent when one attempts to remove the deposit from the object with blunt tools. Cerargyrite and paratacamite associated with cuprite are sometimes found on base silver objects.

We still do not find listed in Dana's System of Mineralogy a compound mineral of copper and silver chlorides, although there is one of silver iodide, AgI, called miersite in which copper substitutes for silver. A new mineral of copper and silver chlorides may first be identified on some silver artifact. This is one more reason to stay the hand of those who may want to put unsightly freshly excavated silver objects through the cleaning bath before they can be properly examined.

IRON

Rust on iron objects is so common and is held in such disfavor that it is got rid of quickly if the object is of any interest. Since the beginning of this century quantities of iron artifacts have been stripped of corrosion crusts by electrochemical and electrolytic procedures. This has no doubt made possible the recovery of many important objects, but it is not likely that much attention was given to the nature of the iron alteration products.

IRON OXIDES

In the process known as rusting, iron is converted to its hydrous oxide *goethite*, FeO(OH), named for the German poet Goethe. In the older mineralogical literature it is called *limonite*. The mineral is dull yellow or yellow-brown in color. Daubrée (1875) noted that iron chains of Roman origin found in the thermal springs at Bourbonne-les-Bains in France were completely transformed to mammillary limonite.

Magnetite [$FeFe_2O_4$], the black oxide of iron, probably occurs on archeological iron more commonly than realized, especially on the interior of deeply corroded large iron objects where reducing conditions are likely to prevail. There is a large technical literature in the rusting of iron, but little that is available or useful to the archeologist except in an excellent short summary given by Plenderleith in chapter 13 of his well-known work (1956) on the conservation of antiquities.

IRON PHOSPHATE

This class of compound seems to be getting some notice by archeological chemists especially in England. The bright blue mineral which is seen on iron artifacts recovered in certain wet clay soils is recognized as *vivianite*, $Fe_3(PO_4)_2 \cdot 8H_2O$. Leo Biek (1963), chief of the Ancient Monuments Laboratory in London, has shown the writer various fragments of ancient iron and of waterlogged wood from archeological sites stained blue by this mineral. Vivianite quite commonly occurs also on nonartifactual organic material found in deeply buried archeological sites especially along river banks, and it testifies to the general soil conditions that prevail there. Vivianite is colorless when freshly uncovered in excavations, but quickly becomes blue in color when exposed to air. Booth (1962) and coworkers in England have observed the protective effect of vivianite coatings on iron nails which have been exposed since the 16th century to normally corrosive soils. The commercial use of phosphate salts in our time to protect iron from rusting is well known. Also, some interesting observations on the role of tannates and phosphates in the preservation of buried iron objects recovered from clay deposits have been made by Farrer, Biek, and Wormwell (1953), investigators from the Ancient Monuments Laboratory. Both vivianite and oxidized vivianite were identified on a Roman knife.[5] It was also identified on an iron axhead excavated from a crannog on Loch Glashan, Argylshire, Scotland.[5] H. Barker (1950) of the British Museum Laboratory has described the occurrence of a dark brown hydrated ferric-phosphate accretion among the materials identified in the famous Sutton Hoo ship burial. It appears that the phosphatic constituent was derived from the dissolution of calcined bone in contact with iron artifacts. The ferric phosphate material was described as "amorphous" since it gave indefinite X-ray diffraction pattern, and no mineralogical species was identified.

There is little doubt that the familiar and well-ploughed field of iron corrosion could be further examined with benefit to archeology.

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[5] Private communication, R. M. Organ.

ZINC

Although the Romans, and later the Chinese, produced brass or copper-zinc alloy, and zinc metal probably came into use in China and India in the Middle Ages, it was not recognized in Europe as a distinct element until the 18th century. After that zinc gradually came into commercial production in the West. Because of its early scarcity and also because of the chemical activity of zinc, few objects of that metal have survived from antiquity, hence little attention has been given to its alteration products. A grayish crust on a 19th century Italian ink pot of zinc, now in the United States National Museum, was shown to be *hydrozincite*, $Zn_5(OH)_6(CO_3)_2$. A single occurrence of *rosasite* $[(Cu, Zn)_2(OH)_2CO_3]$, similar in outward form to botryoidal malachite, but bluer in tone, was identified at the Department of Mineralogy, British Museum (Natural History)[6] on a Chinese bronze cannister of the Han period, and also on a Chinese vessel of the type *tui* of about 300 B.C. Smithsonite, $ZnCO_3$, and perhaps some other rare copper-zinc minerals may appear someday.

CONCLUSION

The accumulated knowledge of mineral alteration products on metal antiquities has practical as well as academic interest. The collector and curator of metal antiquities can use the information to supplement stylistic, historical, and epigraphic evidence in judging age, authenticity, and condition of newly met objects. Although it is rarely possible to estimate age and authenticity or antiquities solely on the kind and extent of mineral alteration products, these materials can provide valuable background information. They permit detailed and close comparison of objects of unknown provenience with those whose age and source are known. The pale green tin oxide water patina on a Chinese bronze ceremonial vessel of Shang Period is unique and characteristic of its time and place of origin. The dark green crystalline crusts of atacamite on an Egyptian bronze figurine may not assure ancient Egyptian origin; but if other attributes indicate the source as Egypt, the presence of mineral chlorides lend supporting evidence. Knowledge of the kind and character of corrosion products is essential to a rational method of cleaning metal objects. To increase the background knowledge necessary for the understanding and the conservation of metal antiquities, archeologists and collectors must begin to look upon decay and rust with a more appreciative and sympathetic eye.

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[6] Private communication, R. M. Organ.

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Religious Art East and West[1]

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[With 6 plates]

The religious art of all peoples and periods has always been the expression in visual form of their belief in unseen supernatural powers governing their lives and destinies. This revelation of the truths of belief may take either a symbolic or an anthropomorphic form, depending on the religion and the social conditions of the times. Although the artist devoted to religious themes may work within a discipline imposed by tradition, it is always possible that a painter like Giotto or El Greco may impose on timeworn themes such humanity or such an aura of supernal mystery as to impel the beholder to belief by this moving pictorial presentation that is in reality the artist's personal interpretation of scripture. Under such conditions religious art becomes a new religious experience. In the same way, an artist working within the framework of a tradition of prescribed iconography and technical procedure may out of his own imagination present such a heightened comprehension, an exegesis of the articles of belief, that his painted or sculptured icon will move the devotee more than an image by another uninspired artisan who simply follows the canons imposed upon him by his tradition. In many of the works to be discussed here, the icons, although not in any sense original inventions, are the works of men who, within the discipline of their craft and using prototypes drawn from many sources, produced creations of compelling splendor.

It can be stated as a generality that religious art employs the same techniques and styles as what is called secular art, so that, for example, the intricate convolutions on a page illuminated by an Irish monk in the eighth century are no different from the ornaments in gold wrought by secular craftsmen of the same period. Again, the pathos and realism of a saint painted in the Baroque period are also present in the representations of pagan themes in the 17th century.

[1] Reprinted by permission from *Midway*, No. 16, autumn 1963, and based on a longer and more detailed version in *History of Religions*, vol. 2, No. 1, summer 1962.

The artist dedicated to producing religious works of art in a period of belief will be possessed of a body of iconographical and technical recipes inherited as part of his training or imparted by clerical instruction. This corpus of information makes him an artist competent to express the truths of the faith comprehensible at different levels and in different ways by the learned churchman and the layman. The icon which he manufactures will be imbued with the symbolic attributes necessary to make it at once magically effective as a revelation of a divine prototype and touching the heart or inspiring the awe of the ordinary worshiper. This language of religious expression manifests itself within the framework of the style determined by such factors as the society and the background of the artist.

It is the concern of the religious artist to translate into concrete terms the concepts of Christian and Buddhist doctrine, sometimes of such a transcendent metaphysical nature as to defy an explicit embodiment in plastic form. Although every great artist will bring what we describe as imagination or originality to his creation, it is as true of Michelangelo as of the anonymous maker of Buddhist images that he is inevitably affected by his knowledge of preexisting forms that provide models for his guidance. Although some forms of religious art are perforce inventions for which no pictorial prototypes existed, the artists of early Christianity and Buddhism in many instances adopted the vocabulary of earlier religious art for the expression of new ideas. This is the principal concern of this essay. There is, of course, the possibility that craftsmen separated in time and place might independently arrive at a similar solution for presenting a like concept, but the history of the development of the style and iconography of Christian and Buddhist art reveals that in the main the artist attached to these religions relied on readymade forms in pagan art or earlier Asiatic art which they found readily adaptable to the solution of their problems. The result of this common heritage is a great number of parallels both in iconography and style, which are of great interest and importance for the study of the interrelationships between Buddhism and Christianity in the beginning of their plastic traditions.

The parallels that exist between religious art in the worlds of early Buddhism and Christianity are partly the result of similarities inherited from beliefs of previous periods, revealing themselves in similar plastic or pictorial form. In other cases they may be attributed to the transmission of artistic influences, in which the preexisting form may in turn affect belief and its artistic expression. At other times these parallels may be attributed to exchanges in doctrine through the intermediary of faiths like Mithraism and Mazdaism that prevailed in the geographic regions separating East and West, or they may be traced to certain common backgrounds in the religions of the ancient Near East. These parallels are not always contemporary but often reflect the taking up of earlier artistic forms or beliefs by one or the other religious system over a period of centuries.

The nimbus is a common attribute of early Christian and Byzantine art, as it is of Indian art from the first century A.D. onward. In this case we are dealing with a common adaptation of the sun disk used as a device to symbolize supraterrestrial splendor or divine light in the Mazdean period or Achaemenid art in Iran. In the Iranian art of this classical period a disk is set behind the personification of Ahura Mazda as a symbolic reference to the sun and the celestial glory of the supreme light. In this very simple example of the adaptation of older emblems by later religious systems the sun disk of Ahura Mazda was transformed into the halo to denote the divine radiance emanating from the persons of Christ and Buddha.

As will be seen, we also have to deal with the phenomenon in art of separate religious systems literally inventing a new imagery based on their common heritage from both the Asiatic and Hellenic past and in each case modified by the requirements of a particular iconography. Although the question of the independent evolution of ideas and belief and their portrayal in art in widely separated places and times is always within the range of possibility, it is logical to assume that many of these parallels represent both developments from a common source or borrowings by one religious system from another. The examination of a number of these spiritual and artistic affinities is a subject of vital importance both for the history of religions and the history of art.

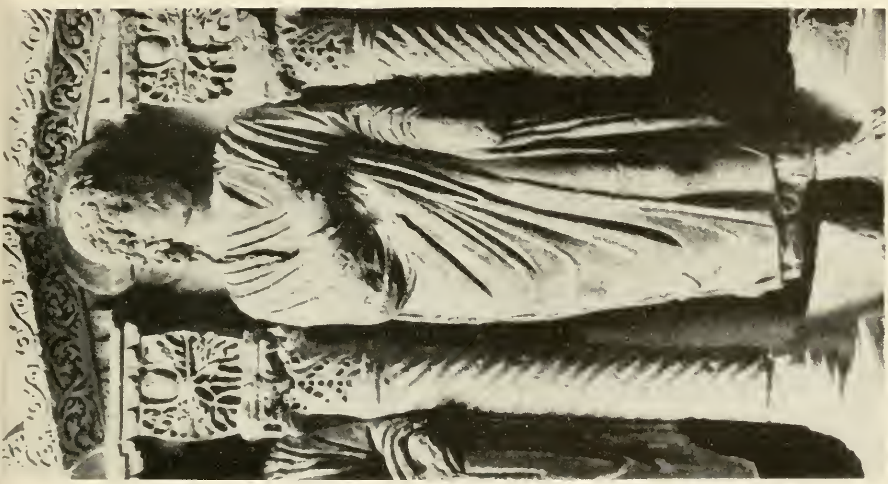
The development of Christian and Buddhist art in the early centuries of our era affords an opportunity for the study of certain parallels in concepts and stylistic expression that are the result partly of similarities in doctrine, and partly the result of common borrowings from the tradition of classical pagan art. Most of the examples chosen for comparison and analysis will be drawn from early Christian sculpture of the third to the fifth centuries and from the semi-Roman school of art that flourished in Gandhāra, now northwestern Pakistan, in the first five centuries of the Christian era.

Among the parallels existing between Christian and Buddhist art that are founded on common iconographical as well as doctrinal background are the first representations of Christ and Buddha in early Christian art and the Greco-Buddhist art of Gandhāra.

GANDHĀRA AND EARLY CHRISTIAN ART: BUDDHA PALLIATUS

The resemblance of certain Gandhāra statues of the Buddha, such as those excavated at Haḍḍa in Afghanistan, to early representations of Christ (pl. 1) has long been noticed, as has the fact that both apparently spring from the Greek orator type as exemplified by the

Sophocles of the Lateran. In these Buddha figures the garment worn is unmistakenly a himation and not the regular *sanghāṭī:* even though the undergarment visible in some of these statues suggests the tunic worn under the Roman toga, this mantle should, as will be explained directly, be described as a himation or pallium from the association of this dress with the ancient philosophers. The various personages in antique sculpture with the right hand emerging from the himation or pallium illustrate a style of wearing the garment that prevailed in every quarter of the late Antique world: it is paralleled at once in the Buddhas of Gandhāra, in Roman portrait statues, in portrayals of Christ, and in the countless grave reliefs of Palmyra. The fact that the pallium, draped in such a way that the right arm was supported as though muffled in a sling, continued to be worn until at least the fourth century is illustrated in many portrait statues, notably the effigy of Julian the Apostate in the Louvre. It was not a prevailing fashion of dress, however, but the association of this costume with ancient representations of philosophers and teachers that led to its adaptation to the early images of Christ and Buddha. However, the resemblance between the first statues of Christ and Buddha is not at all surprising if we consider that both are the result of closely parallel philosophic concepts in the religious complex of the Greco-Roman orbit: Justin had stated that Socrates was the "best" of the classic philosophers, since he denied the ancient gods and enjoined man to seek the unknown god in the Logos; he therefore urged his followers to know Christ as the personal appearance of the Logos indwelling in all people. The implication that Christ is of the line of the great classic teachers is almost too obvious. Augustine again draws a parallel between Christ, the Master of the new doctrine, and the ancient philosophers: "*paucis mutatis verbis*," he says, in speaking of Plato, *atque sententiis Christiani fierent.*" Christ the Pedagogue is here again thought of as replacing the teachers of the ancients. Concepts of this sort made it natural to represent the great teacher of Christianity in the iconography of the "teacher-orator" of the classic world. So also Justin preached the Word of God clad in the philosopher's gown. It seems almost redundant to point out that, in a similar way, Buddha was regarded as the great teacher, the denier of the ancient order as represented by the Vedas: the Greco-Roman workmen who fashioned his images in Gandhāra, like their early Christian cousins, chose the classic orator type as the most suitable for portraying the Teacher, the "Logos" of the Eastern world. The philosopher's gown was worn by holy men in the Roman Christian world of the second and third centuries and it was regarded as a garb of honor. There was nothing unusual in the selection of the pagan orator type for the representation of our Lord, who was Himself the supreme teacher, the eternal Pedagogue.

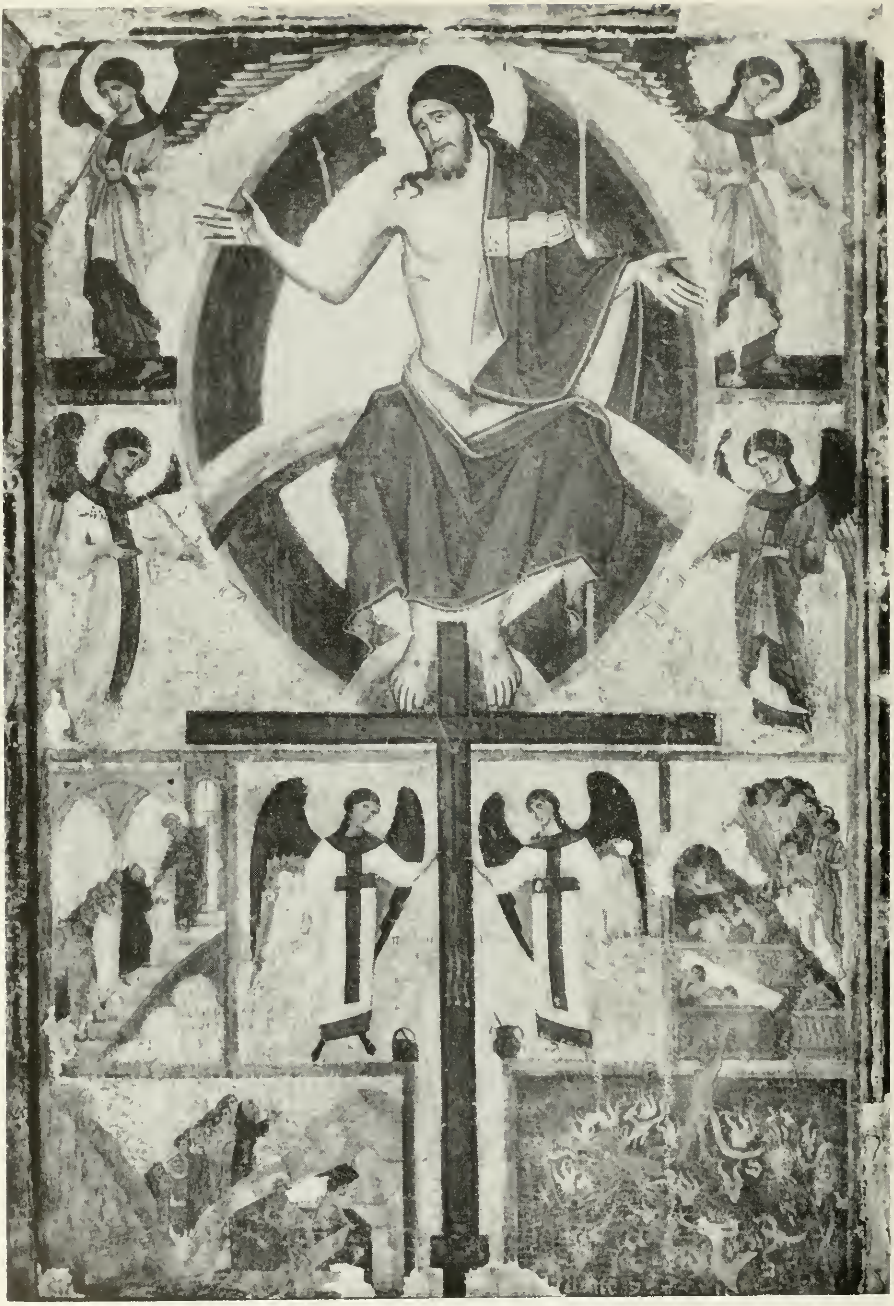


1. Christ, sarcophagus from Psamatia, third century A.D., Kaiser Friedrich Museum, Berlin.

2. Buddha from Hadda, Afghanistan, third-fourth century A.D., Kabul Museum, Afghanistan.

The 175-foot Buddha, Bāmiyān, Afghanistan, fourth-fifth century A.D.

Budda Maitreya, Group E, Bāmiyān, Afghanistan, *ca.* fifth century A.D.



Guido da Siena, Last Judgment, Grosseto

Chirst and the Apostles, early Christian, fourth century A.D., Musée Lapidaire, Arles.

Buddhas in Arcades of *Stūpa*, third century A.D., Haḍḍa, Afghanistan.

It is eminently worthy of note that, in both the Buddha and Christ image, a youthful ephebic type is substituted for the mature bearded faces of the orators. It has been suggested that the early Christian representations of Christ as a young man with long hair are taken over from earlier Apollonian prototypes. Our Lord's Resurrection is the sun's rising; His descent into Hell the setting of the orb beyond the Western rim. The analogy to the daily and eternal course of Helios-Apollo is apparent at once. Beyond this there are many descriptions in the Gospels and the writings of the church fathers that, by the luciferous character attributed to Christ, must have suggested the pagan images of the sun-god as models for representing Him. I need mention only Our Lord's "glory," referred to so often in the Gospels (John 1:14, etc.) or that His face "did shine as the sun" (Matt. 7:2). Ambrose, indeed, addresses Christ directly as "Sol":

Splendor paternae gloriae
de luce lucem proferens,

Primordiis lucis novae
diem dies illuminans.

Verusque sol illabere,
micans nitore perpeti, . . .

A similar choice of the classic sun-god as the type for the Buddha may naturally have suggested itself to the Eurasian artisans who carved the images at Gandhāra from the frequent allusions to the Buddha's solar character in the sutras. The following quotations will illustrate this point:

The Buddhas shine both by night and by day.

Like the Sun bursting from a cloud in the morning, . . . so he, too, when he was born from his mother's womb, made the world bright like gold, . . . dispelled the darkness.

He shone like the young sun descended upon the earth.

He will shine forth as a sun of knowledge to destroy the darkness of illusion in the world.

As far as we can say at the moment, Śākyamuni must have been represented in the guise of Sophocles and Aeschinus at the same time that Christ was given a similar anthropomorphic representation. We may be justified in assuming that the iconographic type was introduced from the Roman Orient. Again the stylistic parallels between this type in the East and West are as close as the spiritual similarities suggested by the literary sources mentioned above: the Buddha in our illustration (pl. 1, fig. 2) has—as is only to be expected—the same sharp and linear caricature of the form-fitting robe of the Hellenistic orator type that we find in the well-known example from Psamatia (pl. 1, fig. 1).

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SOLAR SYMBOLISM IN BUDDHISM AND CHRISTIANITY

The solar nature of Christ and Buddha has already been referred to in our examination of the "palliatus" type. Even more explicit suggestions of solar symbolism in Buddhism and early Christianity are worthy of more intensive exploration.

Significant as at least partly explaining the mentality that led to the eventual emergence of the Buddha and Sun myths is a passage from the Buddhacarita in which Sākyamuni, on entering the "place of austerities," is mistaken for the sun-god or the moon: "This is Sūryadeva or Canadradeva, coming down."

This is enough to show that fundamentally the identification of Buddha with the sun seems to have grown up within the complex of Indian philosophic-religious ideas. The transformation of the Buddha into the driver of the solar chariot is not markedly different from the ideology that deified the Roman emperor as Helios-Kosmokrator, and Khosrau as the brother of the sun and moon: as an example of this iconography we may cite the portrayal of Caracalla and other rulers as the sun-god Helios. Something of the same concept is seen in the early Christian representations of Helios in connection with figures of Peter, the Good Shepherd, etc.; Philo of Alexandria saw the Logos in the rising sun; in the poetry and exegesis of Christian Egypt, the morning orb is Christ himself. The solar character of Christ is, of course, symbolized in the feast of His birth, supplanting the Roman festival for the New Year and the sun, a means whereby the early Christians sought to rival the ancient pagan holiday with their own. In the tympana of the cathedrals of Parma and Piacenza the sun is included as a symbol of Christ as the Light of the World; the moon, the reflector of this light, as a symbol of the church.

An illustration of the Buddha's solar symbolism is provided by a wall painting of the sun-god in a chariot on the vault of the niche of the colossal 120-foot Buddha in the Bāmiyān Valley of Afghanistan. The central figure in the decoration stands upon a crescent and is inclosed in a huge sun disk. It is clad in a long mantle of the Parthian and Kushan sovereigns and surrounded by a variety of emblems stressing the astral character of the decoration. This image is a reference to the Buddha as another sun, rising to illuminate the darkness of the world. A symbolic allusion to the solar nature indicated by the Apollonian type of Buddha is discussed in an earlier section. The painting is evidently intended to be read in context with the giant statue beneath and the paintings of the Buddhas of past eras represented on the haunch of the vault. Pictorially this is only one of a number of such references in Buddhist art to Śākyamuni in his solar aspect.

In a relief from Mathurā, we have a frieze with a series of events from the life of the Buddha: in this arrangement, the place normally occupied by the Nativity of Gautama is replaced by a representation of Sūrya in his chariot. Below this band of carving is a zone with the Buddhas of the past and Maitreya, so that, as at Bāmiyān with the painted representations of the Manushi Buddhas, the symbolical implication is that, like these other teachers of other eras, Śākyamuni at his birth dawned as another sun to illumine the world. In the same way the many other portrayals of Sūrya the sun-god at Bodh Gayā, Bhājā, and elsewhere are allusions to the Buddha's solar nature just as the cars of sun and moon at Parma are references to the celestial light of Christ.

THE COLOSSAL IMAGE IN BUDDHIST AND CHRISTIAN ART

The enlargement of the earliest images of Christ and Buddha to colossal size presents another problem of iconographic and stylistic affinities in the two religions. This problem of the use of magnification to suggest the supernatural aspects of the deity is one that concerns both the iconography of Buddhism and that of early Christianity. Everyone is, of course, familiar with the making of giant statues in the ancient world and the transference of this concept to the statues of the deified Roman emperors in the late Antique Period. In Buddhism the earliest examples of the colossus in art are to be found in the two giant Buddha statues carved in the sandstone cliff at Bāmiyān.

The larger of the two colossi at Bāmiyān (pl. 2) is housed in an enormous cusped niche at the western end of the great cliff. It was carved presumably at about the same time as its smaller companion. Although the hands are now broken off, it seems likely that originally the right hand was raised in "*abhaya mudrā*," and the left, as in so many Buddha statues of Mathurā and Gandhāra, was shown holding a fold of the robe. It is notable that, in his description of this statue, Hsüan-tsang refers to it merely as "Fo hsiang" (Jap. *butsuzō*), or "Buddha image," whereas he specifically designated the smaller idol at Bāmiyān as Śākyamuni.

The scheme of painted decoration in the interior of the great vaulted chamber originally was even more extensive and complicated than the cycle in the niche of the smaller Buddha. We can see standing on the head of the colossus, ornamenting the ceiling above, the images of numerous enthroned bodhisattvas with attendants and musicians. On the haunch of the vault at the right and left again are rows of these seated deities. Immediately below are painted Buddhas in multicolored halos and in various *mudrās*. Looking up from the feet of the giant statue we can see that the under surfaces of the cusps of the arches are painted with the representations of trinities of flying deities in medallions. Below these again are the fragments of row upon row of Buddhas, differentiated from one another by their *mudrās* and the trees under which they are seated. At present the first 75 feet of wall surface is devoid of any painting.

I repeat here that the very scale of this great image at Bāmiyān implies that the religious of this center considered the Buddha as a more than mortal teacher and is thereby thoroughly in keeping with the transcendent nature attributed to him by the Lokottaravādins. We should also consider in this regard the possible influence of classic antiquity on the fashioning of enormous images of the gods not only in Christian iconography, but also as here on Buddhist art. I need only mention the statue of the Olympian Zeus and the effigies of the divinized emperors of Rome among the logical artistic prototypes for the practice of magnification to suggest a supraterrestrial power. There is a possible parallel and explanation for the making of colossi in the beginnings of Christian art. In the West, the early Christian conception of the Lord as the Good Shepherd was in Byzantium of the fourth century and was later replaced by the conception of the superhuman Christ reigning in majesty above the skies. Under influences almost certainly emanating from Iran, the emperors as early as Constantine had assumed the title of kosmokrator; the founder of Byzantium himself was portrayed in statues of giant size, dimensions deemed appropriate for the Lord of the Universe. When the emperor himself had thus grown to colossal stature, it was hardly possible to show any longer the Light of the World as a mere man; there evolved immediately the Christ Pantocrator, Ruler of All, and regal embodiment of the World of the Father. Since colossi do not appear in Buddhism before the Gandhāra school, it may be that among the contributions of this hybrid art was the plastic realization of the superhuman nature of the Buddha contained in the texts, aided and abetted by the Greco-Roman artists' knowledge of over life-sized figures of gods and kosmokrators in the West.

Although Christian art can boast no images on the scale of the Eastern examples, the enormously enlarged representations of Christ in the mosaics of the domes and apses of Byzantine churches are illustrations of the same principle. In both Buddhist and Christian art the colossus is an outgrowth of the ancient device of hieratic scaling, in which the most significant personage was magnified in order to assert its importance over other figures in the painting or relief. Before the colossi at Bāmiyān and the pantocrators of Byzantium the spectator himself provides the scale for the giant being that overshadows him.

One very good reason for creating colossal images of Buddha even at a very early period would be the conception of the Lord as Mahāpurusa. Buddha and Cakravartin, with whom he early became identified, are essentially the Purusa (Prajāpati) of vedic mythology and mysticism: the "laksanas" are derived from the distinctive marks of the Cosmic Man. They are in no sense physiological features but "cosmognomical emblems." The Great Person is at once the year and a solar myth and contains all worlds within his mystic anatomy. One could look on this concept as a synthesism with ideas already expressed in the Bhagavad Gītā where we read: "There in the body of the God of Gods, the son of Pāndu saw the whole universe resting in one" (XI, 13); and "The space betwixt heaven and earth and all quarters are filled by Thee alone" (XI, 20). "Thou art the Ancient Purusa" (XI, 18). As Paul Mus has remarked, there is a suggestion of just such a cosmological stature in the Buddha's flattening the earth with his footsteps, in the likening of his head to an umbrella; indeed, A. K. Coomaraswamy has shown that the early icons symbolizing Buddha by a parasol, altar, and footprints are really likenesses of the "mystical" body of the Great Person, respectively, sky, air, and earth—or, in other words, the cosmic anatomy of Prajāpati. It becomes clear with this that, as cosmic god and universal ruler (Purusa-Cakravartin) equal to all space, Buddha could appropriately be shown in enormous size as though literally filling a whole "cosmos." That cosmos is—in the case of the Bāmiyān Buddhas—the shrine or niche that, like the *chaitya*, the elevation of which it reproduces in cross section, may be understood as the cosmic house—its portals broad as the earth, its roof the sky: "Cut . . . in the vertical direction, the massive world fabric shows its net where everything is fixed in its place."

This idea of the Buddha-Puruṣa is already present in the chapter on the vision of the Universal Form in the Bhagavad Gītā and corresponds to the conception of Vairocana in the Kegonkyō, in which text the Tathāgata's body is described as comprehending all the directions, all space, all living beings; a similar text, the Bommokyō, determined the iconography of the *Daibutsu* at Nara. On the Nara *Daibutsu* the various Buddhas and worlds contained in Vairocana's universal form are represented on the petals of the lotus throne; at Yün Kang the colossal image of Vairocana in Cave 18 has its body clothed in a veritable garment of small Buddhas exactly in the same way that the multiple emanations of Lokeśvara cover the statutes of this deity in Indo-China. It is perhaps not too difficult to see that, as on the Nara *Daibutsu* the worlds are engraved on the petals of the lotus throne so at Bāmiyān these creations of the Cosmic Lord's are painted, row upon row, on the sides and vault of the niche. Although it is, of course, impossible to state categorically that the colossus in Afghanistan already represents a production of the worship of Vairocana or Universal Buddha as understood by the esoteric sects, the implications of what we see at Bāmiyān—an enormous image surrounded by paintings of multiple Buddhas and bodhisattvas—certainly suggests that the idea of Vairocana is there in all but name.

It is safe to say that the concept of Buddhas as Mahāpuruṣa, present even in Hinayāna texts, and the role of *Lokottara*, assigned to him in the Mahāsānghika sects, can be seen as working together to produce these first colossi of the Buddhist world. The giant statues of Yün Kang and Lung-men are the full development of this ideology and show us the Universal Lord of the Lotus Sūtra and the Avatamsaka-Buddha as Brahmā, the Father of the World.

THE TRANSCENDENTAL CHRIST AND BUDDHA

Related to the idea of the colossus as a supernatural portrayal of divinity are certain types of Christian and Buddhist art in which various other iconographical devices are employed to suggest the supernal nature of the divinity. Again, one of the more striking examples may be found at the great monastic site of Bāmiyān.

Group E is the designation given a small complex of caves about a hundred yards to the west of the smaller colossal Buddha at Bāmiyān (pl. 3). The only surviving painted decoration in these caves is a bodhisattva painted on the soffit of the niche that shelters the smallest statue of a seated Buddha at Bāmiyān. The divinity is ensconced under a blunted pediment and wearing a costume that recalls the dress of the Gandhāra bodhisattvas. The right hand is raised in *vitarka mudrā.* A necklace and heavy scarves are the only ornaments of the upper part of the body. In the headdress are fluttering ribbons conventionalized in the shape of French horns. The bodhisattva is represented seated on a rainbow of seven colors that at the same time serves as the aureole of the sculptured figure below it. This conception is strangely suggestive of the vision of the Apocalyptic Christ seated on the rainbow above the firmament. In St. John's description, the rainbow is a familiar natural phenomenon employed in the mystic's vocabulary to suggest more tangibly the transcendent beauty of the Lord, and by its position spanning the heavens to place the pantocrator vividly above the sky beyond the world. Besides its appropriateness as a glory or throne, the rainbow is probably intended as a symbol of the Lord's mercy, an illusion to his compact of Genesis 9:13–17.

A painting of the Last Judgment from the circle of Guido da Siena in the Church of the Misericordia at Grosseto (pl. 4) is illuminating with regard to the function of the rainbow in the iconography of the Revelation: The Pantocrator is seated on an arc of spectral colors that bisects his enframing mandorla; another smaller rainbow serves as a footstool, and below this is the Cross supported by angels, rising like the cosmic tree to the top of the sky and suggestive of Christ's earthly body and sufferings, as the Buddha in the niche may be the *nirmānskāya* of the vision above.

Anyone looking at the Grosseto icon would have been reminded that Christ by his cross brought peace as the rainbow symbolized the peace of the cosmic forces. Although no such allusion to a covenant with the deity is implied in the Buddhist painting, the rainbow still fulfils the function of suggesting a being raised above the world by the heavenly arc with a like implication of transcendence over the cosmos.

In Buddhist iconography, the aureoles of rainbow hue are probably to be taken as standing for the magic rays of varicolored light of "precious substances" that the Buddhas emanate from their persons. A suggestion of the possible symbolic significance of the nimbus that forms the seat of our bodhisattva is contained in the opening of the eleventh chapter of the *Saddharma Puṇḍarīka*: then there arose a Stūpa, consisting of seven precious substances, from the place of the earth opposite the Lord, the assembly being in the middle, a Stūpa five hundred *yojanas* in height and proportionate in circumference." H. Kern explains this phenomenon as follows: "between the Lord and (the Sun) is the *stūpa* of seven *ratnas*," that is, the rainbow of seven colors. He goes on to say that there are in Indian ideology either five or seven colors (RV, *pancaraśmi* and *saptaraśmi*) and that just as there exists a parallelism between the five colors and five planets, there should be a like parallelism between the *ratnas*, seven colors and the seven *grihas* or stellar mansions.

A more pertinent Christian interpretation of this ancient stellar symbolism is expressly stated by John (Rev. 1:20): "As for the mystery of the seven stars that thou seest in my right hand, and the seven golden lamp-stands—the seven stars are the seven angels of the seven churches, and the seven lamp-stands are the seven churches." In other words, the ancient astronomical symbolism has been swept away in favor of a symbolism understandable to the evangelist's contemporaries.

The bodhisattva at Bāmiyān is dressed in the turban-crown and jewels of a Royal Buddha: the position of this deity seated on the rainbow suggests that he may be intended as the *Sambhogakāya* in the skies in relation to the earthly teacher, *Nirmānakāya* of Buddha, personified in the ruined statue below. Such an arrangement would be analogous to the Paradise pictures of Tun-huang in which Śākyamuni in the center preaches of the Buddha Amitābha who appears as a viny vision at the top of the sky; it is Śākyamuni in his transcendental aspect who introduces mortals to the happy land in the West. This is the Buddhist equivalent of the Christ of the dictum in the Fourth Gospel, "*Nemo venit ad patrem nisi per me.*"

THE ARCHITECTURE OF PARADISE IN BUDDHIST AND CHRISTIAN ART

A final and somewhat more complex example of the iconographical relations between Christianity and Buddhism may be examined in the artistic device known as the *homme-arcade* motif, the use of an architectural setting—a colonnade—to frame divine personages for iconographical as well as artistic reasons. Here again the comparisons will be between examples from Gandhāra and early Christian art (pls. 5 and 6).

From what we know of the movement of artistic influences in the late Antique world, it is unlikely that the arcade-and-figure motif originated in Gandhāra and spread from there to the West. The synthetic character of art in the twilight of the classic world is such that probably the truth lies in all the proposed explanations for the appearance of the concept in India; that is, it is derived ultimately from the façades with engaged orders in the Roman world, and more specifically from the form as developed on early Christian sarcophagi through the collaboration of Syrian workmen, who, as will be explained below, saw the appropriateness of this funerary architecture to the needs of the Buddhist church of Gandhāra. Since the developed form of the *homme-arcade* is unknown before the Asiatic sarcophagi of the late second century A.D., it would be impossible to suppose that any occurrence of the type in Gandhāra is prior to this date.

In studying the photographs of the Gandhāra *stūpas* with their multiple images of Buddhas under arcades we are faced with another problem of an iconographical nature. It is not without importance for the stylistic aspects of the question: anyone seriously investigating the religious art of the East is bound to ask himself first of all whether the work of art he is examining was made for the expression of a definite concept that determined its form. In this case, one is bound to ask whether the repeated figures of the Buddha, each one nearly identical to its neighbor, were made as parts of a whole representing the miraculous appearance of the Buddha in many places at one time, as in the Great Miracle of Śrāvastī and in the transcendental sections of the Lotus Sutra (*Saddharma Puṇḍarīka*), or whether these are merely repeated effigies of Śākyamuni duplicated for the merit believed to accrue from the making of statues of the Great Teacher. From what we know of Buddhism in Gandhāra there is little evidence that the sculpture of this region was dedicated to Mahāyāna Buddhism: the only bodhisattva recognizable in Gandhāra art is Maitreya; insofar as we know, the mystic Buddhas of Mahāyāna are unknown, and only Śākyamuni and his mortal predecessors, the *manusi* Buddhas, are carved in the sanctuaries of northwestern India. More often than not, the number of statues seems determined solely by the dimensions of the space to be filled, but since the individual figures are differentiated from one another, it may be that they are either Śākyamuni at various moments of his career, or Śākyamuni and the Buddhas of the Past who were worshipped in Gandhāra.

The story related by Hsüan-tsang about the double-bodied Buddha at the great *stūpa* of Kanishka at Peshawar furnishes us a clue to the significance of Buddha images on the *stūpas:* in this legend two men each engaged an artist to paint a picture of the Enlightened One; when they came to pay their respects to the icons they had ordered, the two patrons were disappointed to find only one painting of the Buddha. At the artist's insistence that he had not defrauded them and that the picture would give some "spiritual indication" of this, the Painted Buddha divided in two from the waist upward, and the two men "believed and exulted." It is specifically implied in this passage that each man wished to have his own picture of the Buddha; in other words, we might well be justified in assuming that the multiple statues of Buddhas on the monuments at Taxila and Haḍḍa are individual donations, or, at least, different likenesses of the same Buddha. In the photograph of the Ali-Masjid *stūpa* one can make out statues of Buddhas and bodhisattvas of various types: it is tempting to think of these as different deities or different aspects of the same deity each in its separate niche like the chapels dedicated to various saints or types of Christ in the ambulatory of a great cathedral. One could see in this repetition of the Buddha images on all four sides of the *stūpas* the germ of the idea embodied in the four-faced statues of Lokeśvara at Angkor which are not four-headed monsters but one deity both seen and seeing everywhere at once. The multiple Buddha images could be interpreted as representing not many different Buddhas but one Buddha seen everywhere and simultaneously.

I have already suggested that the *homme-arcade*, a motif universally employed for sepulchral monuments in the West, was for this reason found appropriate for the decoration of reliquaries and *stūpas* which can be regarded as funerary in function.

It has been suggested that, first and foremost, the pagan sarcophagus was the House of the Dead: it was also a representation of the Palace of Hades as abode of the shades. In Christian art the Palace of Hades is converted into the Halls of Heaven or the Heavenly Jerusalem; Christ and the elect emerge from the colonnade that had formerly sheltered Apollo and the Muses as companions of the departed. What could be more appropriate for a sepulchral monument than the representation of the Celestial City where the soul hoped to dwell in peace with the Savior? In the same way, the pagan sarcophagi with the flora and fauna of Elysium are converted into those Christian coffins that portray the bay trees, the gardens, and goodly walks of Jerusalem the Golden. The conception of Paradise as a "palace" is almost universal in Indian mythology: I need mention only the palace of the Cakravartin, the King of the World who sits enthroned in the center of the great wheel of the world, and that center is his palace on the summit of Mount Meru, the cosmic mountain that pillars apart Heaven and Earth. Sometimes the Heaven of the Tuṣita gods, the dwelling place of the Bodhisattva Siddhartha before his last incarnation, is likewise described as a palace. The nearest textual confirmation to the suggestion that the revetment of the *stūpa* was in a sense a vision of celestial architecture is contained in the description of the building of the Lohāpasada in the Mahāvamsa.

The significance of this seeming digression is that with the acceptance of the *homme-arcade* as a means of representing the architecture of Paradise it seems not at all unlikely, but indeed very probable, that the form was adopted for Buddhist usage to represent the realms of the Buddahs. In earlier Indian art, as, for example, on the east gate at Sāñcī, the palaces of the *devas* are represented as columnar halls probably drawn from contemporary architecture; such a conception of the Buddhist Heaven recurs in the sixth-century fresco of Buddha in the Tuṣita Heaven in Cave 2 at Ajanṭāa. In this regard, it is interesting to note that we may identify the three central figures of the Bīmarān reliquary as a representation of the descent of Śākyamuni from the Tuṣita Heaven. The multiple images of Buddhas on the *stūpas* of Gandhāra, then, could be explained as representing the Buddha and the Buddhas of other *kalpas* enshrined in the golden halls of their heavens: the substitution of classical architectural forms being made the easier by the fact that Indian architectural forms had already been used for paradisiacal settings in earlier Indian art. The fact that the *homme-arcade* was specifically used to depict the architecture of the celestial regions in the West would only make it more acceptable to the Buddhists of Gandhāra who always showed themselves open to borrowing readymade classical types and techniques of all sorts for the realization of their iconographical ideas. The concept of the Buddhas in their heavens as a decoration for the exterior of the *stūpa* is not in the least incompatible with the essential meaning of these monuments as symbols of the universe. The hypothesis becomes even more convincing when we recall that although the arcade undergoes a considerable transformation—into Indian terms—it is still employed to shelter the Buddhas of the Four Directions whose multiple images once crowded the niches of the Mahābodhi temple at Gayā and the many copies of that memorial in the Eastern world. Again, single images of Buddhas, either of the Four Buddhas of the Past or the Four Mystic Buddhas, were often placed at the four sides of *stūpa* bases to symbolize the paradises of these Tathāgatas at the four points of the compass. The Buddhas on the *stūpas* of Gandhāra, sitting or standing in a palatial architectural setting of mixed classical and Indian form, could then be said to be a primitive form of the Paradise iconography, a concept exactly paralleling the prototype of the Heavenly Jerusalem as symbolized by the arcades of the early Christian sarcophagi.

In conclusion, it should be emphasized that, in the examples of religious art we have examined, traditions of the most ancient cosmologies known to man, traditions of magic, craft, and ritual—which, although no longer completely understood in later periods, still determined the forms proper to religious concepts—from the orientation of the temple to the least of the symbols decorating the footprints of Buddha. For the centuries of faith these remain in a way apart from change except insofar as they are variously interpreted in the stylistic form language accidental to different places and periods. This latter problem is a separate one which is no less significant in weighing the—for us—final value of the icon in the history of art.

This problem is separate and different because such "aesthetic" or antiquarian considerations never entered the mind of a craftsman working in a tradition before the rise of the individual "artist" in the modern sense of the term. In the great periods of Asiatic art, before the breakdown of tradition in craft and religion, the geometry of the images of Buddha, the particular concepts that necessitated their particular form, the method and purpose of making and worshiping icons remained very much the same as did the technical training and spiritual approach of the actual craftsman. In later periods the primordial secrets of the time-and-space mechanism of the cosmos, the reasons for the images being as they were—abstract and beyond nature—were remembered only dimly by the majority or else they were repeated only as formulas not truly understood; but even in later centuries in India, China, and Japan there were men by whom the ancient mysteries were still understood in all the awful clarity of their original meaning, and to these the survival of the ancient traditions is due. In periods like our own time when tradition is almost synonymous with superstition, such concepts as the Tree of Life suggest only a design in a modern "Numdah" rug, and no explanation beyond technical inadequacy is deemed necessary for the attenuated proportions of the early icons of Christ and Buddha. In the period with which we are concerned, enough of these traditions were still alive all over Asia to account for the seeming identity in "style"—the identity is really as much in "content." It must be pointed out that, in Asiatic art, comparisons of details according to the systems of modern scientific art history, although revealing to a certain degree, are actually useless and beside the point in such a unified, traditional art as that of Asia in which the artist never emerges completely as an individual, but is dedicated to expressing communal ideas, not his own personality. The language of his expression is based on certain forms which, by common consent through generations of artistic practice, have been conceived as proper to revealing the essential nature of the divinities for the edification of the believers. The likenesses and differences in physical type in such things as detail in ornaments are due to racial likenesses and differences and ideals which are beyond the control even of traditional iconography or what the art historian is pleased to call influences. As Langdon Warner has so well expressed it: "Dealing directly with the artist's Formal Cause and original conception is quite apart from dealing with influences, where the artist either copies externals or is so close in the grip of his tradition that his spiritual stimulus is controlled by traditional shapes. The critic's difficulty is that he often has to deal with material produced under mixed conditions: direct original imagination clothed in traditional shapes."

A valuable lesson in what influences really are can be learned in studying the vicissitudes of the Udayāna Buddha type. The famous sandalwood image was, according to legend, made in the lifetime of Śākyamuni for the king of Udayāna. The original Udayāna Buddha in art was, judging from existing copies, an image of the Gandhāra school which the latter adopted as the legendary effigy of Śākyamuni. The story has the earmarks of a pious fabrication designed to popularize and to justify the worship of the first and very foreign images of Buddha with the "rippling" folds of their Roman togas. Copies were known in China in Hsüan-tsang's time and continued to be made in Japan through the Kamakura Period; the type survives in Tibet and Nepal to the present day. On the grossly humanistic concept of the Gandhāran original, the artist of the dark and mystic figure that we see today in the shrine at Seiryōji has produced something abstract and enormously ghostly. The general lines of the robe of a Gandhāra image are there; we recognize them as superficially related, but in the Japanese statue the folds are worked into rhythms that greatly aggrandize the figure and convey the feeling of the universal character of drapery structure—not the particular attempt to show the surface appearance of a special robe. In the same way the formalization of the realism of the Roman dress in the early Christian images of Christ and the reduction of the sensuous beauty of the Apollo head to a bland mask of serenity in these and the Gandhāra Buddhas impart a ghostly character that was not present in the humanistic originals.

Finally, it must be emphasized that no matter how large the stylistic factor may loom in such problems of art history, more significant still in traditional art is the concept that determined the form: in tracing down the history of the content and in analyzing it we shall come closer to truth than in a pursuit of such will-o'-the-wisps as "influences" so often turn out to be. In the origin of the dominating idea we shall find in part the explanation of the form as well. The biological expansion of the cosmos described with both faith and the authority of science by Père Teilhard is only an ordering of concepts of the metaphysical structure of the universe embodied in the texts of and iconography of mystical Buddhism: that world tree whose branches flower into space, towering upward to infinity to bear us all at last to our astral home, is a scientifically explained miracle embodied in the ancient ideas of the world-axis, of Yggdrasil, and the all-embracing cosmic person who is at once Christ and Buddha.

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