CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 44

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CARNEGIE INSTITUTION OF WASHINGTON
WASHINGTON, D. C.
1945

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PRESIDENT AND TRUSTEES

PRESIDENT

VANNEVAR BUSH

BOARD OF TRUSTEES

WALTER S. GIFFORD, *Chairman*
ELIHU ROOT, JR., *Vice-Chairman*
FREDERIC A. DELANO, *Secretary*

#THOMAS BARBOUR	HERBERT HOOVER	ELIHU ROOT, JR.
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ROBERT WOODS BLISS	ERNEST O. LAWRENCE	RICHARD P. STRONG
LINDSAY BRADFORD	ALFRED L. LOOMIS	CHARLES P. TAFT
FREDERIC A. DELANO	ROSWELL MILLER	JUAN T. TRIPPE
HOMER L. FERGUSON	HENRY S. MORGAN	JAMES W. WADSWORTH
W. CAMERON FORBES	SEELEY G. MUDD	FREDERIC C. WALCOTT
WALTER S. GIFFORD	HENNING W. PRENTIS, JR.	LEWIS H. WEED

Executive Committee

WALTER S. GIFFORD, *Chairman*

ROBERT WOODS BLISS	FREDERIC A. DELANO	FREDERIC C. WALCOTT
VANNEVAR BUSH	W. CAMERON FORBES	LEWIS H. WEED
	HENRY R. SHEPLEY	

Finance Committee

FREDERIC C. WALCOTT, *Chairman*

LINDSAY BRADFORD	HENNING W. PRENTIS, JR.
HENRY S. MORGAN	ELIHU ROOT, JR.

Auditing Committee

FREDERIC A. DELANO, *Chairman*

HOMER L. FERGUSON	JAMES W. WADSWORTH

STANDING COMMITTEES FOR THE YEAR 1946

Committee on Astronomy

HERBERT HOOVER, *Chairman*

ROSWELL MILLER	ELIHU ROOT, JR.
SEELEY G. MUDD	JUAN T. TRIPPE

Committee on Terrestrial Sciences

FRANK B. JEWETT, *Chairman*

HOMER L. FERGUSON	ALFRED L. LOOMIS
ERNEST O. LAWRENCE	FREDERIC C. WALCOTT

Committee on Biological Sciences

LEWIS H. WEED, *Chairman*

#THOMAS BARBOUR	FREDERIC A. DELANO
JAMES F. BELL	HENNING W. PRENTIS, JR.

Committee on Historical Research

HENRY R. SHEPLEY, *Chairman*

ROBERT WOODS BLISS	CHARLES P. TAFT
RICHARD P. STRONG	JAMES W. WADSWORTH

•Deceased January S, 1946.

FORMER PRESIDENTS AND TRUSTEES

PRESIDENTS

DANIEL COIT GILMAN, 1902-1904 ROBERT SIMPSON WOODWARD, 1904-1920
JOHN CAMPBELL MERRIAM, *President* 1921-1938; *President Emeritus* 1939-1945

TRUSTEES

ALEXANDER AGASSIZ	1904-05	WAYNE MACVEAGH	1902-07
GEORGE J. BALDWIN	1925-27	ANDREW J. MELLON	1924-37
JOHN S. BILLINGS	1902—13	DARIUS 0. MILLS	1902-09
ROBERT S. BROOKINGS	1910—29	S. WEIR MITCHELL	1902-14
JOHN L. CADWALADER	1903-14	ANDREW J. MONTAGUE	1907-35
WILLIAM W. CAMPBELL	1929-38	WILLIAM W. MORROW	1902-29
JOHN J. CARTY	1916-32	WILLIAM CHURCH OSBORN	1927-34
WHITEFOORD R. COLE	1925-34	JAMES PARMELEE	1917-31
CLEVELAND H. DODGE	1903-23	WM. BARCLAY PARSONS	1907-32
WILLIAM E. DODGE	1902-03	STEWART PATON	1916-42
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	JOHN J. PERSHING	1930-43
WILLIAM N. FREW	1902-15	HENRY S. PRITCHETT	1906-36
LYMAN J. GAGE	1902-12	ELIHU ROOT	1902-37
CASS GILBERT	1924-34	JULIUS ROSENWALD	1929-31
FREDERICK H. GILLETT	1924—35	MARTIN A. RYERSON	1908-28
DANIEL C. GILMAN	1902-08	THEOBALD SMITH	1914-34
JOHN HAY	1902-05	JOHN C. SPOONER	1902—07
MYRON T. HERRICK	1915-29	WILLIAM BENSON STOREY	1924-39
ABRAM S. HEWITT	1902—03	WILLIAM H. TAFT	1906-15
HENRY L. HIGGINSON	1902—19	WILLIAM S. THAYER	1929-32
ETHAN A. HITCHCOCK	1902-09	CHARLES D. WALCOTT	1902-27
HENRY HITCHCOCK	1902-02	HENRY P. WALCOTT	1910-24
WILLIAM WIRT HOWE	1903-09	WILLIAM H. WELCH	1906-34
CHARLES L. HUTCHINSON	1902-04	ANDREW D. WHITE	1902-03
WALTER A. JESSUP	1938-44	EDWARD D. WHITE	1902-03
SAMUEL P. LANGLEY	1904-06	HENRY WHITE	1913-27
CHARLES A, LINDBERGH	1934-39	GEORGE W, WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902—08
SETH LOW	1902-16		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR THE YEAR 1945

ASTRONOMY

MOUNT WILSON OBSERVATORY

Pasadena, California

Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936; Walter S Adams, Director 1924-1945.

IRA S. BOWEN, *Director,* January 1, 1946
WALTER BAADE
HAROLD D. BABCOCK
WILLIAM H. CHRISTIE
THEODORE DUNHAM, JR.
JOSEPH O. HICKOX
EDISON HOGE
EDWIN P. HUBBLE
MILTON L. HUMASON
ALFRED H. JOY
ROBERT B. KING
PAUL W. MERRILL
RUDOLPH MINKOWSKI
SETH B. NICHOLSON
EDISON PETTIT
ROBERT S. RICHARDSON
ROSCOE F. SANFORD
fGusTAF STRÖMBERG
ADRIAAN VAN MAANEN
OLIN C. WILSON
RALPH E. WILSON

TERRESTRIAL SCIENCES

GEOPHYSICAL LABORATORY

2.801 Upton St., N.W., Washington, D. C.

Organized in 1906, opened in 1907; Arthur L. Day, Director 1909-1936

LEASON H. ADAMS, *Director*
JOHN S. BURLEW
JOSEPH L. ENGLAND
RALPH E. GIBSON
ROY W. GORANSON
JOSEPH W. GREIG
EARL INGERSON
FRANK C. KRACEK
ORVILLE H. LOEFFLER
*HERBERT E. MERWIN
GEORGE W. MOREY
IELBURT F. OSBORN
CHARLES S. PIGGOT
EUGENE POSNJAK
HOWARD S. ROBERTS
JOHN F. SCHAIRER
EARNEST S. SHEPHERD
GEORGE TUNELL
WILLIAM D. URRY
EMANUEL G. ZIES

DEPARTMENT OF TERRESTRIAL MAGNETISM

5241 Broad Branch Road, N.W., Washington, D. C.

Organized in 1904; Louis A. Bauer, Director 1904-1929

JOHN A, FLEMING, *Director*
OLIVER H. GISH, *Assistant Director*
LLOYD V. BERKNER
EDWIN J. CHERNOSKY
DEAN B. COWIE
SCOTT E. FORBUSH
ALBERT A. GIESECKE, JR.
GEORGE K. GREEN
LAWRENCE R. HAFSTAD
NORMAN P. HEYDENBURG
ELLIS A. JOHNSON
HENRY F. JOHNSTON
MARK W. JONES
PAUL G. LEDIG
ALVIN G. MCNISH
WILFRED C. PARKINSON
RICHARD B. ROBERTS
WILLIAM J. ROONEY
WALTER E. SCOTT
STUART L. SEATON
KENNETH L. SHERMAN
WILLIAM F. STEINER
OSCAR W. TORRESON
MERLE A. TUVE
ERNEST H. VESTINE
GEORGE R. WAIT
HARRY W. WELLS

* Retired in 1945.
f Resigned in 1945.

BIOLOGICAL SCIENCES

DIVISION OF PLANT BIOLOGY

Central Laboratory, Stanford University, California

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

HERMAN A. SPOEHR, *Chairman*
JENS C. CLAUSEN
GARRETT J. HARDIN
WILLIAM M HIESEY
DAVID D. KECK
WINSTON M. MANNING
fEMMETT V. MARTIN
HAROLD W. MILNER
*FORREST SHREVE
JAMES H. C. SMITH
HAROLD H. STRAIN

DEPARTMENT OF EMBRYOLOGY

Wolfe and Madison Streets, Baltimore, Maryland

Organized in 1914; Franklin P. Mall, Director 1914-1917; George L. Streeter, Director 1918-1940

GEORGE W. CORNER, *Director*
ROBERT K. BURNS
LOUIS B, FLEXNER
CHESTER H. HEUSER, *Curator of the Embryological Collection* *
MARGARET R. LEWIS
SAMUEL R. M. REYNOLDS
JOSEPH SCHILLER, *Research Associate*
WALTER S. WILDE

DEPARTMENT OF GENETICS

Cold Spring Harbor, Long Island, New Yor

Station for Experimental Evolution, opened in 1904, combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934; Albert F. Blakeslee, Director 1935-1941.

MILISLAV DEMEREC, *Director*
UGOFANO
BERWIND P' KAUFMAN*
EDWIN C. MACDOWELL
TT, - , ^
BARBARA. MCCLIKTOCK
f HARRY E. WARMKE

Research Associates
JOHNJ.B.ESELE
MARKET R. MACDONALD
i>. (J. OTEPHENS

NUTRITION LABORATORY

29 *Biac^fan Street, Boston, Massachusetts*

Organized In 1907, opened in 1908; Francis *G.* Benedict, Director 1907—1937

THORNE M. CARPENTER, *Director*
V. COROPATCHINSKY

Activities discontinued January i, 1946

#Retirai in 1945.
"f Resigned in 1945.

HISTORICAL RESEARCH

DIVISION OF HISTORICAL RESEARCH

IO Frisbie Place, Cambridge, Massachusetts

Department of Historical Research organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905—1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

ALFRED V. KIDDER, *Chairman*

Section of Aboriginal American History

SYLVANUS G. MORLEY
EARL H. MORRIS
HARRY E. D. POLLOCK
TATIANA PROSKOURIAKOFF
KARL RUPPERT
ANNA O. SHEPARD
EDWIN M. SHOOK
A. LEDYARD SMITH
ROBEKT E. SMITH
GUSTAV STRÖMSVIK
SOL TAX
J. ERIC S. THOMPSON

Section of Post-Columbian American History

ELEANOR B. ADAMS
ROBERT S. CHAMBERLAIN
RALPH L. ROYS
FRANCE V. SCHOLES
#LEO F. STOCK

Section of the History of Science

Q EORGE SARTON
ALEXANDER **POGO**

RESEARCH ASSOCIATES

RESEARCH ASSOCIATES ENGAGED IN POST-RETIREMENT STUDIES

ALBERT F. BLAKESLEE, Genetics
FREDERICK H. SEARES, Astronomy
GEORGE L. STREETER, Embryology

RESEARCH ASSOCIATES CONNECTED WITH OTHER INSTITUTIONS

V. BJERKNES (University of Oslo), Meteorology
EDWARD L. BOWLES (Massachusetts Institute of Technology), Physics
JOSEPH C. BOYCE (New York University), Physics
RALPH W. CHANEY (University of California), Paleobotany
A. H. COMPTON (University of Chicago), Physics
TH. DOBZHANSKY (Columbia University), Genetics
FRANK T. GUCKER, JR. (Northwestern University), Chemistry
Ross G. HARRISON (Yale University), Biology
ARTHUR T. HERTIG (Boston Lying-in Hospital), Embryology
VICTOR F. HESS (Fordham University), Physics
THOMAS H. JOHNSON (Bartol Research Foundation), Physics
S. A. KORFF (Bartol Research Foundation), Physics
E. A. LOWE (The Institute for Advanced Study), Paleography
ROBERT A. MILLIKAN (California Institute of Technology), Physics
tT. H. MORGAN (California Institute of Technology), Biology
WALTER H. NEWHOUSE (Massachusetts Institute of Technology), Geophysics
ROBERT REDFIELD (University of Chicago), Anthropology
HENRY N. RUSSELL (Princeton University), Astronomy
H. C. SHERMAN (Columbia University), Nutrition
JOEL STEBBINS (University of Wisconsin), Astronomy

* Retired in 1945.
f Deceased.

OFFICES OF ADMINISTRATION

Office of the President

VANNEVAR BUSH, *President*
WALTER M. GILBERT, *Executive Officer*
SAMUEL CALLAWAY, *President's Secretary*

Office of Publications and Public Relations

FREDERICK G. FASSETT, JR., *Director*
AILENE J. BAUER, *Assistant to the Director*
DOROTHY R. SWIFT, *Editor*

Office of the Bursar

EARLE B. BIESECKER, *Bursar*
J. STANLEY LINGEBACH, *Assistant Bursar*

Investment Office {New Yor\ City)

PARKER MONROE, *Investment Officer*
RICHARD F. F. NICHOLS, *Assistant Investment Officer*

ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use, and in recent years a total of ten million dollars has been paid by the Carnegie Corporation of New York as increase to the Endowment Fund of the Institution. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution,* articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington.* (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many dose relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications and Public Relations provides means for appropriate publication.

ARTICLES OF INCORPORATION

PUBLIC NO. 260. An Act to incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following Individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge,, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel* P. *Langley,* William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Httckcoc{,* Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws

shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or

any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, December 10, 1937, December 15, 1939, December 13, 1940, and December 18, 1942

ARTICLE I

THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies In the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II

MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall$_3$ moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III

OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

ARTICLE IV

EXECUTIVE ADMINISTRATION

The President

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee, He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board,

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize aad direct.

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

ARTICLE V

COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of

expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI

FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be Invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee,

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

AWICLE ¥11

AMENDMENT OF BY-IAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE FORTY-SEVENTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in New York, N. Y., in the Board Room of the Carnegie Corporation of New York, on Friday, December 14, 1945. It was called to order at 11:00 A.M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: James F. Bell, Robert Woods Bliss, Lindsay Bradford, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Henry S. Morgan, Seeley G. Mudd, Henning W. Prentis, Jr., Elihu Root, Jr., Henry R. Shepley, Richard P. Strong, Charles P. Taft, Juan T. Trippe, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Vannevar Bush, was also in attendance.

The minutes of the forty-sixth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The Chairman announced the death of the President Emeritus, and upon motion it was

Resolved, That the Board of Trustees of the Carnegie Institution of Washington hereby records its deep regret at the death, on October 30, 1945, of Dr. John Campbell Merriam,, President of the Institution from January 1, 1921 to December 31, 1938 and President Emeritus from January 1, 1939 until his death. Already distinguished as a brilliant student and notable contributor to his chosen field of paleontology and already recognized as a leader *in* organization of scientific programs, Dr. Merriam brought to the Institution qualities of mind and of humanity which resulted in profound advances in knowledge within the Institution and more broadly throughout the whole realm of science. By repeated emphasis on biological phenomena, he became a rare philosophic interpreter of nature and natural resources in their effects upon human thought and human aspirations. He led the Institution into new channels of scientific endeavor; and by his sympathetic understanding of human relationships, by his discriminating selection of investigators of exceptional ability, by his kindly insistence upon cooperative effort, he molded the various divisions within the Institution into an effective unit for furtherance of human knowledge. Dr. Merriam broadened and strengthened the concept of the Institution as an instrument of utmost value to society in the initiation and support of research. To the members of the Board of Trustees, Dr. Merriam was more than the wise leader and able investigator; he was friend and counselor. The members therefore record a profound personal regret at his death but rejoice that he has left so forceful and lasting an imprint upon the scientific endeavors of the Institution.

The following appropriations for the year 1946 were authorized:

Pension Fund	$95,000
Administration (including expenses of Investment Office and of Insurance)	109,472
Publications (including expenses of Office of Publications and Public Relations)	64,000
Departmental Research Operations	1,062,366
	$1,330,838

Mr. Gifford was elected Chairman of the Board, Mr. Root was elected Vice-Chairman, and Mr. Delano was re-elected Secretary, each for the ensuing period of three years.

Robert Woods Bliss, Henry R. Shepley, and Lewis H. Weed were re-elected members of the Executive Committee for a period of three years.

Walter S. Gifford, Elihu Root, Jr., and Frederic C. Walcott were re-elected members of the Finance Committee for a period of three years.*

Frederic A. Delano, Homer L. Ferguson, and James W. Wadsworth were re-elected members of the Auditing Committee for a period of three years.

The meeting adjourned at 12:40 P.M.

* **At** the meeting of the Executive Committee following the annual meeting of the Board, Mr. Gifford submitted his resignation as a member of the Finance Committee, and Henry S. Morgan was appointed to take his place until the next annual meeting.

REPORT OF THE EXECUTIVE COMMITTEE

FOR THE YEAR ENDING OCTOBER 31, 1945

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1945.

During this year the Executive Committee held five meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report.

A statement of activities of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. Requests for use of facilities and resources of the Institution in carrying on war research under contracts with the Government have resulted in full-time operation of many departments of the Institution in the national interest. During the past year active work has been completed on most of the Government contracts entered into by the Institution. Thirty-eight projects have been undertaken during the past five years in the interest of war activities, and all but ten of these projects, still requiring some months of further work, have been completed. These activities are covered by 140 contracts, orders, or amendments, by means of which a total amount of four and a quarter million dollars has been made available for reimbursement to the Institution for out-of-pocket expenses. The Institution's own contribution in performing these research tasks for the Government has consisted of loan of space and equipment, of service by members of the scientific and executive staffs without cost to the Government, and of allotments aggregating about $100,000 to cover special needs and services. The contribution which the Institution has made to the Government in the form of services by members of its scientific and executive staffs would have added approximately a million dollars to Government contracts if the Government had paid for such services. Furthermore, there has been no charge for overhead expenses in connection with the Institution's own part of the work.

The detailed estimate of expenditures for the succeeding year contained in the report of the President has been considered by the Executive Committee, which has approved the recommetidations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Continued attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1946, and budget recommendations are based upon the judgment of these committees with respect to financial policy in the post-war period.

The Board of Trustees, at its meeting of December 15, 1944, appointed Price, Waterhouse and Company to audit the accounts of the Institution for the fiscal year ending

October 31,1945. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31,1945, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31., 1945, showing funds available for expenditure and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28,1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

No vacancy exists in the membership of the Board of Trustees.

Tenure of office of the following officers of the Board of Trustees will expire at the annual meeting in December: Mr. Forbes, Chairman of the Board; Mr. Gifford, Vice-Chairman of the Board; and Mr. Delano, Secretary of the Board. Tenure of office of Messrs. Bliss, Shepley, and Weed as members of the Executive Committee; of Messrs. Gifford, Root, and Walcott as members of the Finance Committee; and of Messrs. Delano, Ferguson, and Wadsworth as members of the Auditing Committee will also expire at the annual meeting.

W. CAMERON FORBES, *Chairman*
VANNEVAR BUSH
ROBERT WOODS BLISS
FREDERIC A. DELANO
WALTER S. GIFFORD
HENRY R. SHEPLEY
FREDERIC C. WALCOTT
LEWIS H. WEED

November 1, 79^5

	Balances unallotted Oct. 31, 1944	Trustees' appropriations Dec. 15. 1944	Transfers and other credits	Total available	Executive Committee allotments	Transfers by Executive Committee	Unallotted balances Oct. 31, 1945
Departmental Research Operations:							
Embryology		$78,552	$9,500.00	$88,052.00	$88,052.00		
Genetics		114,710	18,000.00	132,710.00	132,710.00		
Nutrition Laboratory		18,610		18,610.00	18,610.00		
Geophysical Laboratory		148,523		148,523.00	148,523.00		
Historical Research		119,583		119,583.00	119,583.00		
Mount Wilson Observatory		203,330		203,330.00	203,330.00		
Plant Biology		67,080		67,080.00	67,080.00		
Terrestrial Magnetism		214,080	7,160.00	221,240.00	221,240.00		
Research Projects of Limited Tenure	$12,232.65		10,500.00	22,732.65	17,000.00		$5,732.65
Publications	525.85	48,700	14,833.38	64,059.23	46,804.44		17,254.79
Administration		128,492		135,992.00	135,992.00		
Pension Fund		75,000	7,500.00	75,000.00	75,000.00		
General Contingent Fund	108,075.24		221,174.80	329,250.04	7,400.00	$265,910.00	55,940.04
Carnegie Corporation Emergency Fund	266,772.15			266,772.15	16,230.00	18,500.00	232,042.15
	$387,605.89	$1,216,660	$288,668.18	$1,892,934.07	$1,297,554.44	$284,410.00	$310,969.63

AGGREGATE CASH RKC EIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1945

RIXKIPTS		DISBURSEMENTS	
Set Hi'ities Sold or Redeemed	$98,797,301.59	Securities Purchased	$113,765,601.37
Inkiest from .Securitivs and Bank Balances	53,499,343.27	Accrued Interest on Securities Purchased	729,215.95
Salt's:. iff. PuhUtat ions	369,915.32	Pension Fund	1,616,543.24
G^biini Estate (nrtjm'st)	52,015.74	General Reserve Fund	30,477.43
Ihirriuuin Fund {Sale vf Land)	4,043.70	Insurance Fund	140,532.24
Tir^'le Estate (Bequest)	6,160.62	Ilarriman Fund	203.28
L'nrm-fiie Corporation of Neiv York {Endowment Increase and fur Sped fie Purposes)	13,680,381.24	Special Emergency Reserve Fund	' 63,819.41
From Other Organizations and Individuals for Specific Purposes	430,749.38	National Defense Revolving Fund	2,729,396.32
Pension Fund (Refunds)	96,303.35	General Contingent Fund	292,521.66
General Reserve Fund	1,972.04	Carnegie Corporation of New York Emergency Fund	76,248.64
Insurance Fund (Refunds)	13,076.02	Administration Building and Addition:	
National Defense Rei'olving Fund (Refunds and Advances)	2,632,587.72	Construction and Site (Old Building)	309,915.69
Administration Building Addition Account, Rentals and Refunds	18,021.09	Construction (Addition to Administration Bldg,)	416,206.07
Employees' Salary Deductions for the **Purchase** of U. S. Bonds	68,570.40	Site (Addition to Administration Building)	68,570.96
Miscellaneous Refunds and Receipts	1,095,637.46	Miscellaneous Expenditures*	40,825.37
		Departmental Research Operations:	
		Departments of Research, Buildings and Equipment	3,921,706.68
		Departmental Operations	33,796,279.42
		Research Projects of Limited Tenure	5,519,905.72
		Publication	2,942,897.87
		Administration	2,993,932.32
		Employees' U. S. Bond Purchases	67,357.90
		National Research Council	150,000.00
		Miscellaneous	9,008.82
			$169,681,166.36
		October 31, 1945, Cash in Banks	1,084,912.58
	$170,766,078.94		$170,766,078.94

* Includes Kuuipmeut §7,206.41, Repairs and Alterations to Old Building $18,599.29.

Administration {October 31, 1945)		
1530 P Street, N.W., Washington, D. C.		
Building, site, and equipment		$847,746.01
Division of Plant Biology (September 30, 1945)		
Stanford University, California (Headquarters)		
Buildings and grounds	$74,125.72	
Laboratory	40,655.01	
Library	26,518.42	
Operating equipment	14,043.22	155,342.37
Department of Embryology (September 30, 1945)		
Wolfe and Madisoyi Streets, Baltimore, Maryland		
Library	$4,498.38	
Laboratory	19,561.44	
Administration	7,989.55	32,049.37
Department of Genetics (September 30, 1945)		
Cold Spring Harbor, Long Island, New York		
Buildings, grounds, and field	$293,071.35	
Operating equipment	34,089.25	
Laboratory apparatus	38,352.99	
Library	54,568.64	
Archives	45,488.90	465,571.13
Geophysical Laboratory (September 30, 1945)		
2801 Upton Street, N.W., Washington, D. C		
Building, library, and operating appliances	$292,267.05	
Laboratory apparatus	171,304.96	
Shop equipment	21,103.00	484,675.01
Division of Historical Research (September 30, 1945)		
10 Frisbie Place, Cambridge, Massachusetts		
Operating equipment	$28,797.96	
Library	15,020.90	43,818.86
Nutrition Laboratory (September 30, 1945)		
29 Blackfan Street, Boston, Massachusetts		
Building, office, shop, and library	$134,613,93	
Laboratory apparatus	31,828.84	166,442.77
Mount Wilson Observatory (September 30, 1945)		
Pasadena, California		
Buildings and grounds	$222,458.33	
Shop equipment	48,976.14	
Instrument ts	685,36$. 21	
Furniture and operating appliances	153,194,77	
Hooker 100-Inch reflector	638,529.83	1,748,522.28
Department of Terrestrial Mapietism (September 3$, 1045)		
5241 Broad Branch Road, k.\V.(Wtiskin«Jtw, D. C		
Building, site, and office	$257,838.42	
Survey equipment	94,016.62	
Instrument*, laboratory, *and shop* equipment	473,429.85	S25,284.89
		$4,769,452.69

REPORT OF AUDITORS

To the Board of Trustees
Carnegie Institution of Washington
Washington, D. C.

We have made an examination of the attached balance sheet of Carnegie Institution of Washington (and supporting schedule of securities owned) as of October 31, 1945 and the related statement of operating income and expenditures for the fiscal year then ended. In connection therewith, we obtained confirmations from the custodian, Guaranty Trust Company of New York, as to the securities owned by the Institution and held in safekeeping at October 31, 1945 and from the depositaries as to the cash balances in banks at that date. The interest maturing during the fiscal year on bonds owned was accounted for, and the dividends received during the year on stocks owned were compared with published dividend records. With respect to a period of three months selected by us the recorded cash receipts were traced to deposits shown on the bank statements and paid checks and approved vouchers were inspected in support of the head office disbursements. We did not visit the branch offices of the Institution but we reviewed internal audit reports of the Bursar covering examinations of the branch records during the year and it appeared that the internal audits were satisfactorily conducted. We also inspected certified copies of the minutes of meetings of the Board of Trustees and the Executive Committee with respect to the appropriations and allotments for the year.

The securities are stated at cost, amortized cost or value at date acquired. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, premiums on bonds purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the dates on which the bonds are first callable or payable at par. The amortization of such premiums applicable to the year ended October 31, 1945 amounted to $5,955-59- Real estate and equipment are stated at cost, and books on hand for sale are carried at sales prices. In accordance with accepted practice no provision has been made for depreciation o£ property owned by the Institution.

In accordance with established custom of the Institution, the budget appropriations are made for the calendar year, whereas the annual financial statements are prepared for the fiscal year ending October 31. In previous years the balance of estimated income applicable to November and December was included in the assets of the General Fund as at October 31 preceding and the unexpended appropriations and allotments for the same period were reflected in the current obligations in the balance sheet. Estimated income and approved appropriations and allotments for November and December 1945 are not reflected in the attached balance sheet as at October 31, 1945.

In our opinion, with the foregoing explanations, the accompanying balance sheet and related statement of operating income and expenditures present fairly the position of Carnegie Institution of Washington at October 31, 1945 and the financial aspects of its operations for the year ended on that date.

PRICE, WATERHOUSE & Co,

Washington, D. C.
November 26, 1945

BALANCE SHEET OCTOBER 31, 1945

ASSETS

Investments			
Securities		$38,559,260.05	
Cash:			
Awaiting investment		503,872.43	
Reserved for current needs		63,833,67	$39,126,966.15
Property Account			
Real estate and equipment, at costs			
Office of Administration		$847,746.01	
Departments of research		3,921,706.68	4,769,452.69
*(*entml Fund*			
Oh::			
GeiH'idl aiTOiiitt	$517,206.48		
Dr-partmental bank balances	51,442.00		
Petty t:d>h and ttami>≥	500.00	$569,148.48	
Ac munis receivable (include.-; re-imhuiable cxitemlituu.= of $lf»1,824.7ft ftt»m F. S. (Jovvanniutt, per cmlta)		186,639.99	
Books on hand at sale price		162,804.80	
Outstaminig ;uotimt« on sales of pnhliiatiom		140.82	
Paper in ₹tock fur inline piihlitati'jus		414.41	919,148.50
			$44,815,567.34

LIABILITIES

Endowment and Other Funds			
Capital Funds			
Endowment Fund	$32,000,000.00		
Colburn Fund	103,310.80		
Capital Reserve Fund	4,440,604.16		
Harriman Fund (excluding $179,628.05 included in Property Fund below)	350,845.61		
Teeple Fund	6,160.62	$36,900,921.19	
Special Funds			
Pension Fund	$231,274.94		
Harriet H. Mayor Relief Fund	10,000.00		
General Reserve Fund	1,534,770.02		
Current funds invested (see below)	450,000.00	2,226,044.96	$39,126,966.15
Properly Fund			
Income invested		$4,589,824.64	
Harriman property (gift)		179,628.05	4,769,452.69
General Fund			
Current obligations and commitments:			
Departmental research operations	$140,353.45		
Research projects of limited tenure	28,164.68		
Publication	48,810.09		
Administration	16,876.78		
General Contingent Fund	63,891.00		
Carnegie Corporation Emergency Fund	259,166.39		
Employees' U. S. Bond Purchase Fund	1,212.50		
Annuity premium deposits	60.20		
Excess of advances received on U. S. Government contracts over disbursements made thereon	55,726.37		
National Defense Revolving Fund (includes reimbursable expenditures of $161,823.76 from U. S. Government carried in accounts receivable, per contra)	300,000.00	$914,261.46	
Unexpended and unallocated current income		291,527.01	
		$1,205,788.47	
Less—[1]Current funds invested (see above)		450,000.00	
		$755,788.47	
Value of publications and invoices		162,945.62	
Publication paper in stock		414.41	919,148.50
			$44,815,567.34

GENERAL FUND

Statement of Operating Income and Expenditures for the Fiscal Year Ended October 31, 1945

Income:			
Interest and dividends on securities		$1,368,018.87	
Less—Amortization of bond premiums		5,955.59	
		$1,362,063.28	
Sales of publications		6,146.26	
Carnegie Corporation of New York—grants		13,000.00	
Other credits		22,366.19	$1,403,575.73
Expenditures:			
Pension Fund—annuity and insurance		$123,879.57	
Carnegie Corporation Emergency Fund—grants		8,230.00	
Hanlroan Fund—commissions		43.12	
General Contingent Fund		6,785.70	
Departmental research operations:			
Salaries	$627,463.92		
Operating expenses	148,854.55	776,318.47	
Research projects of limited tenure:			
Salaries	$21,281.90		
Operating expenses	15,115.74	36,397.64	
General publication:			
Salaries	$2,114.91		
Expenditures	11,043.52	13,158.43	
Office of publications:			
Salaries	$16,007.09		
Operating expenses	1,760.79	17,767.88	
Administration expenses		119,381.05	
		$1,101,961.86	
Le$s—Salariesand operating expenditures charged to previous appropriations		173,837.84	928,124.02
Excess of income over expenditures			$475,451.71
2>w—~Credits to Genera! Reserve Fund and other accounts			183,924.70
i'ni'vpendt>d and unallocated current income			$291,527.01

SCHEDULE OF SECURITIES OWNED OCTOBER 31, 1945

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
	UNITED STATES GOVERNMENT BONDS				
$304,000	U. S. of America Treasury 2s	1951-49	$304,000.00	$312,740	$6,080.00
312,000	U. S. of America Treasury 2s	1951-49	312,000.00	320,970	6,240.00
200,000	U. S. of America Treasury 2s	1952-50	200,000.00	205,875	4,000.00
4,500,000	U. S. of America Treasury 2s	1954-52	4,500,000.00	4,657,500	48,442.58
800,000	U. S. of America Treasury 2¼s	1955-52	800,000.00	838,250	18,000.00
520,000	U. S. of America Treasury 2½s	1962-59	524,846.88	524,225	(838.42)
1,239,000	U. S. of America Treasury 2½s	1954-52	1,243,438.79*	1,315,276	30,975.00
350,000	U. S. of America Treasury 2½s	1967-62	350,000.00	360,172	8,750.00
75,000	U. S. of America Treasury 2½s	1968-63	75,000.00	76,664	1,875.00
1,200,000	U. S. of America Treasury 2½s	1969-64	1,200,000.00	1,224,000	30,000.00
400,000	U. S. of America Treasury 2½s	1969-64	400,000.00	407,500	10,000.00
50,000	U. S. of America Savings Defense "G" 2½s	1953	50,000.00	47,350	1,250.00
50.000	U. S. of America Savings Defense "G" 2½s	1954	50,000.00	47,400	1,250.00
50,000	U. S. of America Savings Defense "G" 2½s	1954	50,000.00	47,550	1,250.00
100,000	U. S. of America Savings Defense "G" 2½s	1955	100,000.00	95,600	2,500.00
100,000	U. S. of America Savings Defense "G" 2½s	1956	100,000.00	96,900	2,500.00
100,000	U. S. of America Savings Defense "G" 2½s	1957	100,000.00	98,800	1,250.00
2,700,000	U. S. of America Certificate of Indebtedness ⅞s	1945	2,701,372.88	2,700,837	(8,520.49)
	Income from bonds sold				10,308.79
$13,050,000	Total U. S. Government		$13,060,658.55	$13,377,609	$175,312.46
	FOREIGN BONDS				
$90,000	Canadian National Ry. Co., 4 J^s Guar	1951	$90,219.54*	$102,600	$4,050.00
UK),000	Canadian National Uy. Co., 4j^s Guar	1957	112,000.00	119,000	4,500.00
57,000	Canadian National Ry. Co., 5s Guar	1969	61,727.76*	66,120	2,850.00
35,000	Canadian National Ry. Co., 5s Guar	1970	37,766.58*	40,600	1,750.00
300,000	Canadian Pacific Railway Co., Perpetual Cons. Deb. 4s		264,475.00	318,000	12,000.00
100,000	Province of Alberta Deb. 4M^s	1958	93,750.00	120,000	2,250.00
100,000	Province of Alberta Deb. 5s	1950	101,150.00	121,000	1,250.00
150,000	Province of Manitoba Deb. 4j^s	1958	142,886.77	169,500	6,750.00
100,000	Province of Nova Scotia Deb. 4j^s	1952	100,312.50	104,000	4,500.00
200,000	Shawintaan Water and Power Co.. 1st Mtg. & Coll. Tr. S. F. 3½s	1970	201,963.64*	210,000	2,994.44
100,000	City of Toronto Cons. Loan Deb. 5B	1949	96,164.59	111,000	5,000.00
	Income from bonds called				5,625.00
$1,332,OX)	Total Foreign		$1,302,416.38	$1,481,820	$53,519.44

* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

SCHEDULE OF SECURITIES—*Continued*

Aggregate par or noinmiil value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
	PUBLIC UTILITY BONDS				
#243,000	Columbus & Southern Ohio Klectric Co., 1st Mtg. 3Ms	1970	$259,068.40*	t262,440	$7,897.50
23.900	Commonwealth Kdison Co., Conv. Deb. 3 J^s	1958	23.910.75	30,831	836.50
50,000	Consolidated Edison Co. of N. Y., Deb. 3 j&?	1948	50,875.00	51,000	1,750.00
40,000	Consolidated Edison Co. of N, Y.. Deb, 3>$s	1958	40,730.00	42,000	1,400.00
100,000	Detroit Edison Co., Gen. & Rcf. Mtg. 4H	1965	106,500.00	106,000	4,000.00
200,000	Gulf Stated Util. Co.. 1st Mtg. & Ref. 3 Ms	1969	103,500.00	216,000	7,000.00
200, IKK)	Illinok Power Co., 1st Mtg. & Coll. Tr. 4s	1973	213,924.19*	210,000	8,000.00
200,000	Minnesota Power & Light Co.. l«t Mtg. 3 \-£q	1975	201,920.00	210,000	(416.67)
50,000	Northern States Power Co., 1st & Ref. Mtg. 3J&	1967	204,500.00	52,000	1,750.00
100,000	Ohio Power Co., 1st Mtg. 3Us	1968	47,500.00	106,000	3,250.00
100,000	Ohio Public Service Co., 1st Mtg. 4s	1962	101,625.00	106,000	4,000.00
100,000	Oklahoma Natural Gas Co., 1st Mtg. 2 *M$*	1961	102,441.17*	103,000	2,875.00
200,000	Public Service Co. of Indiana, Inc., 1st Mtg. 3)^gs	1975	101,920.00	212,000	(520.80)
125,000	Puget Sound Power & Light Co.. 1st Mtg. 4Ms	1972	204,896.46*	132,500	5,312.50
146.000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3Ms	1956	129,079.42*	153,300	4,745.00
250,000	Tennessee Gas and Transmission Co., 1st Mtg. Pipe Line 3s	1965	149,625.00	255,000	(145.83)
120.000	Toledo Edison Co., 1st Mtg. 3 *y&a.*	1968	255,800.00	127,200	4,200.00
294,000	United Gas Corp., 1st Mtg. Coll. Tr. 3s	1962	121,000.00	305,760	7,423.50
190,000	Utah Power & Light Co., 1st Mtg. 3 *Ms*	1968	294,113.27*	197,600	7,125.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3 \4$- -. ^	1968	191,875.00 232	238,500	7,875.00
	Income from bonds called or sold				62,923.19
#2,956,900	Total Public Utility		$3,030,803.66	$3,117,131	$141,279.89
	COMMUNICATION BONDS				
$314,000	American Telephone & Telegraph Co., Deb. 3Ms	1966	§326,706.75	1329,700	§10,205.00
25,000	Mountain States Telephone & Telegraph Co., Deb. *3}4s*	1968	25,500.00	26,500	812.50
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s	1952	51,748.00	58,760	2,600.00
	Income from bonds converted or sold				8,302.88
$391,000	Total Communications		1403,954.75	$414,960	$21,920.38
	RAILROAD EQUIPMENT TRUSTS				
mi.aim	Pennsylvania R. R. Co., 2 J^s Guar	1956	$81,283.64	$84,460	$1,947.50
"$82^000	Total Railroad Equipment Trusts		181,283.04	§84,460	§1,947,50

* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

SCHEDULE OF SECURITIES—*Continued*

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
	RAILROAD BONDS				
1100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg, 4^3	1992	$99,464.29	$140,000	$4,500.00
75,000	Chicago & W. Indiana R. R. Co., Cons. 4s	1952	70,357.66	81,000	3,000.00
200,000	Krie R. R. Co., 1st Cons. Mtg. 3Ms	1990	201,293.75*	202,000	886.40
100,000	Gieat Northern Ry. Co., Gen. Mtg. 5s	1973	104,385.84	134,000	5,000.00
SO,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5s	1946	48,405.15	51,000	2,500.00
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4Ms.	1965	75,918.75	92,250	3,375.00
iOO.000	Pennsylvania R. R. Co., Cons. Mtg. 4Ms	1960	104.662.50	124,000	4,500.00
50,000	Pittsburgh, Cin., Chi. & St. L. R, R. Co., Gen. Mtg. 5s Guar.	1975	898.98	66,000	2,500.00
100,000	Southern Rwy. Co., 1st Cons. Mtg. 5s	1994	si;580.34	132,000	5,000.00
67,000	Terminal R. R. Assn. of St. Louis, S. F. Gen. Ref. Mtg. 4s.	1953	103 878.03	73,700	2,680.00
100,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3Ms Guar.	1960	60,000.00	103,000	3,750.00
2,084,000	Union R. R. Co., Deb. 6s Guar	1946	2 99 000.00	2,167,360	125,040.00
100.000	West Shore R. R. Co., 1st Mtg. 4s Guar	2361	,084,,140.00	83,000	4,000.00
50,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5 Ms	1977	78 677.19 42,	53,000	2,750.00
	Income from bonds called or sold				14,277.78
$3,251,000	Total Railroad.		$3,224,662.48	$3,502,310	$183,759.18
	INDUSTRIAL AND MISCELLANEOUS BONDS				
1100,000	Atlantic Refining Co., Deb. 3H	1953	$102,347.98*	$103,000	$3,000.00
200,000	Eastern Gas and Fuel Associates, 1st Mtg. & Coll. Tr. 3Ks	1965	204,340.00	212,000	(972.22)
190,000	Empire Ga* and Fuel Co., S. F. Deb. 3Ms.	1962	176,403.12	191,900	6,650.00
300,000	B. F. Goodrich Company, 1st Mtg. 2J^s	1965	301,500.00	303,000	(68.83)
75,000	Greyhound Corporation, S. F. Deb. 3s	1959	75,870.54*	76,500	2,250.00
149,000	Phillips Petroleum Co.. S. F. Deb. 2MB	1964	150,378.41*	153,470	4,097.50
70.000	Railway Express Agency, Serial Notea 2 J|s~2 Ha	1945-48	79,000.00	79,000	1,803.75
300,000	Seagram (Joseph E.) & Sons, Inc., Deb. 3 Ms	1965	306,000.00	315,000	(270.81)
371,000	Shell Union Oil Corp., Deb. *2H&*	1954	356,323.47	378,420	9,275.00
258,000	Swony-Vacuum Oil Co., S. F. Deb. 2 *J4s*	1955	266,490.39*	269,610	7,417.50
75,000	Soi-ony-Vaeuum Oil Co., Deb. 3s	1964	78,000.00	79,500	2,250.00
	Income from bonds called				15,972.49
$2,00.7,000	Total Industrial and Miscellaneous.		$2,096,653.91	$2,161,400	$51,404.38
	MORTGAGES				
StOO,000	Lawyer* Mtg. Co., Guaranteed 1st Mtg. Ctfs. *4H%-* No. 29940T.	1940	$92,642.60	**	$2,700.00
	Income from mortgages sold or liquidated				12,513.72
$1(10,000	Total Mortgages		$92,642.60	**	$15,213.72
$23,259,900	BONDS AND MORTGAGES—Funds Invested.		$23,293,075.97	$24,139,690	$644,356.95

* After deduction for amortization of premiums on bonds purchased subsequent to January I, 1940.
** In liquidation, market quotations not available.

SCHEDULE OF SECURITIES—*Continued*

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
	PREFERRED STOCKS			
100	Arutikarti Brake Shoo Co., 5[M% Cum. Pi·of	$12,653.50	$12,900	$525.00
2,[illegible]	Anmi«c»m Cyanamid Co., 5% Cum. Pref	28,059.62	27,544	1,252.00
1,[illegible]	Appalacln:m l\h\ trie Power Co., 4 j-^% Cum. Prcf	159,000.00	169,500	6,750.00
1 900	A»n>«n<>tiK Cork Co., $1.75 Cum. Pref.	195,225.00	205,200	.....
l.Soo	Uetlik'lu'in Stwl C\iti>.. '?% Cum. Pref	183,637.50	226,500	10,500.00
I;500	Biistol Myers Co.. 3'h% Cum. Pref	158,734.38	163,500	1,406.25
1,000	Buffalo, Niagara & Kastcrn Power Corp., $5.00 Cum. Pref	112,225.00	119,000	.....
5CM)	Case CJ, I.) Co,, 7% Cum. Pref	62,225.00	79,500	3,442.98
600	Cleveland Klectric Illuminating Co., $4.50 Cum. Pref	68,112.25	66,000	2,700.00
1,125	Continental Can Co., Inc., S.V/5 Cum, Pref	US.312.50	121,500	2,250.01
IDS	Coin Piotiuvtii Refining Co., T'/„ Cum. Pief	19,409.25	19,950	551.25
1,000	Deere & Company. 1% Cum. Pref	28,812.50	38,000	1,400.00
1,125	duPcint (K. I.) de Nemours & Co., §4.50 Cum. Prcf	116,125.00	142,875	5,062.52
1,5<M»	General Motors Corp., $5.00 Cum. Prcf	187,937.50	190,500	7,500.00
1,300	Ifjodrlch U*. F.) Co., $5,00 Cum. Pref	129,867.50	133,900	6,500.00
700	Goodyeai Tire & Rubber Co., §5.00 Cum. Conv. Pref	73,195.00	79,100	3,500.00
1,000	Grunt (W. T.) Co., 3 h % Cum. Pref	100„447.91	108,000	937.SO
220	Johns'Mauville Corp., 3 W^{7}_{0} Cum Conv. Pref	22„000.00	28,600	.....
1,090	May Prpurtment Stores Co., S3.75 Cum. Pief	113„291.91	116,630	2,043.75
1,500	McKc^m & Kot>hin.« Inc., §4.oo Cum. Pref	144„000.00	159,000	6,000.00
^50	Minneapolis-Honeywell Regulator Co., 4}£% Cum. Conv. Pref.	95„200.00	91,800	1,810.50
1,IHMI	New York State Kfectric & Gas Corp., 5.10% Cum. Pref	103,250.00	108,000	5,100.00
1,000	Northern States Power Co., $5.00 Cum. Pref	103,000.00	112,000	5,000.00
6M5	Ohio Power Co., 4 W/v Cum. Pief	76,552.00	79,925	2,964.39
1,500	Pacific Telephone and Telegraph Co., 6% Cum. Prcf....	235,220.75	256,500	9,000.00
1,000	Panhandle Kahtei·n Pipe Line Co., 4% Cum. Pref	104,166.68	109,000	1,000.00
1,000	Philip Morris & Co., Ltd., Inc., 4% Cum. Pref	171,737.50	176,000	3,200.00
860	Pillnbury Mill*. Inc., $4.00 Cum. Pref	92,637.00	92,020	2,135.00
600	Public Service Co. of Oklahoma. B% Cum. Pref	60,900.00	66,000	3,000.00
2,000	Reynolds! (R. .I.) Tobacco Co.. 3.60% Pief	199,683.75	208,000	.....
2,000	Pervel, Inc., $4.50 Cum. Pref..	225,250.00	220,000	4,500.00
1,134	Hherwin-Williams Co., 4% Cum. Pref	124,985.95	125,874	1,134.00
250	Cnited States Gypsum Co., 7% Cum. Pref	45,187.50	48,000	1,312.50
1,SOO	I'. 8. Rubber Co., 8% Non Cum. 1st Pref	184,337.50	244,500	12,000.00
3,100	U. S. Steel Corp., 7% Cum. Pref	443,407.57	483,600	21,700.00
	Income from stocks converted, called, or exchanged	.....	.....	31,999.87
40,#58	Total Preferred Stocks	14,295,787.52	14,628,918	1168,177.52

SCHEDULE OF SECURITIES—*Continued*

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
	COMMON STOCKS			
600	Air Reduction Company	$35,968.38	$29,400	$1,600.00
1,700	American Can Company	150,886.36	171,700	5,100.00
2,900	American Cyanamid Co	90,321.12	133,400	5,075.00
1,800	American Radiator & Standard Sanitary Corp.	32,901.71	30,600	720.00
3,200	American Telephone & Telegraph Co.	472,918.99	598,400	18,170.00
800	Armstrong Cork Company	35,939.37	44,800	1,200.00
1,600	Boston Edison Company	58,267.61	68,800	3,200.00
2,700	C. I, T. Financial Corporation	139,684.19	140,400	1,350.00
1,300	Caterpillar Tractor Co	87,905.50	88,400	2,925.00
2,500	Chase National Bank of N. Y.	84,918.15	112,500	3,500.00
33.00	Chrysler Corporation	294,502.76	412,500	9,900.00
1,000	Cleveland Electric Illuminating Company.	36,356.63	45,000	2,000.00
700	Coca-Cola Company	92,163.75	126,000	2,800.00
800	rulcate-Palmolive-Ppet Company	23,217.66	34,400	1,500.00
2,500	Commercial National Bank and Trust Co. of N. Y	108,152.78	127,500	4,000.00
2,100	Commonwealth Edison Company	58,733.36	69,300	2,940.00
3,000	Continental Can Co	119,869.67	138,000	3,000.00
1,300	Continental Illinois National Bank & Trust Co. of Chicago	111,236.66	150,800	5,200.00
2,KO8	Continental Insurance Co	105,654.17	157,248	5,616.00
6,000	Continental Oil Co. of Delaware	162,943.08	210,000	9,000.00
1.100	Coming Glass Works	27,500.00	38,500	275.00
2,100	Delaware Power & Light Company	33,497.78	48,300	2,340.00
000	Dow Chemical Co	72,657.09	90,600	1,800.00
2,400	duPont (E. I.) de Nemours & Co	371,430.73	444,000	12,600.00
2,100	Eastman Kodak Co	337,422.75	462,000	13,650.00
60	First National Bank of N. Y.	91,704.00	116,400	4,800.00
1,093.75	Food Machinery Corporation	51,931.39	77,655	1,364.40
8,400	General Electric Co	328,655.07	394,800	13,020.00
4,600	General Foods Corporation	189,521.09	230,000	7,360.00
7,200	General Motors Corporation	369,589.82	532,800	21,600.00
1,700	Goodrich (B. F.) Co	72,040.78	119,000	3,400.00
1.400	Goodyear Tire & Rubber Co.	54,800.38	85,400	2,800.00
10.400	Grant (W. T.) Co	177,153.63	301,600	
440	Guaranty Trust Co. of N. Y.	119,782.55	168,080	5,280.00
9,100	Gulf Oil Corp	392,405.24	527,800	16,975.00
1,700	Hartford Fire Insurance Co	146,767.87	195,500	4,250.00
8,200	Humble Oil & Refining Co.	245,069,64	377,200	12,300.00
2,300	Insurance Company of North America	172,486.59	250,700	6,900.00
1,166	International Business Machines Corp	153,029.21	258,852	6,897.00
1,000	International Nickel Company of Canada, Ltd	30,588.46	35,000	1,360.00
1,000	Jnhns-Manvillc Corp	96,629.23	138,000	3,250.00
1,000	Kennecott Copper Corporation	35,500.73	44,000	2,500.00
4,5«H)	Krcsge (S, S.) Company	103,455,81	153,000	5,400.00
662	Lawyers Mortgage Corp., Voting Trust Ctf		2,648	
1,900	Liggett & Myers Tobacco Co., "B"	171,301.08	182,400	6,650.00
1,300	Liquid Carbonic Corporation	34,177.35	49,400	1,950.00
2,600	Meick & Co., Inc	106,118.30	109,200	2,600.00

(Continued on following page)

SCHEDULE "op SECURITIES—*Continued*

Xiimi>ert of AiA res	Description	Cost, amortized eoist, or value at date acquired	Market value	Dividends for year
	COMMON STOCKS—*Continued*			
',500	MinneapoIKHmieywell Regulator Co	$58,930.51	$79,500	§1,875.00
2j 5O0	Mimsanto Chemiral Co	230,809.39	270,000	5,625.00
5,;400	Montgomeiy Wutl & Co	253,876.10	360,400	10,600.00
4] 7CM)	National Cash Renter Co.	135,074.89	183,300	5,875.00
1,,UiiU	National City Bank of New Yuik	38,625.00	49,000	1,300.00
1,,460	National Fire Insurance Co. of Hartford	84,378.41	89,060	2,920.00
225	National Union Fire Insurance Co	38,900.90	39,150	1,125.00
3,,100	Newbeiry (J. J.) Co	164,239.94	294,500	7,440.00
2,!soo	New Jei-«*y Zinr Co..^	160,159.81	180,000	7,500.00
2.JiM)	Owens-Illinois Glass? Co	129,438.09	155,400	4,200.00
1,,700	Penney (J. C.) Co.	245,919.43	367,200	13,500.00
1,600	Pep-i-Cola Company	32,872.29	57,600	840.00
5!,400	Phillips Petroleum Co	262,565.68	270,000	7,200.00
I,,3OO	Pittsburgh Plate Gla^s Co	142,810.48	188,500	5,525.00
2,,700	Proi-tei· & Gamble Co	151,181.83	175,500	5,400.00
1,500	Sirott Paper Co	61,907.05	84,000	2,700.00
15,200	Sears, Roebuck & Co	301,538.07	562,400	16,150.00
4,600	Sharp & Dohnie, Inc	64,873.96	96,600	2,300.00
1,,600	Sherwin-Williams Co	157,573.57	214,400	6,000.00
1,,700	Squibb (K. R.) & Sons	100,304.05	170,000	3,400.00
1,,100	Standard Brands Incorporated	33,090.76	48,400	1,265.00
6,5W)	Standard Oil Co. of Indiana	193,467.24	266,500	9,750.00
4,500	Standard Oil Co. of New Jersey	232,971.92	288,000	11,250.00
2,200	Texan Company	92,614.25	125,400	5,500.00
3,600	Timken Roller Bearing Co	173,837.79	219,600	7,200.00
3,000	Union Carbide & Carbon Corp	253,960.66	288,000	9,000.00
70	Union Tni>t Company of Pittsburgh	117,587.88	131,600	2,922.00
2,800	United Fruit Company	207,853.85	319,200	11,200.00
2,200	United States Gypsum Co	187,979.92	224,400	4,400.00
11,000	Westinghouse Klectiic Corp	288,374.69	385,000	2,750.00
2,200	Woolworth (F. W.) Co	84,919.68	107,800	3,520.00
	1 Income from stocks sold or exchanged			125,135.00
224,484.75	Total Common Stocks	$10,970,396.56	$14,612,393	$555,484.40
265,342.75	COMMON AND PRJ-FKiiRLP STOJKS--Funds Invented	$15,266,184.08	$19,241,311	$723,661.92
	AMIKH"\H² IN\1²SI ME MS (BONDS AND STOCKS)	$38,559,260.05	$43,381,001	$1,368,018.87*

* Represents total interest and dividend income before deduction of amortization of bond premiums.

Noir:: *Xet profits from sales and redemptions nf securities for the year ended October 31, 1045 aggregated $765,576.01, and that amount has been credited to the Capital Reserve Fund shown in the tiltaihed balance sheet.*

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1945

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

This report to the Trustees of the Carnegie Institution of Washington, made in accordance with the By-Laws, finds the Institution in a period of transition. Staff members are returning from war activities, and we look forward to peace.

The Institution can take satisfaction in the contribution it has made to the war effort. Many members of its staff have carried heavy responsibilities, in uniform and in the laboratories. Others whose professional talents could not be brought directly to wartime application have been equally unselfish in their participation as citizens in various forms of war work. The facilities of the Institution have been largely diverted to war research, with important results. In fact, one of the most striking technical developments of the war, which had a decided influence on the outcome, had its origin in the Institution early in the conflict. Radar arose from many sources, but from none more clearly than from early work in the Department of Terrestrial Magnetism on reflections from the ionosphere. Many of the staff, and of the Trustees as well, have served in the civilian scientific organizations concerned with war instrumentalities and war medicine, and the Administration Building has become the gathering place for the scientists of the country during its use as the focus of these activities. The effective relationships thus initiated will long continue on an informal basis.

With the return of peace there does not seem to be any obligation on the part of the Institution to continue military research. Such research should continue; in fact it is essential that until the world can develop better ways of ensuring the safety of all peace-loving peoples, the nation maintain this highly important aspect of its efforts for security. But there are other organizations which are more naturally fitted for the task of supplementing the military research of the armed services themselves, because their normal programs lie closer to application. The primary responsibility of the Institution hence is to return to that basic scientific research which is its normal function, and which now needs increased emphasis after five years of drawing on scientific capital for the imperative task of making applications to war. For this reason the military research programs of the Institution are being closed out as rapidly as is consistent with the preservation of values already attained.

With the return of peace the several departments and divisions can take a fresh start. The programs of many of them have been so severely interrupted that they are practically beginning anew. We can look ahead, choose the lines of research in which the promise is greatest, and proceed. There need be no limitation to the choice of programs, other than that dictated by the extent of our resources and the nature of our talents, as we evaluate where our contributions to human knowledge will be most fruitful. We should choose deliberately and take proper time to do so> for the opportunity thus to choose may be rare, and it is none too easy to

alter a program once it is embarked upon. There is no need for continuing a program merely because it has been a past activity. Neither should we allow labels to constrain us unduly. Certainly whatever we attempt should be such that every member of the staff can contribute substantially to some portion of it, and derive satisfaction in doing so. It is also clear that the Institution should ordinarily not pursue those objectives which can be pursued equally well or better by other organizations, for the Institution is unique in many ways. It has unique opportunities, and in general it should seek unique ends if it is fully to justify its existence and is to exert among research organizations of the country the beneficent influence which its position should ensure.

The programs of the several divisions should become formulated by the staffs of those divisions themselves. This condition is fundamental to the success of any undertaking in basic science. The President and the Trustees, of course, have the duty to review and approve, for the programs should measure up to certain over-all criteria, and there is moreover the obligation to ensure that the programs of various divisions become so interrelated that they may lend support one to another. In fact, in advance of review, consultation is very much in order, and it is hoped that in the months ahead there will be close contact between the members of the staff and the committees of the Board concerned with the various disciplines, either in joint meetings or in frequent informal individual discussions. But the staffs of the divisions, under the leadership of their several directors, will and should take the burden of analysis, comparison, initiation, and formulation, with the greatest freedom for the vision of individuals to be expanded and the aspirations of individuals to be weighed. Out of such deliberations emerge sound programs which groups will pursue with enthusiasm.

Some of this will have to wait, for not all our absent members have yet returned. Moreover, we are weary, and brilliant plans are seldom formulated by tired men. It is well that there should be a respite, as the opportunity for vacation offers, before we turn fully to the making of plans. No time will be lost, for seldom does the time spent in contemplating a program of research before vigorously embarking upon it exceed what is wise and reasonable.

In planning, moreover, it is necessary that we take due note of what is going on in scientific research in the country as a whole. The war has brought great changes in this regard, and even the organizational forms under which research will be conducted in the future in this country will differ from those in use before the war.

The country is at last awake to the value of scientific research. It may indeed even be too much awake, for it was awakened rather violently, and there may hence be unwarranted distortions of view. There is certain to be plenty of emphasis on applied research in industry, governmental organizations, and universities and colleges, but it is not so certain that there will be sufficient emphasis on fundamental or pure research. Similarly there is bound to be emphasis on research in the physical sciences, because their applications have been spectacular, and on direct medical science for the same reason. It is not nearly so certain that every area where the scientific method can acid to man's understanding of himself and his environment will be adequately explored.

This situation will probably be exaggerated because of the serious deficit which policies pursued during the war produced in the scientific manpower of the country.

The country learned fully of the importance of science, and of its application by engineers and industrialists, after the war, not before. Moreover, it did not grasp the fact that, in any rapidly altering technological field, the young men are often the only ones who fully comprehend some of the ramifications. Two principles governed our actions: one that every citizen should be ready to sacrifice equally in the common cause, and the other that every man should be used in the place where his talents could contribute most fully to the common effort. These principles were not in balance. As a result, by taking altogether too many trained young scientists and engineers out of the laboratories and industry, we very nearly wrecked that part of our war effort which consists in keeping the instrumentalities in the hands of our fighting men substantially superior to those of the enemy. We also sacrificed the future to immediate needs, more than did any of our allies or indeed our enemies, by halting our processes of advanced education, thus creating a lack of scientific manpower from which we shall not recover for many years. We are a strange country. As this is written we are at peace, but we are still doing both these things.

The result is that, as the Institution turns back to its normal functions, it will find the path difficult in many ways. The lack of a sufficient number of brilliant young men with a basic training in fundamental science will be particularly unfortunate. We need such men throughout the Institution; their presence will be good for them and also for us. I have discussed this point with many members of the staff and I find uniform agreement. No research program which proceeds without the benefit of the impact of young minds can expect long to remain virile. Few individuals can retain their crcativencss i'ully unless they are also engaged in teaching those who will follow in their footsteps and some day pass them on the road, and one of the finest types of teaching is that exemplified by the master surrounded by his disciples. There are many ways of finding such young men and of giving them opportunity to spend a few years with us. But we shall be severely hampered in the undertaking in the immediate post-war years, for there will just not be enough young men of talent to go around.

The vista ahead in science is, however, attractive indeed, if we can assume a peaceful world in which the energies of scientists need no longer be diverted, almost entirely, to activities necessary for military security. This is not so much because new opportunities have been opened during the war, for most of the war effort in science consisted in applying results in ways long familiar to scientific men. Rather it is because the great part which science and its application have played ensures that, taking the country as a whole, there will be adequate support for scientific effort in the future if the country remains prosperous. It is also due to another factor. Many a scientist has now applied himself assiduously for five years to tasks often far from his inclinations, assigned by the needs of the moment, and requiring his full energies. Yet the speculative mind has not been idle, even though it has been temporarily inhibited from entering those inviting trails that have been glimpsed in the midst of harassing and confining duties. Every brilliant scientist in the country's service probably has one or more of these prospects which he has promised himself he would pursue when the release came, and it has now come. We have had a partial moratorium on the creations of fundamental science, we have unwisely produced a deficit of scientific

manpower, but we undoubtedly have a new stock o£ dammed-up ideas. It will be interesting to watch what happens as the dam breaks.

One further point should be made before we turn to definite planning. There is some fear prevalent, and there is basis for the fear, that the present emphasis on science may result in an unbalance in this country and a neglect of other fields of intellectual effort. The Institution is indeed directly interested in this matter, for since the extension of knowledge is not all by means of application of the scientific method, the field of the Institution has long included activities on the scientific borderland, or indeed in the humanities. Research has objectives that are broader than practical knowledge, immediate or potential, and involves those cultural aspects of knowledge which respond to the innate curiosity of the race, and its ponderings in regard to its origins and possibly in regard to its destiny.

From a more practical point of view as well, it is important that no unbalance occur. We have entered a new world. It is a terrifying world perhaps, as we view the power of new forces which can destroy, but then the world has always been terrifying in many aspects to those who have really regarded it face to face, rather than substituted contemplation of an idealized model with some of the seamy aspects omitted. It is certainly, however, a world in which there is much need for courageous and intelligent thinking in every department of man's activities, not merely in the scientific field. It is a world in which young keen minds need to grapple with many phases of the common problem of keeping progress uninterrupted by such cataclysms as have twice jarred it within a generation, or by other disasters, for there are others that do not come under the heading of war. There is a problem before us, therefore: Will science become overenthusiastic and will other departments of intellectual endeavor suffer as a consequence?

The answer to this problem will not come through holding science back, or through requiring of it some self-denying restraint. It has too much to do, the national security and prosperity require its full efforts, and the vistas are much too attractive. The solution will not come from pulling down but from building up. Specifically, we need to educate fully in this country all the young brilliant minds that can be found, wherever they may be located and whatever their station. We have never done so nearly well enough. If we do there will be sufficient to man the various professions and intellectual pursuits, and as young men start their careers the various callings should be clearly presented so that none requiring recruits will be overlooked. We should not forget, for example, that political careers must be made fully attractive for sound thinkers if democracy is to function effectively in a world of growing complexity. This may not be directly the Institution's affair, for it is not primarily an educational institution, even though it has a function to perform in advanced scientific education of its own younger staff; but it is certainly an important matter, and in one way or another the Institution can perhaps lend a hand.

FINANCES

The Institution has emerged from the war in sound financial 'condition. Its endowment is in fact increased, because of the generosity of the Carnegie Corpora-

tion. Its investments have been safely managed thus far through a very difficult period.

It has conducted a large amount of war research for government under contract, on a basis where it contributed its facilities, its normal overhead, and the services of its regular staff, and was reimbursed only for out-of-pocket expenses for additional staff, equipment, and overhead. This policy has of course cost something, for there have inevitably been expenses that were not in either category, but the direct cost has not been large.

On the other hand, some of the amounts budgeted for support of departmental research programs have not been expended, on account of absence of staff members on war assignments with other organizations. These items have been reverted and placed in reserves where they will be available for the expenses of reconverting to normal activities. Though this expense will be substantial, for the equipment of the Institution will need attention after five years, the money thus placed in the reserve fund will apparently be sufficient for the purpose. The expenditure of this reserve awaits the return of the staff and the formulation of programs for the future.

It is difficult to foresee the future from a financial standpoint. In general it appears that, if the financial affairs of the country remain in sound condition, so also will those of the Institution. The rate of income from endowment has dropped severely, but thus far this loss has been offset by additions to endowment, economies in operation, and the termination of matured programs. Still, either a further decrease in rate of income or a substantial rise in the cost of living would bring severe stress. Of course, a real inflation would wreck the Institution completely as well as the country generally, but there is no way for us to guard against such an eventuality except by our influence as citizens on the general trends.

If the pattern following World War I is repeated, we may expect a few years of abnormal costs of living and of operation, followed by a return to the long-time trends which preceded the war. If such a pattern repeats, we may well need to operate with a succession of deficit budgets and draw on our reserves, for we now have little margin in operations. This procedure would not be disastrous, if the period is actually temporary, for the condition of our reserves is excellent.

Entirely apart from the short-term trends, however, there is one point which needs our attention as soon as the financial outlook allows. The salary scale of the Institution is not, by and large, high enough in view of the position of the Institution among research organizations in the country. This disparity should be carefully and thoroughly corrected, even if in order to rectify it we must forego opportunities to enter new fields of research for some time.

NEW RETIREMENT PLAN

Restudy of the Institution's position with respect to retirement provisions has resulted in modification and restatement of our procedure for annuity and life insurance, and adoption of a revised Retirement and Insurance Plan which became effective on January i, 1945. Specifications of the old plan have been modified to provide increase in joint contributions toward premiums on annuity contracts and to eliminate provision for supplementary annuity except in so far as supplementary aid

may be required in the few cases in which the new provision for minimum retiring allowance becomes applicable.

It is hoped that the minimum provisions of the new plan will enable the average male member to retire with a single life annuity of about 40 per cent of final salary. This is a reasonable goal, but present actuarial and financial conditions require an increase in annual contributions to reach it. For new members the procedure is compulsory, with the provision that entrance of those of advanced age will be conditioned by agreement with the Institution concerning the extent of contributions which may be necessary to produce appropriate retirement benefits.

The new plan also offers opportunity to present members to increase their contributions to the minimum percentage required of new members. Many have taken advantage of this offer, and with policies which have prospect of low returns, such action has been particularly helpful. Furthermore, there is provision for extending the coverage of collective insurance. In this connection it should be noted that, if the United States Government authorizes changes now contemplated in social security provisions, the Institution and its members may be called upon to participate, in which case further modification of our own Retirement and Insurance Plan will be in order.

Annual appropriations for the Pension Fund have been sufficient in the past to cover the Institution's contributions toward payment of premiums on annuity and collective insurance contracts as well as payments by the Institution in the form of supplementary annuity authorized by the old retirement plan. The peak of the supplementary annuity load has been reached, and obligations of this character will gradually diminish in the future. On the other hand, there is sharp increase in cost to the Institution of contributions toward premium payments on annuity contracts, as authorized by specifications of the new plan. It is estimated that a net increase of about $20,000 in the annual appropriation for the Pension Fund will be required if this Fund is maintained as a reservoir from which we shall continue to make payments as in the past.

RETIREMENTS AND CHANGES

Inauguration of a plan for joint action by the Institution and the California Institute of Technology in the future operation of the great astronomical centers at Mount Wilson and Palomar Mountain promises much positive accomplishment in this important field of research. The cordial informal cooperation which has existed between the Mount Wilson Observatory and the California Institute since the Inception of the project for building a 200-inch telescope reaches maturity in the formulation of a unit scientific program for the observational work of the two observatories, to take effect as soon as the Palornar equipment is completed, and in the reinforcing of this program by educational activities on the campus of the California Institute. Graduate training leading to the doctorate will be given under the auspices of the Institute by an astrophysics staff drawn from both the Institution and the Institute.

Thus the fortieth anniversary year of the Mount Wilson Observatory, witnessing the retirement on January 1, 1946, of its distinguished Director, Dr. Walter S. Adams, after more than two decades' service, witnesses also the institution of a plan calculated to extend in future the

contribution to knowledge which has made the observatory notable in the past. Dr. Ira S. Bowen, Professor of Physics at the California Institute of Technology, known for his work in spectroscopy and astrophysics, will succeed Dr. Adams as Director. Elected to the Astronomy Section of the National Academy of Sciences in 1936, Dr. Bowen was awarded the Draper Medal in 1942 in recognition of his discoveries in astronomical physics.

The report of Dr. Thorne M. Carpenter as Director of the Nutrition Laboratory reviews in this Year Book an activity which during the past thirty-eight years has produced results of the highest importance in advancing knowledge of the nutritive processes in man. The program of the Laboratory, which was organized in 1907, grew out of metabolism experiments supported earlier by the Institution and out of needs for fundamental work in the general field of nutrition. The experimental studies were of pioneering value in dealing with fundamental laws governing vital activity as expressed in the chemical and energy transformations in the animal body. Directed by Dr. Francis G. Benedict from 1907 to 1937 and by Dr. Carpenter thereafter, the Laboratory made memorable contributions to knowledge of the physiological chemistry of the human body, to the development of instruments and techniques, and to the accumulation of physiological data concerning vital activities of normal man and of special pathological cases as well. In recent years Dr. Carpenter and his small staff have effectively carried on programs of special war research.

It is thus after a noteworthy career that the activities of the Laboratory are being brought to termination with Dr. Carpenter's retirement, in pursuance of the policy which research organizations like the Institution must follow—of relinquishing work *in* which they have carried the initiative when the time comes that other organizations are prepared to continue it.

Growing in part out of the general correspondence which preceded the appointment of a new Director of the Office of Publications and Public Relations, and in part out of his study of the Institution's past publications and publication policies, basis has been laid for discussions by all interested members of the Institution's staff designed to consolidate policy and to consider expansion of the program so as to aid increasing the intelligent nonscientific citizen's comprehension of science. Plans are in preparation for the rearrangement and rehabilitation of the stocks of Institution publications, which have been disarranged because of unprecedented demands for space imposed by wartime uses of the Administration Building; better coordination of orders and shipping practices has already been achieved, and will be increased as present physical handicaps are removed.

RESEARCH ACTIVITIES

Though the departments and divisions of the Institution have been to a great degree withheld by war research from vigorous pursuit of projects in their usual fields of interest, some regular research activities have been carried on. Since much of the Institution's investigation for war purposes bears directly on problems with which it is engaged in normal times, many findings have been made in war programs which will be directly useful as regular programs are resumed.

At Mount Wilson, Dr. Walter S. Adams reports, the full observational program

with solar instruments and with the 100-inch telescope has been conducted. Further study has been made of the so-called irregular sunspots which do not undergo change in magnetic polarity at the start of a new cycle. In the literature, these have been characterized as "small unstable groups/' but the Mount Wilson study shows them to be as large and as stable as the spots which shift in polarity with the new cycle. Present preliminary results indicate, in fact, that their polarity is the only irregular feature of the so-called irregular spots.

The cyclotron of the Department of Terrestrial Magnetism has been in almost continuous daily operation for cooperative studies with the Naval Medical Research Center and the United States Public Health Service. These agencies and the Department have each contributed workers of special skills to the research teams carrying on this work.

The needs disclosed by experience as probable in any future research of the kind are discussed in detail in the thirteenth and final volume of "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929 under Command of Captain J. P. Ault," which has been completed for publication. Compilations of secular changes in the characteristics of the earth's magnetic field, described in the Year Book report for 1944, have been completed.

The volcano Paricutin in Mexico was visited by a representative of the Department of Terrestrial Magnetism for a preliminary survey for a program expected to be useful in the general problem of investigation of thunderstorms, and by a representative of the Geophysical Laboratory who went at the request of the Division of Geology and Geography of the National Research Council in order to obtain firsthand information upon which to advise the National Research Council group set up to coordinate studies of the volcano.

Oxidation of unsaturated fatty acids in the material has been found to be the source of the antibiotic properties of chlorellin, which was first isolated from cultures of the alga *Chlorella* in the Division of Plant Biology. As a result of this important discovery, Dr. Spoehr reports, other more direct sources of unsaturated fatty acids, such as corn, olive, and raisin oils, are now being utilized, and the oxidation reaction produced by exposure of them to air and light is under study. The *Chlorella* research, which of itself offered interesting possibilities in the development of antibiotic materials, thus has served as introduction to very promising fields. Since unsaturated fatty acids are available in such readily obtainable and relatively inexpensive source materials as vegetable oils, and since the mechanism of oxidation giving rise to antibiotic values is, though highly complex, susceptible of direct chemical study, the program is being stressed by the Division.

This Division's program of development of improved range grasses to produce more feed by better utilization of the soil and the growing season has resulted in the production of promising hybrids from which it is hoped to establish improved types. Testing of the more satisfactory hybrids—for example, one between Big bluegrass from eastern Washington and a hardy race of Kentucky bluegrass from Swedish Lapland—is being carried 00 at the Institution's mountain stations as well as at the central laboratory. Some are being delivered to the Soil Conservation Service for more extensive final testing.

Though published research of the Department of Embryology during the year past has been relatively small, because of

the wartime scattering of workers, the main lines of the Department's work have been continued. The development of the Embryological Collection has progressed, instruments and techniques have been brought nearer final perfection, and other programs have been carried out in performance of the basic plan of research stated in Year Book 40.

Successful development, under a War "Production Board contract, of a strain of *Penicillium* yielding a high content of penicillin was accomplished during the year in the Department of Genetics. Mutants produced by X-ray irradiation were screened to pick out exceptional high yielders rather than to screen out low yielders, about 10 per cent of the samples being retained. Of the 504 selected strains sent to the University of Minnesota for further testing, one, yielding about twice as much penicillin as the strain from which it originated, is now used in production.

The genetics of acquired bacterial resistance to drugs and other antibacterial agents is being studied in an extensive program started in June 1945. Solving of practical problems arising from bacterial resistance to therapeutic agents, and attaining of fundamental knowledge of the mutational patterns of bacteria and the underlying physiological mechanisms, Dr. Demerec states to be the two purposes of the project. Work on resistance to penicillin, sulfonamides, inorganic salts, bacteriophages, and ultraviolet radiation is included.

Interruption of the field work of the Division of Historical Research and diminution of its staff by the war led to opportunity, which has been thoroughly utilized, for the organization and writing up of the results of various investigational programs. Dr. Kidder reports that definitive publication of several projects has thus been brought into immediate prospect. Reconnaissance investigations of several sites, for the collection of data, preparation of preliminary maps, and similar purposes, have been made during the year, in anticipation of the opportunity to resume field operations.

REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

ASTRONOMY

Mount Wilson Observatory

TERRESTRIAL SCIENCES

Geophysical Laboratory
Department of Terrestrial Magnetism
Special Projects

BIOLOGICAL SCIENCES

Division of Plant Biology
Department of Embryology
Department of Genetics
Nutrition Laboratory
Special Projects

HISTORICAL RESEARCH

Division of Historical Research

MOUNT WILSON OBSERVATORY

Pasadena, California

WALTER S. ADAMS, *Director*

The present year is the fortieth anniversary o£ the establishment of the Mount Wilson Observatory by the Institution. During this period progress in astronomy and especially in astrophysics has been extraordinary, in keeping with the great developments in atomic physics. In addition, our knowledge of the universe has increased remarkably, and the development of methods for studying matter in its various forms throughout the depths of space has been successful almost beyond belief.

The Observatory has contributed notably to many of these advances, particularly in the fields of solar and stellar physics, in that of cosmogony, and in the application of new methods and instruments to the solution of astronomical problems. Between the discovery of magnetism in the sun in 1908 and the development of the observational basis for the theory of the expanding universe in more recent years lie a multitude of discoveries which have aided in the interpretation of the intricate and fascinating aspects of the physical world. The Observatory has fulfilled in large measure the hopes and expectations of its founder and first Director, Dr. Hale, and of the Institution which supported his plans and ideals so fully and generously.

As the war reaches its end, scientific research will encounter many problems of readjustment, both material and psychological. In some respects the present is the beginning of a new epoch which will call for a close study, selection, and revaluation of the problems of physical science. This is especially true of astronomy, to which the rapid development of new physical and optical methods and devices, and of great telescopes like the 200-inch reflector, will bring remarkable opportunities and corresponding responsibilities. It is with high anticipations for a future of great accomplishment that the present Director submits to the President and the Trustees of the Institution his last annual report of the activities of the Observatory.

The part taken by the Observatory in the study of various problems relating to the war has been especially extensive during the past year. In addition to previous contracts entered into with the Office of Scientific Research and Development, two new contracts have been undertaken. One of these is directly with the Army Air Forces; the second, under the Applied Mathematics Panel of the OSRD, has required a portion of the services of nearly the entire scientific staff. This contract has involved much statistical investigation.

With a single exception, all the members of the staff who have been on leave of absence for war investigations are still absent from the Observatory. As a result there has been some difficulty in carrying on the full observational program on Mount Wilson; but through the cordial cooperation of the remaining members of the staff it has been possible to maintain completely observations with the solar instruments and the 100-inch telescope. A few interruptions have occurred in the work of the 60-inch reflector.

STAFF AND ORGANIZATION

RESEARCH DIVISION

Solar Physics: Harold D. Babcock, Seth B. Nicholson, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond.

Stellar Motions and Distances: Adriaan van Maanen, Ralph E. Wilson,* A. Louise Lowen.

Stellar Photometry: Walter Baade, Mary Joyner Seares.

Stellar Spectroscopy: Walter S. Adams, William H. Christie,* Theodore Dunham, Jr.,* Milton L. Humason, Alfred H. Joy, Paul W. Merrill, Rudolph Minkowski, Roscoe F. Sanford, Gustaf Strömberg, Olin C. Wilson,* Ada M. Brayton, Sylvia Burd, Cora *G.* Burwell, Dorothy D. Locanthi,* A. Louise Lowen.

Nebular Photography, Photometry, and Spectroscopy: Edwin P. Hubble,* Walter Baade, Milton L. Humason, Rudolph Minkowski, Sylvia Burd.

Physical Laboratory: Robert B. King.*

Editorial Division: Paul W. Merrill, editor; Elizabeth Connor, assistant editor and librarian; Alice S. Beach, secretary and stenographer.

Alfred H. Joy has continued as Secretary of the Observatory throughout the year.

RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell has been actively engaged in the analysis of the neutral iron spectrum in collaboration with Mrs. Sitterly, and his advice and experience have been of great value in the preparation of the extensive Multiplct Table by Mrs. Sitterly, and of the Infrared Solar Spectrum by Babcock and Mrs. Sitterly. The *Fe* i Table has been published and the other two catalogues are nearing completion. The solar material used in all three investigations has been provided from Mount Wilson.

Dr. Seares with the aid of Miss Joyner has completed an extensive analysis of the basic magnitudes of southern stars measured by Stoy at the Cape of Good Hope and has compared them with standards in the northern hemisphere. In addition, Dr. Seares and Miss Joyner have studied certain statistical problems arising in the course of the analysis.

The wave length of the strong infrared radiation in the night sky detected by Dr. Stebbins and Dr. Whitford several years ago has been measured by Stebbins with sufficient accuracy to enable Dr. Swings to establish its origin as molecular nitrogen. Dr. Stebbins has also completed photoelectric measurements of 238 stars of different spectral types in six regions of the spectrum. The results are most interesting in their bearing on space reddening and the distribution in wave length of stellar radiation as compared with that of a black body.

TEMPORARY ASSOCIATES

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, spent about six weeks of the summer of 1944 in Pasadena, continuing his observations of radial velocities with the 60-inch telescope. Dr. John C. Duncan, Director of the Whitin Observatory, made numerous direct photographs of a variety of diffuse and planetary nebulae with the two reflectors during the summer of 1944 and compared some of the negatives with similar photographs made by him in 1921. Dr. P. Swings, professor at the University of Liége, has remained in Pasadena through-

* On leave of absence for investigations relating to the war.

out the year and has carried on active studies in stellar spectroscopy during a portion of his time. These have resulted in important identifications of forbidden and highly ionized lines in several stars of peculiar spectrum, in the identification already mentioned of the strong infrared radiation at *X*10440 in the night sky with a band of molecular nitrogen, and in numerous other interesting results.

Miss Suzanne van Dijke spent several of the summer and autumn months of 1944 in Pasadena, continuing her investigation of the spectral differences between giant and dwarf stars. Mr. W. C. Miller, of Pasadena, has continued the observations of bright-line B-type stars which he began several years ago with the 10-inch telescope, and has supplemented them with spectrograms he has obtained with the 60-inch reflector.

Several members of the Ballistic Research Laboratory of the Aberdeen Proving Ground were at the Pasadena offices of the Observatory during the autumn of •1944. A large measuring instrument was placed at their disposal and assistance was given in other ways.

INSTRUMENT DESIGN AND CONSTRUCTION

Design: Edgar C. Nichols, chief designer; Harold S. Kinney, draftsman.

Optical Shop: Donald O. Hendrix, superintendent.

Instrument Shop: Albert Mclntire, foreman; Elmer Prall, instrument maker; Fred Scherff, Oscar Swanson, Albert Labrow, Donald Yeager, machinists; Harry S. Fehr, cabinet maker.

MAINTENANCE AND OPERATION

Office: Anne McConnell, bookkeeper; Dorothea Neuens, stenographer and telephone operator.

Operation: Ashel N. Beebe, superintendent of construction; Sidney A. Jones (on leave of absence for military service) and Kenneth de Huff, engineers; Thomas A. Nelson, Floyd Day, Louis S. Graf, Hobart Wright, night assistants; Ernest W. Hartong, truck driver and machinist helper; Anthony Wausnock, Mrs. Wausnock, and Mrs. Pauline Byers, stewards; Arnold T. Ratzlaff, Irving Angel, and Harry Sering, janitors.

Several of those whose names are listed above have been with the Observatory but a part of the year.

Numerous temporary additions were made during the year to the personnel of the optical and instrument shops and to the experimental laboratory outside of the Observatory buildings to provide for the government contracts undertaken by the Institution.

OBSERVING CONDITIONS

Because of interruptions in the observing schedule^ the detailed table showing the monthly record of observations with the 6o-inch telescope is omitted. Solar photographs were obtained on 316 days between July i, 1944 and June 30, 1945, and the 1 QO-inch telescope was used on approximately 240 nights. In general, observing conditions were below the average, as is frequently the case when the winter season Is abnormally cold. The total snowfall was 52 inches and the precipitation for the year 31.75 inches, 6.35 inches below the normal amount for Mount Wilson. More than one-half the snowfall came during the month of March.

SOLAR RESEARCH

SOLAR PHOTOGRAPHY

Solar photographs were made on 316 days between July 1, 1944 and June 30, 1945 by Hickox, Hoge, Nicholson, Pettit, and Richardson, as follows:

Direct photographs	632
Ha spectroheliograms of spot groups, 60-foot focus	576
Ha spectroheliograms, 18-foot focus	1,248
K2 spectroheliograms, 7-foot focus	10,700
K2 spectroheliograms, 18-foot focus	1,220
K prominences, 18-foot focus	1,080

SUNSPOT ACTIVITY

The magnetic classification and study of sunspots have been continued by Nicholson and Mrs. Mulders. During the calendar year 1944, sunspot activity continued to decrease. Observations were made on 320 days; 123 days were without spots, as compared with 46 in 1943. In the new cycle, the number of groups increased from 6 in 1943 to 52 in 1944: the number in the northern hemisphere increased from 0 to 19; in the southern hemisphere, from 6 to 33. In the waning cycle, the number decreased from 89 in 1943 to 20 in 1944: the number in the northern hemisphere decreased from 54 to 8; in the southern hemisphere from 35 to 12.

The monthly means of the number of groups observed daily during the past two and one-half years are given in the accompanying table. A curve of these monthly means smoothed by overlapping three months' means indicates that the sunspot minimum occurred about 1944.3. The minimum in 1933 was lower than that in 1944. The total number of spots has increased more rapidly since the minimum in 1944 than in the corresponding interval after the minimum in 1933,

MONTH	DAILY NUMBER		
	1943	1944	1945
January	1.1	0.3	2.5
February	2.0	0.1	1.1
March	2.4	1.1	1.9
April	2.1	0.1	2.8
May	1.8	0.2	3.6
June	1.1	0.7	3.8
July	1.3	0.6	...
August	2.2	2.1	...
September	0.9	1.1	...
October	0.8	2.1	...
November	1.3	1.3	...
December	1.5	2.4	...
Yearly average	1.5	1.0	...

SUNSPOT POLARITIES

This new cycle is the fifth in which the magnetic fields in sunspots have been observed. The magnetic polarities of the spots of each new cycle have been arranged oppositely to those of the preceding cycle. "Regular" groups of the new cycle in the northern hemisphere are those in which the preceding spot has S (south-seeking) polarity and the following spot N polarity; in the southern hemisphere the polarities are reversed.

Magnetic polarities in each spot group have, so far as possible, been observed at least once. The classification of groups observed between July 1,1944 and June 30, 1945 is indicated in the table on the following page.

One of the most fundamental facts concerning the nature of sunspots is the change in their magnetic polarity with the new cycle. It cannot be said, however, that all spot groups have the new polarity* for about 2.5 per cent conform to the polarity of the previous cycle. Such spot groups are classified as "irregular." A catalogue

HEMISPHERE	POLARITY					
	REGULAR		IRREGULAR		UNCLASSIFIED	
	Old cycle	New cycle	Old cycle	New cycle	Old cycle	New cycle
North	2	28	0	0	2	9
South	10	62	1	1	3	22
Whole sun	12	90	1	1	5	31

has been made by Richardson of all spot groups of irregular polarity observed at Mount Wilson since systematic magnetic records were begun in 1917. The only mention of irregular spot groups in the literature is that they are "small unstable groups." Careful study fails to confirm this rather casual characterization. On the contrary, the irregular spot groups are fully as large and stable as the regular spots. In fact, several irregular groups have been naked-eye objects which endured for two and three revolutions.

In addition to the statistical study, intensive investigation was made of a large, stable irregular spot which appeared recently in the southern hemisphere. This spot reached naked-eye proportions and endured for a second revolution. Photographs were taken for Zeeman effect In and far outside the spot; also for Evcrshcd effect, Wilson effect, and direction of hydrogen vortex. The only unusual feature was that the direction of the hydrogen vortex was distinctly opposite to that prevailing in the southern hemisphere. Too much significance should not be attached to this circumstance, since about 20 per cent of all observable whirls fail to conform.

The present preliminary results indicate that the only irregular feature about "irregular" spots is their polarity. As a possible explanation, it is suggested that a solar cycle never completely dies out, but consists of alternate strong and very weak cycles, the weak cycle corresponding to the so-called irregular groups. That is, if the number of spots all of the same polarity were plotted for three cycles, the shape of the curve would consist of two large humps with a srnall one between of amplitude about 2.5 per cent of those on either side. In this sense, the irregular spots are really not "irregular" at all, but merely a feeble manifestation of the previous strong disturbance.

PROMINENCES

Although the minimum of prominence activity which accompanied the sunspot minimum during the year reduced considerably the opportunity for prominence study, several phenomena of importance have been observed by Pettit.

An eruptive prominence was photographed on July 2, 1944, which moved to a distance of 355,000 km from the chromosphere along a trajectory whose apparent angle with the extended solar radius was 51°, one of the three highest inclinations observed in the catalogue of 68 eruptive prominences. Eruptive prominences arc seldom seen near sunspot minimum. One other was observed at the present minimum (April 16, 1944) and one each at three previous minima.

A large interactive prominence extending over 60° of the solar limb appeared

at the beginning of January 1945. This was remarkable for being the first known instance in which a coronal cloud over a sunspot group took a direct part in an interactive prominence group. In previous cases material from the cloud had rained downward into the sunspot exclusively, but in this case a neighboring prominence drew the material to it with velocities increasing from 18 to 61 km/sec along a trajectory nearly parallel to the chromosphere.

GENERAL MAGNETIC FIELD OF THE SUN

Poor observing conditions have prevented some of the observing planned for the investigation of the general magnetic field, but one series of 28 plates in the green region has been obtained with the Lummer plate.

INFRARED SOLAR SPECTRUM

Final identifications and excitation potentials, now being added by Mrs. Sitterly to the principal table of infrared data prepared at Mount Wilson by Babcock, make this table nearly ready for publication. Additions made at Mount Wilson during the year include: (1) numerous classifications of weak lines according to origin, whether solar or terrestrial; (2) further instrumental checking and calibration" of the visually estimated intensities of solar lines. Over a wide range of spectrum the estimates have required but small systematic corrections, and their accidental deviations from uniformity average only about 1 intensity unit.

ULTRAVIOLET SOLAR SPECTRUM

Measurements by Babcock show that, in the main, the scale of ultraviolet wave lengths given in the Revised Rowland Table requires systematic corrections of only 0.001 or 0.002 A to fit it to the present International scale. Below A3100, however, the individual errors become greater, and Rowland's intensities are in some cases obviously wrong. The wave-length scale between A3133 and A2995 has been redetermined by reference to adopted standards in the blue region, and about 525 lines between A3060 and A2950 have been measured in the usual way. Twenty-five additional lines and other features of the spectrum were observed between A2950 and A2914; these have been roughly measured with a scale and magnifier.

Estimates of intensity are consistent with laboratory data, and identifications are well advanced. As would be expected, singly ionized elements become more prominent than in the visible spectrum.

LUNAR AND PLANETARY INVESTIGATIONS

CO-ALBEDO OF THE MOON

The albedo, *A*, of a planet has been defined as the ratio of the whole of the reflected light to the whole of the incident light. A similar definition applies to the ratio of the whole of the planetary heat emitted to the whole of the incident solar radiation; and, if *A* is measured radiometrically, this quantity Is $1 - A$ and is called the co-albedo. A calculation of $1 - A$ by Pcttit shows that the magnitude of the planetary heat from the full moon outside the atmosphere is —15.63, a value 0.4 mag. numerically smaller than that obtained by direct measurement of planetary heat. Of this discrepancy, 0.26 mag. is accounted for by a rediscussion of the calibrations and the reductions to *no* atmosphere. The co-albedo of the moon from the corrected measures of planetary heat is 0.93, and from the calculations of $1 - A$ it is 0.90.

PLUTO AND JUPITER'S NINTH SATELLITE

Several photographic observations of Pluto and the ninth satellite of Jupiter have been made by Nicholson with the 60-inch telescope. With the assistance of Miss Richmond the positions of both objects have been measured and the results published.

STELLAR INVESTIGATIONS

PARALLAXES AND PROPER MOTIONS

Measurements of nine additional parallax fields, mainly of faint stars with large proper motion, have been completed by van Maanen. The most interesting of these is Ross 882, which, like the companion of Lalande 21258, appears to be a variable of very faint absolute magnitude. With a normal photographic magnitude of 13.1 to 13.3, it appeared of magnitude 11.8 on two photographs taken on March 11, 1943. Its absolute magnitude, based upon a measured parallax of o".i46, has a minimum range of from +14.1 to +12.6. Its spectral type as determined by Joy is M4C A negative parallax was found for the Wolf-Rayet star C. du C. -f i6°5i6, which has a radial velocity of +195 km/sec.

Five pairs of plates covering 0.8 square degree in the center of the Pleiades cluster, taken at the 80-foot focus of the 60-inch telescope and separated by an interval of about 25 years, have been measured by van Maanen. Of the 452 stars measured, 71 are found from their proper motions to be probable members of the cluster. Nine others with motions of the same order are probably not members. One star of photographic magnitude 15.6 has a motion which indicates that it may be a member of the Hyades.

COLOR PHOTOMETRY AND STANDARD MAGNITUDES

Scares and Miss Joyner have seen through the press three of the four investigations reported last year. Before the revised color indices of standard polar stars were printed, the results were extended to include all the useful data now available. Other investigations are:

(1) Reduction of the Cape basic magnitudes by Stoy to the International system. These standards, of high internal accuracy, in the Harvard Regions at declination -45^0, were connected with the north polar standards through Cape and Mount Wilson observations of the southern comparison stars for Eros. The Mount Wilson data, obtained in 1930 for another purpose, have rather large accidental errors; but the magnitude scales and the mean zero points are in close agreement with Yerkes measures of the Eros stars. Further, the color indices are independent of magnitude, and the zero-point correction to the spectrum-color relation is only 0.03 mag. Similar tests applied to the Cape magnitudes also show a very satisfactory accordance. As a final check, the Eros stars should again be compared with the Pole, although it is believed that the present reduction is close to the truth. All together, the results provide a photometric connection of the two hemispheres that should meet modern requirements.

(2) In certain problems the squares of the errors of measurement appear in the coefficients of the normal equations. These terms do not cancel out, and when the percentage error is large,, they affect seriously the solution for the unknowns. The method of removing this regression effect already reported for the case of a single unknown has been generalized to include any number of unknowns.

(3) The difference in scale for the color temperatures of stars derived from the In-

ternational color indices and from the Ci and C_2 series of Stebbins and Whitford found in an earlier investigation was attributed to departures from black-body radiation. Proof is now available, with an indication that hydrogen-continuum absorption is chiefly responsible. Approximate corrections for the absorption, which it is hoped may be improved later, bring the scales into good agreement. With the zero point fixed at 11,000° for A5 stars, the color temperature for giant Ko (HD system) is 3800° and for Ao 15,000°-16,000°. These results are derived from the spectral interval 3400-5900 A.

PHOTOELECTRIC PHOTOMETRY

The strong infrared radiation in the night sky detected several years ago by Stebbins and Whitford has been shown by Swings to be caused by molecular nitrogen. The wave length of 10440 A, determined by measures with suitable filters, agrees with that of the (0,0) band of the first positive group of nitrogen. The absence of other *N2* bands suggests that emission of the (0,0) band involves conversion of the energy of dissociation *D(N2)* into excitation in a three-body collision

$$N + N + N_2 \rightarrow N + 2V_2^{exe}.$$

Stebbins has completed the photoelectric measurements of 238 stars of different spectral types in six regions of the spectrum from A3500 to A10000, and the results are ready for publication. The early-type stars from O to B^ show small dispersion in intrinsic color, but many are strongly affected by space reddening. A dozen late-type giants in low galactic latitudes are also affected by such reddening. The most marked effect of absolute magnitude is near spectrum Ko, where the colors of dwarfs, ordinary giants* and supcrgiants are all different.

The distribution of the radiation of different stars over the large range of wave lengths agrees with the distribution for a black body at suitable temperatures, but until a zero point of the temperature scale has been fixed, such so-called color temperatures must be relative. The determination of absolute stellar temperatures based upon a standard terrestrial source still remains one of the important problems of astronomy.

The colors of most of the stars fit into a uniform series. One of the few anomalous cases is that of the bright stars of the Trapezium cluster of the Orion nebula, where the previous result of Baade and Minkowski is confirmed, namely, that the optical properties of the absorbing interstellar material are modified to cause the Trapezium stars to stand out from a larger cluster in that region.

Comparison of the new colors with the International colors and the previous photoelectric colors of the North Polar Sequence give the ratios of the scales of color index. These ratios depend upon whether change of color is caused by change of spectral type or by change in the amount of space reddening for different stars.

•VISUAL MAGNITUDES OF DOUBLE STARS

The measurement of the magnitudes of systems containing a bright star with a companion fainter than 11.0 was begun by Pettit in December 1944. The wedge photometer was adapted to the Casscgrain focus of the 60-inch reflector, where a magnification of 746 was obtained. A high-speed sector was used to reduce the light of the bright star, and, in combination with the shade glasses of the artificial star and the wedge, provided a range of 9 magnitudes in the instrument.

Systems in which the separation is less

than 3 seconds were given special attention, many measures being made on doubles of slightly less than i second of arc separation. This work is limited to periods of good seeing, but even with this handicap 94 double-star measures were obtained, many of which include two sets of determinations.

VISUAL MAGNITUDE OF NOVA PUPPIS

Nova Puppis was measured by Pettit on 36 nights between October 15, 1944 and April 19, 1945. There was little net change in magnitude over this period. The mean magnitude October to January was 9.97? and January to April, 10.00.

VISUAL MAGNITUDE OF *a* ORIONIS

This star is passing through a minimum of light. Measures on 19 nights from February 21 to April 16, inclusive, give a mean magnitude of 1.15, which is just within the range usually given, 0.1 to 1.2 magnitudes.

STELLAR SPECTROSCOPY

TAURUS CLUSTER

Since the 1943 report, 159 spectrograms of 120 stars in the region of the Taurus cluster have been obtained and measured by R. E. Wilson. Sixteen of these stars had not been previously observed. Radial velocities have now been determined for 239 stars in this region. All but 10 of the velocities are based upon more than one spectrogram. Of the stars observed, 157 are probably cluster members, 26 are doubtful, and the remainder definitely do not belong to the cluster. The survey covering all suggested cluster members brighter than 10.5 visual magnitude will be completed with the reobservation of some 25 stars during the latter half of this year.

DWARF STARS

Spectrographic observations of 140 stars with proper motions greater than 0^35 have been completed by Joy, and the radial velocities, spectral types, and spectroscopic absolute magnitudes will soon be ready for publication. About 40 dwarf M-type stars having emission lines of hydrogen and calcium (H and K) have been listed and observed spectroscopically. The radial velocities have been measured and studies of the spectra are under way. These stars are among the faintest known as regards intrinsic luminosity.

RADIAL VELOCITY OF RIGEL

Further observations by Sanford show that although the radial velocity of Rigel (j3 Orionis) undoubtedly varies, no definite period seems to exist. The possibility of a period of less than one day, though not ruled out, seems unlikely. Velocities derived from the hydrogen and helium lines differ systematically from those of other lines. In some respects there seems to be a similarity in behavior between this star and *a* Cygni.

RADIAL VELOCITY OF *a* ORIONIS

The recent minimum of light of a Orionis has afforded an opportunity to examine possible changes of spectrum with phase. Several spectrograms taken by Adams with the 114-inch camera of the coudé spectrograph show no striking differences from the spectrum at maximum, but some interesting changes in detail. Changes are especially marked in such lines as those of *Mn* 1 and *Cr* 1, which arise from the zero level of excitation. These lines appear as relatively sharp components superposed upon broad hazy

lines which seem to shift back and forth beneath them. The sharp components show no variation in radial velocity over a period of eight years, whereas the diffuse lines show a range of about 8 km/sec. With lower dispersion the lines would blend and an intermediate value would be observed. This may account for the somewhat discordant results found by different observers for this star and a few others of supergiant M type.

VARIABLE STARS

Studies of the spectra of numerous classes of variable stars have been made by the stellar spectroscopic observers. These have included long-period variables of spectral types M and N, Cepheids, a few short-period variables, and stars of the T Tauri and SS Cygni classes of variability. Some of the stars had been investigated previously but have now been reobserved with higher dispersion.

The results of a comprehensive study by Joy of the spectroscopic behavior of a group of II variable stars resembling T Tauri in many respects have been collected and prepared for publication. The physical properties of these stars suggest that they may form a new class characterized by irregular light-variations of three magnitudes or more, spectral types of dF5 to dG5 with emission lines resembling the upper solar chromosphere, and association with dark or bright nebulosity.

Observations for determining the period and radial-velocity curve of the SS Cygni-type variable AE Aquarii have been continued. The velocity changes appear to be regular with a period of approximately 0.7 day. The shape and intensities of the bright lines show considerable variation.

During the past two years Merrill has obtained about 80 spectrograms of long-period variable stars with the coudé spectrograph (dispersion 10 A/mm). A number of these plates, taken when the variable was relatively faint, required long exposure. More than half the plates, many of which extend far into the ultraviolet and record a large number of lines, have been measured, and a beginning has been made on the reduction and discussion.

The curious multiple structure of the bright hydrogen lines in the spectra of certain red variable stars has puzzled astronomers for many years. New evidence that the minima in some of the lines correspond to dark lines of the reversing layer was supplied by a comparison of spectrograms of 0 Ceti, dispersion 3 A/mm, taken near the maximum of January 1945, with one of 3 Pegasi, a non-emission M-type star whose absorption-line spectrum is much like that of 0 Ceti. The close correspondence of details in several bright lines, particularly in *HQ* and *H*, with similar details at the same wave lengths in the spectrum of (3 Pegasi seems convincing. Six or eight minima within the bright lines *Ht, Hv\, H6,* and *Hi* have been identified with metallic lines. The conclusion is that the minima which cause the bright lines to appear multiple are just a part of the normal dark-line spectrum, and that the hydrogen series is emitted as single, slightly widened lines at a level *below* the stratum of absorbing metallic gases. This is an unusual inversion.

A series of six spectrograms of the short-period variable star RR Lyrae well distributed in phase has been obtained by Sanford with the coudé spectrograph. The spectrograms taken at maximum and minimum of light show that the amplitude of the radial-velocity variation given by the hydrogen lines is about 30 per cent, and that by the H and K lines about 60 per cent, larger than that given by other lines in the spectrum. These results confirm those obtained previously with lower dispersion.

B-TYPE STARS

Merrill has observed at intervals with the coudé spectrograph certain Be-type stars with spectral lines which show anomalous displacements, and Sanford has devoted considerable time to observations of B-type stars in open clusters.

Mr. W. C. Miller, in addition to making many instrumental tests of the 10-inch telescope, has obtained a number of excellent objective-prism spectrograms on which numerous bright-line objects, some previously unknown, are present. He has also obtained slit spectrograms of Be stars and other objects with the 60-inch telescope.

CN BANDS IN N- AND R-TYPE STARS

An examination by Sanford of "carbon" stars of types N and R shows that in the cooler N-type stars the CN bands are weak in the violet part of the spectrum and strong in the red, whereas in the hotter R-type stars the reverse is true. The N star Y Canum Venatkorum, for example, shows no violet *CN* spectrum, but very strong bands in the red. The laboratory investigations of *CN* bands by Dr. King and the theoretical study of the absorption transition probabilities by Dr. Swings afford an adequate explanation of the stellar results.

PECULIAR STARS AND NOVAE

A cooperative study by Joy and Dr. Swings has led to numerous very interesting identifications of lines in the spectrum of RS Ophiuchi at the time of the appearance of the coronal lines. These include a strong line at A6827 due to [i& in]; a line at A6914 due to *[A* xi] and one at A5536 of *[A* x]; and several lines due to *[Fe* VH], *iPevt%* [Itiv], [C*VH], [FVIII], and other elements. This is the first identification of krypton in celestial spectra, and of forbidden argon xi in any object.

A similar investigation by Sanford and Dr. Swings has led to the following identifications in Nova Puppis in the region A4585-A8600: Civ, ATV, OI, 67I, *Sin,* [itiv], [Cavil], *Fen,* [F<?vi], [F<?vn], and possible identifications of Niv, [M/2V1], *[Fex],* and [F<?xi].

On April 3, 1945 the recurring nova T Pyxidis, which had maxima in 1890, 1902, and 1920, was found by Joy to be three magnitudes brighter than normally. Spectrograms indicated that the star had passed the maximum of an outburst several months previously. The spectrum was typical of novae at a late phase. The emission lines were much wider than those of Nova Puppis 1942 or of the well known recurring nova RS Ophiuchi. Of especial interest is the identification in T Pyxidis of the coronal lines A5303 *[Fe* xiv] and A6374 [Ftfx], the former being the stronger of the two. Other identified lines of high excitation are those of iVni, [Mr m], [Mriv], [Om], [F<rv], [F<?vi],and [F<?VII].

In the course of his examination of peculiar spectra. Dr. Swings has identified several lines in P Cygni with those of *O* 1 and *C*11, and a line on Lick Observatory spectrograms of *Y*\ Carinae as the principal forbidden line of *Cr* n. An emission line at A7155.1 found by Merrill in u Sagittarii is identified as a low-level *Fe* 11] transition. From a study of high-dispersion spectrograms of (3 Coronae Borealis which extend to ^3100, Dr. Swings concludes that no lines due to neutral or doubly ionized rare earths are present, although lines of the singly ionized earths are prominent.

INTERSTELLAR LINES

The investigation of complex interstellar H and K lines in the brighter O- and B-type spectra has been continued by Adams,

and about 250 stars have been observed in the second order of the coudé spectrograph on a scale of 2.9 A/mm. The lower dispersion of the 32-inch Schmidt camera has been used for stars fainter than magnitude 6.5. The most interesting result found is the rapid motion o£ some of the interstellar clouds in Sagittarius and Cygnus, amounting in some cases to as much as 60 km/sec.

Photographs of the interstellar D lines in the spectra of a few bright stars have been obtained by Merrill with the coudé spectrograph on a scale of 6 A/mm.

GALACTIC NEBULAE AND NOVAE

DIRECT PHOTOGRAPHY

Among direct photographs obtained by Dr. Duncan with the 100-inch telescope are two of the Trifid nebula, and one each of the diffuse nebula NGC 6357, the planetary nebula NGC 7293, and the dark nebula Barnard 86 Sagittarii. Photographs with the 60-inch telescope include those of diffuse nebulae M 8, M16, and M17. Some star clusters and the short-period variable star CY Aquarii were also observed. The photographs of the Trifid nebula and the 86 Sagittarii nebula were compared with similar photographs made by Dr. Duncan in 1921, but no change in the nebulae or the neighboring stars was detected.

SPECTRA OF PLANETARY NEBULAE

The survey of objects on objective-prism photographs which show *Ha* in emission with little or no continuous spectrum has been continued by MinkowskL Of 82 such objects investigated, only 8 have been found to be Be stars. Most of them are nebulae, 50 being planetaries and 15 diffuse nebulae. The remaining 9 objects are stars of peculiar types.

The investigation of the spectra of these objects is stili in progress, and it is too early to summarize .the results. Some planetaries have been found which show only the *H* lines together with mere traces of forbidden lines. The relative intensity of the [Nu] lines varies widely; even in nebulae which are similar in other respects, they may be the strongest lines in the spectrum or negligibly faint. Such intensity variations may have to be explained by variable nitrogen content.

Many of the planetaries are very strongly reddened by space absorption. A systematic survey, which can readily be extended to limits fainter than that of the available objective-prism plates, should permit investigation both of space absorption at large distances and of the galactic distribution of planetary nebulae. Of the 9 peculiar stars, 3 are of type B with strong *Fen* lines, 1 being a close duplicate of *Y* Carinae. The other 6 are M-type stars with emission lines of high ionization, 1 showing strong lines of [F«?vi] and *[Fevxi]*. In all these stars *Ha* has very high relative intensity; this explains the relatively large number of peculiar stars included in the material.

COLORS OF FAINT CEPHEIDS IN THE CYGNUS CLOUD

The photovisual scale in Selected Area 40, which had previously been used for intercomparison of four distant Cepheids in the Cygnus cloud, has been established more accurately by an entirely new determination of both scale and zero point undertaken by Baade in cooperation with Dr. Scares. To determine the absorption beyond 10 kpc in the Cygnus cloud, nebular counts were made on a series of i-hour exposures taken at the ioo-inc}i telescope. The area investigated on these plates is a narrow strip at longitude 41° between latitudes $+4^0$ and $+15^0$.

SHELL AROUND NOVA HERCULIS

The shell of this nova, which has been observed photographically by Baade at the Cassegrain focus of the ioo-inch telescope, has continued its steady decrease in brightness. The decrease is especially marked in the emissions of A4959 and A5007 of [Oin]. Interesting structural changes have taken place in the shell images of the *[N*11] lines A6548 and X6584 and the [O n] lines at X3727. The strong [Nil] emission along the minor axis of the shell has broken up into three distinct condensations, two at the ends of the minor axis and one at its center. In the [On] image, which until 1944 presented the appearance of an amorphous elliptical disk, the ring structure suddenly emerged between 1944 and 1945. The [On] ring has two gaps at the ends of the minor axis where the strong *[N11]* condensations are located. Since the same gaps occur in the [0 in] ring, it would appear that forbidden oxygen emissions are suppressed where the [Nn] emissions are unusually strong.

EXTRAGALACTIC NEBULAE

The successful resolution of the inner part of the Andromeda nebula and of the early-type members of the local group of galaxies mentioned briefly in the last report has brought within our grasp the solution of a number of important problems. The technical difficulties encountered in precise observations of this sort are many, since the optical power of the 100-inch telescope has to be utilized to its extreme limits. Progress should be easier in the near future, however, because of certain new photographic emulsions now being developed at the Eastman Kodak Research Laboratories through the generous cooperation of Dr. Mees. The new plates are sensitized for a region of the near infrared which is free from strong night-sky emissions. Thus far, an increase in speed by a factor of 2 over the emulsions previously used has been achieved, but there is good reason to expect that a gain of a full magnitude will be realized before long. Several nights in the spring of 1945 were devoted by Baade to tests of the experimental emulsions sent by the Eastman Research Laboratory.

During the year under review, the main part of the program was a search for kmg-period variables in other members of the local group. If the recently derived absolute magnitudes of these variables are not seriously in error, they should be observable (at least those with periods shorter than 200 days) with the present technique. So far the search has been restricted to M 32 and NGC 205. In both, a considerable number of faint variables have been found. Observations in the next two seasons should make it possible to decide whether these stars are the elusive long-period variables.

Nights on which the definition was not sufficiently good for the resolution of M 32 and NGC 205 were used for a search for emission nebulae in M31. Emission patches in M31, which were first noted on red exposures taken in 1944, present a problem. Invisible on ordinary blue-sensitive plates, they are outstanding features when photographed in *Ha* light; they range in size from giants about 100 parsecs in diameter to small specks just distinguishable from stars. Only a spectroscopic investigation can decide whether their weakness in the blue is caused by selective absorption alone, or whether some other factor is involved. In any event, the generally accepted statement that emission patches are a common feature only in late-type spirals and irregular systems needs radical revision.

CEPHEIDS IN THE SEXTANS SYSTEM

The investigation of the Cepheids in this important dwarf system has been continued by Baade. Because the nebula can be observed only during the unfavorable winter months, the necessary plates are being accumulated very slowly.

NEBULAR VELOCITIES

Velocities of *63* extragalactic nebulae have been observed and measured by Humason during the year. The number of extragalactic nebulae with velocities determined at Mount Wilson now totals 433 It is hoped that this number can be increased to 500 during the coming year after which time the results will be published and discussed.

A redetermination of the radial velocities of the members of the local group OJ galaxies, with the highest possible dispersion for each object, is under way. Preliminary solutions with the data alread) available indicate that the new velocitie; will furnish a well determined value of the galactic rotation.

LABORATORY INVESTIGATIONS

NIGHT-SKY RADIATION

A brief reference has already been made to the identification by Dr. Swings of the intense infrared radiation in the night sky observed by Stebbins and Whitford. The radiation is the (0,0) band of the first positive system of A2. Failure to observe other strong A2 bands indicates a mechanism which enhances the (0,0) band relatively to the other vibrational transitions. Such a mechanism has been suggested by Dr. Swings, in which during the night A2 molecules are brought into the zero vibrational level through three-body recombinations. The presence of a fairly large number of nitrogen atoms in the upper atmosphere is implied.

VIOLET AND RED BANDS OF CN

Reference was made in last year's report to the laboratory investigations by Dr. A. S. King of the relative intensities of the *CN* bands. Dr. Swings has studied the ratio of the absorption transition probabilities between the violet and the red systems, and obtains an estimated ratio of 87 to i. This would explain the weakness of the red system in absorption in the laboratory.

Some astrophysical conclusions are that red bands of CAT" should not be expected in cometary spectra; that no line of the red system should appear in interstellar absorption; and that in carbon stars with weak violet bands of *CN* there is less continuous absorption in the red than in the violet.

MAINTENANCE AND OPERATION

During the year, as in the past three years, the work of the instrument shop has been very largely upon apparatus for military use. About 16 per cent of its time has been given to Observatory work, mainly for maintenance and repairs. Very little new equipment has bcea added. In the optical shop and the department of design and drafting the situation has been similar to that in the instrument shop.

Albert Mclntire has been in charge of the instrument shop, Donald O. Hendrix of the optical shop, and Edgar C. Nichols has carried out the design of nearly all the apparatus which has been constructed. These three departments of the Observa-

tory have had to meet the problems of a great variety of instruments of difficult design and frequently of unusually high precision, and have been most successful in solving them.

On Mount Wilson, A. N. Beebe, superintendent of construction, has carried on necessary repairs and has cared for the difficulties of transportation during the winter months. He has also provided for such construction in Pasadena as has been required by the government work in progress. Kenneth de Huff, engineer, has maintained the extensive equipment on Mount Wilson necessary to the operation of the instruments, and in addition has been able to give considerable time to work in the instrument shop.

THE LIBRARY

During the past year the library has added 299 volumes, making a total of 15,608 in the collection. Of the volumes acquired, a large proportion are from Dr. Hale's library, described in last year's report; 48 volumes were purchased; but only 47 were bound because of difficult conditions at the bindery due to the war. The number of periodicals and serials received is still small; 27 of these are gifts or exchanges, including publications from several research organizations in Sweden and Switzerland. Distribution of the Observatory publications (since 1942 sent only to the Americas) will be resumed when conditions permit.

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GEOPHYSICAL LABORATORY

Washington, District of Columbia

L. H. ADAMS, *Director*

During the year ending June 1945 the Geophysical Laboratory has continued in essentially the same program of war work that was carried forward during the preceding three years. One government contract under the auspices of the National Defense Research Committee was brought to a conclusion, except for final report writing, at the end of June; but the work under a larger contract had not diminished in volume on that date. Two additional members of the regular scientific staff were given leaves of absence without pay for the purpose of taking positions with war agencies, but as before a considerable number of persons employed on a temporary basis have supplemented the efforts of the regular staff in carrying out the various investigations, the results of which have found specific application to military needs. Closely related to the work under NDRC supervision have been a variety of services performed directly for the Army and the Navy.

It has not yet been deemed practicable to resume any considerable part of our normal activities. Upon request from the Division of Geology and Geography of the National Research Council, however, one of our staff members made a brief trip to the newly formed volcano Paricutin in Mexico for the purpose of obtaining firsthand knowledge of that volcano and of being thereby enabled to advise the National Research Council group that had been set up to coordinate the volcano studies.

At the time this report was written, it became evident that the experimental work for NDRC at the Geophysical Laboratory could properly terminate in October, and that the additional obligations to that agency in connection with its final reporting would be fulfilled by the end of January; after which the Laboratory will be in a position to turn its attention again toward fundamental research in earth sciences. Comprehensive plans will be made for a future program; also, at an early date, unpublished results of studies interrupted in 1941 will be assembled. During the past year, it was found possible to prepare one short paper (described below) for presentation at a scientific meeting and subsequent publication.

SUMMARY OF PUBLISHED WORK

(1083) Relations of lamellae and crystallography of quartz and fabric directions in some deformed rocks. Earl Ingerson and O. F. Tuttle. Amer. Geophys. Union, Trans. 1945, pt. I, pp. 95-105 (1945).

Measurements of quartz lamellae in metamorphic rocks of the Washington, D. C, area and new measurements from the Ajibik quartzite confirm previous generalizations as to the relations of the lamellae to the c-axis of quartz and to the fabric axes of the rocks.

A more detailed statistical study than has been made previously yields interesting and significant results. This study is carried out by dividing each fabric diagram of lamellae into four zones according to the angles that the c-axes of the quartz make with the *B* fabric axis, and tabulating measurements for each zone.

The tabulations show that the lamellae are not controlled by definite crystallographic planes or zones in the quartz structure. They

are apparently controlled almost entirely by the stress pattern which determined the (quartz) fabric axes for the rock. Since the orientation of the c-axes is also at least in part controlled by this pattern, there is an indirect relation between lamellae and the structure of the quartz.

Lamellae can be important in geologic interpretation in determining not only the I?-axis, but also direction of motion, if the lamellae and c-axes of the same grains are plotted. Lamellae can also serve in certain cases as an index of intensity of deformation.

(1084) Annual Report for 1944-1945.

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DEPARTMENT OF TERRESTRIAL MAGNETISM

Washington, District of Columbia

JOHN A. FLEMING, *Director*

SUMMARY

The long-sustained effort required for waging a war of world-wide extent continued unabated through the report-year (July i, 1944, to June 3°> 1945) and rendered impossible the execution of anything like the normal program of the Department of Terrestrial Magnetism. Military and naval operations have greatly interfered with geophysical* investigations requiring international cooperation, of which terrestrial magnetism and electricity are good examples. It has not been possible to equip expeditions for field-work in foreign lands and on the oceans, to provide the much needed data for secular-variation studies. Nevertheless, although practically all of the Department's staff have turned attention to the solution of problems connected with the war, considerable progress has been made along certain lines. Moreover, much important work, the results of which are not yet publishable, has been brought to a successful conclusion.

Operations relating to national defense continued to make use of observational, theoretical, and instrumental material, and of experience of members of our staff, accumulated during more than forty years- These have involved since August 1940, Under thirty individual contracts (at actual cost and without overhead charge) with the Office of Scientific Research and Development, National Defense Research Committee, various bureaus in the Army and the Navy, and the Maritime Cornmission, a total expenditure of slightly over $2,006,000. The Institution has contributed services of Its regular scientific personnel in the Department* an aggregate compensation amounting to something over $478,-500, in addition to use, without charge, of laboratories, scientific equipment, machine-tools, and site. On July 1, 1945, obligations with the War and Navy Departments and the Maritime Commission were still in effect, involving work of high postwar priority. It may be sometime in 1946, therefore, before all contracts are completed and the full normal program of research can be resumed.

The contractual obligations required over 90 per cent of the services of the available full-time and part-time regular staff of 81 in Washington and at the observatories. One hundred and fifty-four temporary employees (including physicists, engineers, mathematicians, computers, machinists, clerks, and guards) were necessary, and the peak number of persons at the Department during the year was thus 235. Besides these, 12 of our regular and 2 of our temporary personnel were dn leave of absence either in the armed services or in governmental war agencies; of these, 1 returned to duty at the Department on January 1, 1945. Many of the temporary personnel were again made available by various universities and individual organizations through generous granting of leaves of absence.

REVIEW OF YEAR'S ACTIVITIES

Geomagnetic investigations. The voluminous tables required to correct magnetic observations for secular changes, for the natural magnetic variations and disturbances, and for cosmic variations were

extended to include the year 1944. The reductions of field-observations to the four epochs 1912.5, 1922.5, 1932.5, and 1942.5 were completed for over 10,000 stations on land and sea. Isoporic charts of the world for declination and horizontal intensity for these four epochs were completed, and others for the five remaining elements or components were well under way. Forty-five isomagnetic charts of the declination and horizontal and vertical intensities with indications of anomalies were completed for the area of the western Pacific and were printed. Further useful tests for adjusting isomagnetic charts to mutual consistency were evolved.

Calculations were made for continuation of magnetic fields on a plane or a sphere to adjacent regions of space.

Isolines of equal daily and hourly percentage-frequency of occurrence of visually observed aurora were mapped for the Southern Hemisphere. The extent and frequency of expansions of the auroral zone during magnetic storms are being studied, using geomagnetic as well as auroral data.

Cosmic relations. Further analyses of cosmic data were made with regard to solar, geomagnetic, ionospheric, and auroral correlations. The operational value of previous conclusions regarding the effects of ionospheric and geomagnetic disturbances on conditions of radio transmission and reception was confirmed.

Provision for the maintenance and operation of the recording cosmic-ray meters at Cheltenham (Maryland), Huancayo (Peru), Godhavn (Greenland), Christchurch (New Zealand), and Teo-Ioyucan (Mexico) was continued* with only minor interruptions, in spite of difficulties occasioned by the war. Analyses of the resulting data must await return of personnel from war activity. By 1949 the records will include at least a complete sunspot-cycle for all five stations —ample for statistical analyses concerning seasonal effects in different localities, solar-day and lunar-day variations, and geomagnetic and other possible correlations.

The Department continued to act as a clearing house for observations of sunspots by many observers of the American Association of Variable Star Observers, pending re-establishment of communication with the international center at Zürich, Switzerland.

Terrestrial electricity. Following some improvements in CIW ionization-meters, particular attention was directed to effects of secondary radiation, "volume-contamination," and "wall-contamination."

An important program was begun on adaptation of electronic circuits to atmospheric-electric instruments in place of electrometers. This has resulted in improvements in investigation of rapidly varying fields associated with thunderstorms and in observations under difficult operating conditions, for example, on airplanes in storm regions.

Tests showed that the diminution in the rate of ionization which occurs when people occupy a room is due to a diminution in the radon and thoron content of the air. It is not yet determined, however, why this occurs. Automatic records of rate of ionization, for investigation of diurnal-variation and annual changes, were obtained for almost the entire year. For equilibrium-conditions the alpha-ray ionization inside a room was found to be about double the gamma-ray ionization. This ratio is about 50 per cent greater than that obtained from estimates by Eve for outside air-conditions.-

The small-ion content of the air was found to vary directly as the rate of ionization, becoming zero when the ionization

is zero. Results indicate that the recombination-coefficient between small and large ions may vary with the rate of ionization. The alpha-particle stopping power of cellophane was found to be much greater than that anticipated irom calculation.

The probable error of a single observation in measurements of ion-content and air-conductivity at sea was determined, from analysis of results obtained during the last three cruises of the *Carnegie,* to be about 12 per cent. The average error for each instrument also appears to be systematic and of such a nature as to give too low a value for the element measured, perhaps not over 1 per cent in mean values.

Research on seasonal changes in the diurnal variation of earth-currents and the geomagnetic field from 12 years of record at Tucson (Arizona) was completed. The changes were found to be consistent with effects attributable to recognized current-systems in the ionosphere. Two anomalous features disclosed, in addition to the regular seasonal changes, were explained as probably due, the one to space-variation in the conductivity of the ionosphere, and the other to erratic shifts in the latitudes of current-centers.

Ionosphere. Activities of the Ionospheric Section were devoted almost exclusively to military applications. Additional important contributions to improvement in radio-communication circuits resulted from the continued accumulation of ionospheric data at Huancayo, Watheroo, and College, and the five other sites outside the continental United States. Arrangements were well under way by the end of June for two more strategically placed stations.

The active program of research and development and the instruction of observing teams were continued at the Kensington Laboratory and at several field-stations. These resulted In design and construction of improved and simplified manually operated ionospheric equipment.

Seasonal features of sporadic-I? already established for the Northern Hemisphere were confirmed for the Southern Hemisphere. Tests for recurrence-tendency with the 27-day period of solar rotation did not show positive correlation.

Further attention was devoted to post-war observational program and items of research (see Year Book No. 43). Most important are (1) completion of the program at Huancayo and Watheroo to cover a full sunspot-cycle, (2) extended analyses of accumulated data, and (3) new projects directed toward specific problems which promise positive solutions in a reasonable length of time.

Nuclear physics. The 60-inch cyclotron was in almost continuous daily operation, without any major breakdown and with few minor changes, and with almost automatic operation. A new ion-source was developed giving 80 to 90 hours of operation.

In the emergency the cyclotron was almost wholly used in bombardments for special researches of the Naval Medical Research Center and the United States Public Health Service. The research-program utilizing the cyclotron and the 5,000,000-volt static generator for nuclear physics must be postponed until sometime during 1946 to meet immediate post-war needs for radioactivated products for chemotherapeutic and similar research. Special bombardments were also made for the National Defense Research Committee, the National Bureau of Standards^ and the Department of Agriculture.

A method was developed for making a stable colloidal preparation of metallic antimony which is free from other forms of antimony.

Observatory- and field-wor\. The complete geomagnetic, atmospheric-electric,

ionospheric, seismic, and meteorological programs were maintained at the Watheroo, Huancayo, and College magnetic observatories. Special studies relating to geomagnetic, atmospheric-electric, and ionospheric problems were made by the staffs at each observatory. The atmospheric-electric program in cooperation with the United States Coast and Geodetic Survey at its Tucson Magnetic Observatory was continued. The Department cooperated, through loan of instruments and otherwise, with eight observatories abroad.

Maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was effected through the Division of Geomagnetism and Seismology of the Survey.

Though no field-work other than that at the observatories could be undertaken, it was possible to assist various governments, through loans of magnetic instruments, in undertaking new magnetic surveys and obtaining repeat-observations at established stations.

Miscellaneous. The report-year included the fiftieth anniversary of the establishment of the *Journal of Terrestrial Magnetism and Atmospheric Electricity.* That journal was founded by Dr. L. A. Bauer, first Director of the Department, and has been conducted since 1932 by his successor. In it have been published many of the original papers of members of our staff. It has been a potent factor in the promotion and diffusion of geomagnetic and geoelectric knowledge and progress, not only in the United States, but throughout the world as well.

The continued services of three of the retired staff—J. W. Green and W. F. Wallis during the whole year and A. Smith until December 29, 1944—have been most useful in the emergency.

Dr. Harry Marcus Weston Edmonds, who retired in 1930 after 20 years of activity in the Department, died in his eighty-second year at Berkeley, California, April 4, 1945- He was surgeon and magnetician of the *Carnegie* for several years, and in command of the vessel from December 1917 to June 1918. He did arduous field-work in Canada and constructed and equipped the Huancayo (Peru) Magnetic Observatory. He represented the Department in its cooperation at the Apia Observatory during part of the transition period after World War I. His record is one of unselfish devotion and high efficiency in a long life of scientific service.

Once more the necessarily brief detailed accounts in this report of our activities illustrate the team work and professional partnership so singularly necessary in the scientific provinces of the Department.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM

Those of the staff at Washington chiefly concerned with geomagnetic research were Fleming, J. W. Green, Hendrix$_9$ Johnston$_3$ Miss Lange, McNish, Scott, Sherman, Vestine, Wallis, and Wells, with Bernstein, Mrs. E. G. Crow, Davids, Shapley, and Zimmcr (until his death February 5$_9$ 1945) of the temporary staff. McNish gave his full time to war problems related particularly to applications of geomagnetism. The others named gave the greater part of their time to matters related directly or indirectly to the war effort.

GEOMAGNETIC ANOMALIES

Vestine and Davids developed analytical and computational procedures for the analysis and interpretation of geomagnetic

anomalies. These relate particularly to techniques of geophysical prospecting by magnetic and gravitational methods. Relations among the surface-components of field and their gradients were compiled, and techniques of analysis using models, Fourier series, Fourier-Bessel series, power series, and surface integrals described. These methods do not permit unique location of the sources of field from magnetic data alone, but under favorable conditions permit useful inferences regarding subsurface structure, of advantage in prospecting for certain minerals and petroleum. Application of the results to illustrative examples is being undertaken.

GEOMAGNETIC DISTURBANCES AND COSMIC RELATIONS

The geographic incidence of aurora and magnetic disturbance in the Southern Hemisphere was studied, using observations at about 40 auroral stations and 13 magnetic observatories. The position of the southern auroral zone was estimated from geomagnetic data and compared with the results of observations of aurora. Tentative isochasms were drawn for aurora observed in absence of cloud, results being corrected also for the influence of sunlight on observing conditions, and they appear closely to resemble corresponding isochasms for the Northern Hemisphere.

The geomagnetic disturbance daily variation (Sj>) was derived for stations in southern auroral regions. Little evidence was found of important differences in the average characteristics of geomagnetic disturbance as between south and north polar regions, but more observations are necessary, particularly at the auroral zone, where as yet no observatory has operated, before a definite conclusion can be reached.

Lines of equal average hourly percentage-frequency of aurora were mapped for the Northern Hemisphere for several positions of the Sun relative to the Earth. The region of highest average hourly percentage-frequency coincides with the region of most concentrated electric current-flow estimated for the average of 40 magnetic bays of the Polar Year 1932-1933.

Vestine and Miss Lange are deriving the average position of the northern auroral zone for the various years of the sunspot-cycle. The statistical frequencies of the magnitudes of daily departures of the auroral zone north and south from its average position are being compiled, using measurements of geomagnetic disturbance at stations in high latitudes.

PERMANENT FIELD

Davids and Bernstein continued studies and tests for ensuring greater mutual consistency among isomagnetic charts. Professor James H. Taylor, of George Washington University, completed theoretical examination of the problem of adjusting isomagnetic charts to mutual consistency, the definition of the normal geomagnetic field, and intrinsic properties of mapping contours.

Current compilations of magnitude of major short-period magnetic fluctuations have been made for results measured at Ivigtut (Greenland) and College (Alaska).

Tables are under construction to permit analysis and continuation of surface magnetic fields over a sphere, using the method of surface integrals previously reported.

At least 90 per cent of Vestine's time was spent on war contracts of the Department, with the Director's supervision and advice. The main activities may be listed as follows: (1) Continuation of work of the previous two years in supervising, with assistance of Miss Isabelle Lange, temporary professional and asso-

ciate workers. Many of these activities were along lines ordinarily normal to the investigations of the Department, so that this work remains of enduring value in time of peace. These activities were greatly facilitated by the cooperation and assistance of many others of the Department's staff, and especially by the following: Johnston and Scott, who generously gave of their time in providing geomagnetic data; Seaton, with Malich of the temporary staff, and Corp, who made measurements of geomagnetic fluctuations at College (Alaska) and Ivigtut (Greenland), respectively; and Harradon, who translated numerous foreign passages in publications and who together with Dove made available almost daily the geomagnetic data in the library. Green and Wallis made particularly valuable revisions of data on land and sea, especially in preparing final summaries of data as corrected to International Magnetic Standard. Hendrix and Harrison, with Doepke of the temporary staff, drew the necessary graphs, maps, and diagrams, and Capello and Dove typed and prepared manuscripts.

Sherman, Scott, and Vestine installed a visually recording magnetograph in the field at Sterling, Virginia.

In supervision of work, Vestine and Miss Lange had the valuable assistance of the computing supervisors Cooper, Laporte, Meier, Saltarelli, J. W. Smith, and E. J. Snyder, of the temporary staff. Between 40 and 50 others contributed in temporary technical and computing capacities.

TERRESTRIAL ELECTRICITY

War research in the Section of Terrestrial Electricity continued on a slightly reduced scale from that of the three previous years. Nearly all of Sherman's time was spent on war projects. Torreson remained on leave of absence with the Applied Physics Laboratory of Johns Hopkins University for the Office of Scientific Research and Development and United States Navy through December 1944, and returned to the Department January 1, 1945. He then began editing, compiling, organizing, and preparing material relating to the atmospheric-electric work done at sea on the *Carnegie* in 1928 and 1929, for the volume Oceanography III in the series "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929." About one-quarter of Rooney's time was given to war research problems and the remainder to Section routine and research. Gish and Wait devoted most of their time to atmospheric-electric research but gave some time to consultations and investigations related to the war effort.

ATMOSPHERIC ELECTRICITY

Development of instruments and methods. Some minor modifications and improvements were made in the ionization-meters (Gish and Sherman) developed for the investigations of Professor V. F. Hess. Considerable study (Gish) was directed to the interpretation of the results obtained by Hess, with particular attention to the effects of secondary radiation, "volume-contamination," and "wall-contamination." The method of Hess involves the use of three ionization-chambers of identical shape but with different ratios of area to volume, so that the effects of wall-radiation can be segregated and eliminated from the measured values. Examination of the data obtained with the three chambers under different conditions with respect to the freshness of the nitrogen they contain^ the amount of contamination probable on the walls, and the type of direct radiation to which they are exposed, leads to the following conclusions: (1) The effect of soft secondary radiations

or of some equivalent is definitely noticeable. (2) Immediately after the chambers are filled with fresh filtered nitrogen, radioactive contamination of the nitrogen, or something producing a like effect, is prominent for several days. At such times there is little or no evidence of contamination on the walls, presumably because any which existed previously has been removed or greatly reduced in the process of refilling. (3) Following refilling, the "volume-contamination" decreases as the radioactive material in the nitrogen diffuses and is absorbed in a thin film on the walls of the chambers. (4) After a period of from 10 to 20 days a condition of equilibrium is reached in which the "volume-contamination" is practically negligible. (5) The "volume-contamination" and the "wall-contamination" are apparently of very nearly the same density in all three chambers. Hence the fundamental idea underlying Hess's method can be expected to result in satisfactory data once the nitrogen has aged in the chambers.

A further theoretical study of the effects of secondary radiation in ionization-chambers was made (Gish), based on a discrepancy by a factor of 3 in the "Eve's value" for a Kolhörster penetrating-radiation meter, as reported by Kolhörster in 1928 and redetermined by Sherman in 1942. Assuming that the capacitance of the meter was determined originally by comparing the rate of discharge of the meter with that of a standard instrument without allowance for difference in the secondary radiation in the two, the discrepancy can be completely explained if the secondary radiation in the meter under test was much greater than that in the standard and afterward decreased with time in much the same way as the "volume-contamination" does in the Gish-Hess chambers. The validity of this explanation is supported by the fact that the inner surfaces of the meter were electroplated with zinc and that the photoelectric effect of a fresh surface of zinc is much greater than that of a surface aged in air.

Adaptation of electronic circuits to atmospheric-electric instruments. An important instrumental program begun during the year was the further adaptation of electronic circuits to atmospheric-electric instruments in place of electrometers. The advantages of electronic equipment lie in greater flexibility and power of resolution, ruggedness, and convenience in recording. A satisfactory amplifier of high gain, stability, and ruggedness was completed (Sherman) and used successfully in air-conductivity measurements over a wide range of conductivity-values and difficult operating conditions. Experimental work on amplifiers for the determination of other atmospheric-electric quantities such as field-strength was also begun and shows promise, particularly in the investigation of the intense and rapidly varying fields associated with thunderstorms.

Phenomena of thunderstorms. Toward the end of the report-year various conferences relating to ways and means of investigating phenomena of thunderstorms were held with representatives of the United States Weather Bureau by Gish, Wait, Torreson, Rooney, and Sherman. These point toward an extensive future program in which staff members of the Department should find opportunity for extending contributions in the field of atmospheric electricity.

As a result, tentative plans were made (Gish) for the investigation of electrostatic phenomena at the Mexican volcano Parícutin. In cooperation with the United States Paricutin Committee and the United States Weather Bureau, Gish made a field-trip to the site in June 1945 to undertake a preliminary survey, including simple

measurements of electric field-strength, with a view to establishing a program for more comprehensive measurements later in the year. The work at Paricutin may be expected to be valuable in developing instruments and technique for investigation of thunderstorms.

Rate of ionization inside a room. The apparent response of the ionization of the air to the presence of people has previously been reported (see Year Book No. 38). Additional information (Wait) was obtained during the year. The ionization by two chambers having different wall-thicknesses was compared; one chamber with relatively thick walls excluded the ionization due to alpha particles, while the other had no covering and consequently included the alpha-ray ionization. Only the alpha-ray ionization is affected when people first come into the room. It is only after a lag of several hours that the beta- and gamma-ray ionizations show response. The results are consistent with the idea that the presence of people acts, in some manner not yet understood, to reduce the amount of radon and thoron present in the air. The effect is too large to be accounted for on the basis of the retention of radon and thoron in the lungs of the people occupying the room.

Comparison of the rate of ionization due to gamma rays with that due to alpha rays. The use of the two chambers also provided a comparison (Wait) of the rate of ionization by gamma and alpha rays inside a closed room. For equilibrium-conditions the alpha-ray ionization was approximately double that due to gamma rays for the particular conditions of the experiment- This ratio is about 50 per cent greater than that estimated by Eve for out-of-doors conditions.

*Annual **variation** in the rate of ionization of air in a **room.** A* large annual variation in the rate of ionization in one of the rooms of the Department's laboratory is apparent from the records of this element during the year (Wait). A maximum value occurs in summer and a minimum in winter. The average value during the summer is about double the average value during the winter. This variation is probably due to the combination of two factors. One factor is the increased rate of exhalation of soil-gases during the summer over that during the winter season. The other factor is the increased number of condensation-nuclei in the air during the winter months over that during the summer months. It has been found from test that the ionization responds to the presence of smoke and other pollution-products in the air. The rate of ionization decreases as the amount of pollution in the air increases.

Relation between small-ion and large-ion content of the air and the rate of ionization. From simultaneous measurements (Wait) on the small-ion and large-ion content of the air and the rate of ionization of the air inside a room, a relation among the various elements has been obtained. The small-ion content of the air is found to vary directly as the ionization, that is, a plot of ion-content and ionization gives a straight-line relation. lf the plot is extrapolated back to zero ion-content, the line passes also through the zero-value of ionization, thus indicating that the residual ionization of the chamber is small. A plot of the reciprocal of the small-ion content and the large-ion content is likewise a straight line. When extrapolated back to zero-value of the reciprocal of small-ion content, the large-ion content is not zero, but is equal to 1250 ions per cc. The ratio of Ionization to the product of small- and large-ion contents is not constant, but is highest when the ionization is highest and lowest when the ionization is lowest. This ratio, theoretically,, is a

measure of the average rate at which the small ion combines with a large ion.

Alpha-ray stopping power of cellophane. The stopping power of ordinary commercial cellophane for alpha particles was found (Wait) to be about 70 per cent as great as that of aluminum, assuming equal thickness. According to calculation the stopping power is only about one-seventh as great. There appears, therefore, considerable disparity between the calculated and the observed stopping power of cellophane.

Errors in measuring the ion-content and the conductivity of the air. From an analysis of the data on "mobility of the small ions" in the regular observational program aboard the *Carnegie,* information was obtained concerning the errors of observation in connection with the measurement of the ion-content and the conductivity of the air during the various cruises. It appears that, on the average, there was a systematic error, both elements being measured too low. The probable error of a single observation was around 12 to 13 per cent on all cruises, and that of the mean generally amounted to 1 per cent or less.

GEOELECTRICITY

Reduction of the earth-current records from Watheroo and Huancayo was kept current (Rooney) and a final summary of the records from Tucson, covering a complete sunspot-cycle, was published (Terr. Mag., vol. 49, pp. 147-157, 1944).

Seasonal changes in diurnal variation at Tucson. Rooney*s study of the seasonal changes in diurnal variation at Tucson was completed and prepared for publication. The seasonal changes both in earth-currents and in the magnetic field at Tucson are of unusual interest because of the location of the Observatory in the transition-belt, where the type as well as the magnitude of the variations changes markedly during the year. For the most part, the changes observed are consistent with the effects attributable to the recognized movements of the current-systems in the ionosphere northward and southward with the Sun. Two anomalous features, not so simply explained, are found in the earth-current records in addition to the regular seasonal change. The first starts just about at the winter solstice, becomes most pronounced early in January, and disappears by the end of that month. It consists of a marked increase in activity, appearing as a large increase in the amplitude of both components without any change in the phase-relation between them. During the 12 years of recording at Tucson the amplitude of variation in January was nearly twice as great as the average amplitude in December and February, and only 3 times out of 12 was it less than 50 per cent greater. Comparing earth-current and magnetic records for the 5-year period 1932-1936, a very closely parallel anomaly is found in the latter. In January the total magnetic field, F, also increases to a value well above its mean winter level, with the variations of the northward *(X),* eastward (Y), and vertical (Z) components of the magnetic field, like the two earth-current components, all showing the same proportional increase and no change in the phase-relations between them. Moreover, the parallelism is specific and not merely statistical. During the winters of 1933-1934 and 1935-1936 the winter anomaly was unusually pronounced in the flow of earth-currents and equally strongly marked in the magnetic variations. The intervening winter, 1934-1935, was one of two in which the anomalous increase in activity was small in earth-current Sow, and the magnetic data were also conspicuously less affected. This close parallelism effectively rules out structural features of the region

as the cause of the anomaly and points to a space-variation in the conductivity of the ionosphere as the most probable explanation. This space-variation must, moreover, be local rather than zonal in character; otherwise all stations at the same approximate latitude would show similar anomalies. The records from Cheltenham do show a slight trace of a similar increase in activity in January, but those from other stations do not.

The second departure from regularity in the variations at Tucson occurs in March. It is less pronounced than the winter anomaly and also less consistent in its recurrence. At this time of the year the northward component of earth-current flow is little modified and follows its normal trend toward increasing amplitude with increasing altitude of the Sun. The eastward component, on the other hand, becomes very small and erratic. Here again the parallelism with the magnetic variations is striking. As should be expected, the curve of variation in *Y,* like that in the northward earth-current component, is nearly normal, whereas that for *X,* like the eastward earth-current vector, is reduced almost to the point of disappearance. A simple explanation of the anomaly during March can be given by assuming that during March the center of the northern current-circulation in the ionosphere shifts to the north of its general springtime position and follows a desultory course which provides an average passage just over, or slightly south of, Tucson. This explanation ignores the cause of such erratic behavior of the ionospheric currents and the question why they behave that way only in March. There is, however, other evidence that erratic shifts in the latitudes of these current-centers do take place at certain places, such, for instance, as those adduced by Hasegawa from his studies of the day-to-day changes in diurnal variation at stations in and near Japan. An examination of the magnetic records from a number of other stations situated at latitudes not greatly different from that of Tucson showed no traces of this anomaly. Hence it is probably quite local.

THE IONOSPHERE AND ITS RELATIONS TO GEOMAGNETISM

OBSERVATIONS

Existing stations in the coordinated program of the Ionospheric Section for ionospheric research were continued and one new station was installed in the Pacific area. In addition to the established installations of the Department at Huancayo (Peru), Watheroo (Western Australia), and College (Alaska), five other overseas ionospheric observatories are being operated. All these stations continued to provide ionospheric data, using automatic recorders giving essentially complete records for 24 hours each day with the exception of brief interruptions for adjustment or maintenance of equipment.

The automatic ionospheric recorders of DTM design and construction have been in continuous operation at Huancayo Magnetic Observatory since 1937 and at Watheroo Magnetic Observatory since 1938. Performance of these instruments continues to be satisfactory although they have more than completed their normal expectancy of useful service. At the Huancayo Magnetic Observatory the new ionospheric laboratory was constructed, with additional facilities for field-intensity recorders.

Organization of the solar observational program for the purpose of short-term forecasting of ionospheric and magnetic

disturbances continues essentially as in the previous years. Daily reports of solar observations are received from United States Naval Observatory, Mount Wilson Observatory, Harvard College Observatory at Climax (Colorado), and the McMath-Hulbert Observatory. In addition to the above, frequent reports from other groups continue to be helpful in studying the progress of solar activity.

RESEARCH AND DEVELOPMENT

An active program of research and development was maintained at the Kensington Ionospheric Laboratory and at the several field-stations. Activities of the Kensington Laboratory were directed toward development and construction of improved and simplified manually operated ionospheric equipment with a considerably extended frequency-range. Development at the field-stations included improvements to existing equipment with appropriate modifications to assure uninterrupted registration of ionospheric characteristics.

Construction of four additional field-intensity recorders was completed; and these were installed at the Huancayo Magnetic Observatory. Subsequent to the installation, certain specific tests were conducted to determine the effectiveness of fringe-type E-layer reflections and F_2 scatter signals in supporting radio-wave propagation.

COOPERATIVE ACTIVITIES

Fleming and Wells maintained active participation in the Wave Propagation Committee of the Joint Communications Board, and continued to cooperate in a consulting capacity with authorized Army and Navy representatives in matters concerning the ionosphere, geomagnetic activity, and radio-wave propagation. The Committee, composed of Army and Navy members and of representatives of the Interservice Radio Propagation Laboratory (IRPL) and the Carnegie Institution of Washington, controls activities of the IRPL and the CIW as regards radio-wave propagation matters.

During the year two complete teams of Signal Corps personnel were trained for overseas assignment and training of a third team was started. Facilities of the Kensington Ionospheric Laboratory and the Department were also devoted to a program of equipment-development sponsored by the Radio Propagation Section of the United States Army Signal Corps. Sergeant Peter G. Sulzer was principally responsible for the development of a manual ionospheric recorder using a 12-inch cathode-ray tube. In addition, a promising version of an automatic recorder was constructed; satisfactory preliminary tests on this unit indicate that it may provide the basic design for equipment which will ultimately replace existing automatic ionospheric recorders.

Particularly close liaison was maintained with the Australian and Canadian Radio Wave Propagation Committees. A complete manually operated recorder was constructed and loaned to the Canadian group for expansion of its observational program. Canadian and Chinese representatives were trained to operate ionospheric equipment and to interpret results.

REPORTS AND PAPERS

A paper on [a]Sporadic-£ ionization at Watheroo Magnetic Observatory" was presented by Wells at the May meeting of the American Geophysical Union. The paper was based on analyses of ionospheric records for June 1938 to December 1941. Seasonal features of sporadic-E already established for the Northern Hemisphere were confirmed for the Southern Hemi-

sphere with maximum occurrence in local summer months. Annual trends show increasing values during 1938 to 19415 suggestive of an inverse relation to solar activity. Tests for recurrence-tendencies of sporadic-!} with the 27-day solar rotation period did not show any positive correlation.

POSTWAR PLANS

Postwar activities of the Ionospheric Section must be preceded by a period of at least several months to readjust personnel from highly specialized war activities to the broader fields of peacetime research. During this period attention must be given to assimilation of progress made by other groups or agencies in ionospheric and related fields of research.

The general plan for ionospheric research should include both observational activities at the Huancayo and Watheroo magnetic observatories and definite investigational projects. Certain equipment, for example the automatic multifrequency apparatus—designed and constructed in 1935 and 1936—needs to be replaced in view of new and improved techniques developed since 1940. Because of the impending probable loss of our Kensington Ionospheric Station on account of building operations close by and the resulting radio disturbances, a new field-station and site of sufficient area to ensure protection against encroachment of other interests will be necessary.

The present observational program at both Huancayo and Watheroo should be maintained through 1950 so that registration of ionospheric characteristics at each observatory may be complete for a sunspot-cycle. Subsequent to 1950, control-observations of a simplified nature will be sufficient to fulfill civilian and military requirements for ionospheric data from these locations.

Important items of postwar research are (1) extended analyses of accumulated data and (2) new projects directed toward specific problems for which positive solutions may be expected in a reasonable length of time. There are many short-term projects of a fundamental character which merit immediate prosecution and do not involve additional long-term observational programs. Six specific projects of this kind were listed in the Department's report in Year Book No. 43 (p. 34).

Personnel. Wells spent several months in Australia on a war mission. During this assignment he visited the Watheroo, Magnetic Observatory and conferred with Observer-in-Charge Parkinson and members of the staff. Seaton, of the College Observatory, spent several weeks during February 1945 at Washington in special conferences. He has also been active in connection with the proposed Geophysical Institute for the University of Alaska at College. Ledig and Jones, of the Huancayo Magnetic Observatory, spent several months at the Department on a rotation plan, for conferences and instructions regarding instrumental improvements and new techniques for interpretation of ionospheric records.

Activities of temporary staff members were as follows: Hluchan returned from his Arctic assignment in October 1944, and subsequently installed the new field-intensity recorders at the Huancayo Magnetic Observatory. Max returned from his overseas assignment and has accepted other employment. Peavey returned from his Arctic assignment and was subsequently reassigned to a Pacific station. Goldman returned from his overseas station to accept assignment as observer-in-charge of an Arctic station. Ventre made a brief trip to the Department for certain urgent repairs to equipment. Huebsch, after contributing materially to development work at Kensington, was assigned to a new

Pacific station. The services of Watts in the Pacific area have been particularly helpful in the establishing of new stations and in the training of personnel. Easley accepted a second year's assignment to an isolated Arctic station, thereby providing an extremely valuable continuity of personnel which greatly facilitated the performance of this station. Settle was returned from his Arctic station by special plane as a result of inability to adjust himself to conditions of Arctic life. Murray, W. G. Johnson, and Sullivan continued in their overseas assignments and maintained continuity of observations in spite of occasional handicaps due to both instrumental failure and effects of environment. Halpin and Stansbury returned from College after completion of their tour of duty and will establish another new station in the Pacific area. Schmieder assisted in developmental work at the Kensington Laboratory prior to his assignment to the College station. Other members of the College staff, including Wolff, Malich, Kowalak, Rolfe, Wilder, Bliss, and E. F. George, contributed materially to the successful program throughout the year. Gammon was trained in the use of ionospheric equipment and interpretation of records; he is soon to take an overseas assignment. D. E. George was engaged at the Kensington Ionospheric Laboratory. Shapley worked primarily on the short-term forecasting program and assisted in the training of personnel. Miss Hodder aided Shapley in the successful forecasting program. Miss Follin engaged in special investigational work and Miss Puffer in secretarial work of the Section.

MAGNETISM AND ATOMIC PHYSICS

Cowie had charge of the 60-inch cyclotron with the assistance of Ksanda, P. Johnson, Buynitzky, and Mendousse. (Dr. Mendousse, captain in the French Army, continued to be made available through the courtesy of the French Military Mission in Washington.) These five men kept the cyclotron in operation throughout the report-year.

Tuve, Hafstad, Roberts, Green, and Heydenburg of the nuclear-physics group were engaged full time during the report-year on war-research activities or in the Services.

As in the past year, lack of personnel prevented further improvements to, and operation of, the large static generator in the Atomic-Physics Observatory and the small one in the Experiment Building.

CYCLOTRON

The fact that the cyclotron was in almost continuous daily operation without any major breakdowns and with few minor changes was fortunate because it made available long and dependable bombardments for special purposes.

Most of the operation was devoted to researches in which this Department collaborated with the Navy, Army, and Public Health Service. The staff, laboratories, and equipment of the Department, coupled with the scientific and medical personnel of the above groups and their facilities, made possible the organization of well equipped research teams. This is very important because no one man can meet the requirements for a clinician, chemist, physicist, pathologist, and biologist, or do justice to an investigation requiring the knowledge of such specialists. The assignment of specialists in each field by the collaborating agencies permitted rapid and efficient organization of a team in which each individual became responsible for a fraction of the work done. Some of the more interesting results obtained can now be reviewed.

The Division of Zoology of the United States Public Health Service attempted to correlate, by means of radioactive-tracer techniques, the localization of heavy metals in the body and their chemotherapeutic activity. Filariasis, schistosomiasis, and other diseases in which the heavy metals serve as chemotherapeutic agents were studied. Drs. Frederick J. Brady (Acting Chief of the Zoology Laboratory), Alfred H. Lawton, and A. T. Ness took part in this research, some of the results of which are as follows:

(i) The blood and tissue distribution of antimony was determined following single-dose administration of radioactive trivalent compounds of antimony to dogs naturally infected with *Dirofilaria immitis*.

(2) The specific uptake of the antimony by the adult worm and the subsequent elimination of the microfilarids from the blood-stream were established.

(3) An unexpected high concentration in the thyroid of the dogs followed single-dose treatment with the compounds of antimony. This organ, 24 or 36 hours after injection, appears to have a concentration greater than any tissue except the liver. In two cases, 7 days after a single treatment with tartar emetic, the thyroid was the highest of all tissues in the dogs.

(4) After 12 injections of antimony over 14 days, the thyroid was highest in antimony concentration of all the 36 tissues studied. Attempts are being made to see if this thyroid concentration is related to toxicity or to chemotherapeutic effect.

(5) Cotton rats naturally infected with *Litomosoides carinii* and treated with single doses of radioactive arsenic (sodium, arsenite) showed a specific arsenic uptake by the adult filarids similar to the antimony uptake by the *Dirofilaria immitis** The thyroid in these arsenic-treated animals showed no large arsenic concentration.

(6) White rats, when treated with either arsenic or antimony, showed quite anomalous tissue distribution. In fact, these laboratory animals retained in the blood for several days most of the arsenic and antimony injected intravenously as sodium arsenite or as tartar emetic, in contrast with the rapid elimination by chicks, cotton rats, dogs, rabbits, guinea pigs, and hamsters. This is rather significant, since the white rat has been the standard laboratory animal for arsenic chemotherapy studies for many years.

Two papers on the results were published (see bibliography at end of report) and another is in press under the title "The distribution of radioactive arsenic following intraperitoneal injection of sodium arsenite into cotton rats infected with *Litomosoides carinii*," by Alfred H. Lawton, A. T. Ness, Frederick J. Brady, and Dean B. Cowie.

Drs. J. M. Steele, R. E. Smith, and R. E. Eakin, of the Naval Medical Research Institute, initiated a vigorous program of antimony research. The medical and military importance of antimony therapy and the problems which are rising from its use justify the priority given this element. The pharmacological investigations of antimony reported above deal entirely with trivalent and pentavalent compounds. This Navy group, therefore, is investigating antimony in its two other valency states, —3 and 0. Stibine was found to be thcrapcutically effective against malarial parasites in chick erythrocytes, and the antimony distribution following stibine therapy was determined using radioactive antimony. The significant finding of the study was the unusually high antimony content of the red blood cells immediately following stibine therapy. Studies were made on the chemical fate of stibine in the body* *In vitro* experiments with blood and blood fractions in-

dicate that: *(a)* stibine, during the gaseous exchange in the lung, is taken up almost entirely by the red cells; *(b)* stibine is almost instantaneously decomposed, antimony being trapped within the red cells in the colloidal form as metallic antimony; *(c)* this extremely rapid decomposition of stibine in the red blood cells is catalyzed by hemoglobin; and *(d)* this catalytic action of hemoglobin is apparently unique, inasmuch as no other biological agent has been found which will cause this rapid reaction. The reaction is independent of the oxygen tension or the presence of oxidizing agents. The conclusion from these findings is that stibine itself is not the therapeutically active agent, but that it serves as a method of producing a high concentration of metallic antimony within the red cells. It is believed possible to establish beyond all doubt the identity of hemoglobin as the stibine-decomposition catalyst, and determine the quantitative relations of this phenomenon.

A method was developed for making a stable colloidal preparation of metallic antimony which is entirely free from other forms of antimony. A nonradioactive preparation was made for therapeutic testing against the extra-erythrocytic stage of a malaria parasite in the chicks. Radioactive samples are being prepared which will be used for *in vitro* and *in vivo* distribution and metabolism studies.

A series of hamsters infected with *Schistosoma mansoni* and their normal controls were injected with radioactive tartar emetic and the antimony distribution was measured as a function of time in the blood, tissues, and parasites. Significantly it was found that there was a marked accumulation in the liver and thyroid. The adult flukes also showed this specific uptake. The orders of rank of tissue and parasite concentration at 48 hours confirmed in exact detail the findings of the United States Public Health Service on the 36-hour dogs infected with *Dirofilaria immitis.* No outstanding differences were found between the controls and the infected hamsters. The marked and progressive accumulation by the liver and the thyroid perhaps indicates that toxicity of antimony may be related to these findings.

Jane Strane, Ensign, Robert Englert, HA i/c, Louis P. Cecchini, PhM 3/c, and Morton Harfenist, PhM 3/c, assigned from the Naval Medical Research Institute to the Department, have greatly assisted in the progress of the antimony research. C. J. Spear, PhM i/c, R. L. Evans, PhM 2/c, L. H. Gordon, PhM 2/c, and F. N. Gillespie, PhM 2/c, assisted both at the Department and at the Naval Medical Research Institute.

Ksanda assisted in many of the radioactive measurements of biological samples in the above cooperative research projects. Buynitsky and Ksanda provided any improvements in the cyclotron that were found necessary during the year and maintained a supply of ion-source filaments and additional target and ion-source assemblies. P. A. Johnson, with Mendousse and Cecchini, developed new probe-targets which permit large beams with maximum cooling. This work is important for the operation of cyclotrons, since large yields from probe-target bombardments are thereby made possible. Antimony, phosphorus, arsenic, and tellurium are some of the newer targets worked on. Johnson was responsible for the numerous target-holders and the daily target-supply. Buynitsky was in sole charge of the operation of the cyclotron. Since the instrument has been running so efficiently with little or no trouble, almost automatic operation has resulted.

A new ion-source was developed permitting 80 to 90 hours of operation. Large, steady beams are possible with this source,

which has a direct-current filament supply (motor-generator) and a constant-current network for the arc-current. A paper by Cowie and Ksanda describing this ion-source is in press.

Among other organizations which utilized the facilities of the cyclotron were the National Defense Research Committee, the Army, the National Bureau of Standards, and the Department of Agriculture.

The administrative officers of the Naval Medical Research Center and of the Public Health Service, by their encouragement and assistance, have contributed much to the success of these collaborative researches.

MISCELLANEOUS

Besides the reports which are noted above, two Bureau of Medicine of the Navy reports were prepared as follows: "Quantitative analysis of antimony evaluation of Maren's modification of Webster's rhodamine-B method by means of radioantimony," by Lois F. Hallman, Lieutenant (jg); Cyrus J. Spear, PhM i/c; and Dean B. Cowie. "The distribution of radioactive antimony in hamsters infected with *Schistosoma mansoni* with particular reference to accumulation by the thyroid/' by R. E. Smith, Dean B. Cowie, Robert E. Eakin, and C. H. Hill.

Lectures relating to the collaborative use of the cyclotron in the several investigations were presented as follows: On localization of trivalent radioactive antimony following intravenous administration (see bibliography at end of report), at Fortieth Annual Meeting of American Society of Tropical Medicine, St. Louis, Missouri, November 1944. On the cyclotron and artificial radioactivity, by Dean B. Cowie, before Biochemistry Seminar, National Institute of Health, Bethesda, Maryland, March 1945. On use of radioactive substances in biology with special reference to uptake of antimony by *Dirofilaria immitis,* by F. J. Brady, D. B. Cowie, and A. H. Lawton, at Helminthological Society, Washington, D. C, April 1945.

As in 1944, the Annual Conference on Theoretical Physics was not held because of limitations of time and travel.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

The manuscript of a new volume (VIII) of the Researches of the Department of Terrestrial Magnetism was revised to include results of recent cooperative surveys in 1944 and the finally compiled magnetic data obtained aboard the *Carnegie* during 1928-1929 on the last cruise of that vessel It is hoped this volume may be published in 1946.

The compilations of world-wide secular changes in declination (£>), horizontal intensity (//), inclination (/), vertical intensity (2), total intensity (F), north intemity (X), and cast intensity (Y) described in last year's report were completed. The results in intensity in particular have been considerably improved by removing the effects of various geomagnetic fluctuations from the data of observatories and at stations on land and sea used in estimating secular change. The results were plotted on large-scale Mercator and polar projections for the four epochs 1912.5, 1922.5, 1932.5, and 1942.5.

Isoporic charts for declination and horizontal intensity for the four epochs were completed, except for minor modifications near the principal magnetic dip-poles based on theoretical study now under way. These new charts show substantial Im-

provements over previous estimates of secular change made in many regions. There remains, however, some uncertainty regarding the magnitude of secular change in certain polar and oceanic areas—a defect that can be effectively remedied only by future measurements in these areas. The sparsely stationed areas have been bridged, with a degree of success difficult to assess, by using the line-integral and curl-tests of potential theory. In this way the *D*~ and //-isoporics have been drawn so that they are mutually consistent for the first time to a good degree of approximation, mainly by suitable adjustments of contours over oceanic and polar areas. Care was also taken to draw the contours in conformity with singularities present in field—a feature neglected in previous charts, as pointed out recently by Chapman. Good use has also been made of the opportunity to compare the new charts with one another at adjacent ten-year epochs in arriving at the final estimated contour-lines for each epoch in secular change.

Noteworthy features are the existence of large positive foci in *D*- and if-isoporics for the South Polar region, and the great and remarkable changes both in magnitude and in pattern which have appeared in many regions during the relatively short time-interval of only 40 years in the Earth's history.

Isoporic charts for the remaining components are in construction and will be adjusted, in so far as is deemed advisable, to mutual consistency with the JD- and H-isoporic charts.

Isornagnetic charts of *D*, H_f and Z for the Western Pacific area were completed, including magnetic anomalies observed or estimated in cooperation with the United States Geological Survey. The isomagnetic world-chart for declination, in 17 sections, is nearing completion.

Loan was maintained, as in the past, of field-instruments and equipment to seven observatories in surveys in South America, South Australia, Northern Australia, New Zealand, British East Africa, Belgian Congo, South Africa, and the United States, as well as to other organizations. International magnetic standards and corrections thereto were maintained in cooperation with the United States Coast and Geodetic Survey at the Cheltenham Magnetic Observatory.

Tables of departures in geomagnetic field used in estimating secular change were extended to December 31, 1944.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Africa. Dr. A. Walter, Director of the British East African Meteorological Service, continued observations in Tanganyika Territory using CIW magnetometer and inductor 13.

Dr. A. Ogg, of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa, Hermanus Observatory, continued frequent and valuable observations using CIW magnetometer-inductor 17. In June 1945 CIW magnetometer-inductor 17 was transferred to G. Heinrichs for use as standard instrument at the Elisabethville Magnetic Observatory in the Belgian Congo.

Australia. Chief Geophysicist J. M. Rayner and L. A. Richardson continued valuable and extensive surveys in Australia as a cooperative endeavor of the Aerial, Geological, and Geophysical Survey of Northern Australia, Department of Supply and Development, Canberra, and the Department of Terrestrial Magnetism. During June to December 1944, 34 stations were occupied in South Australia, Western Australia, New South Wales, and Northern Territory. In this work assistance was rendered by Observer-in-Charge W. C. Parkinson of the Watheroo Magnetic Observatory, and W. D. Parkinson of the Observatory accompanied Mr. Richardson on a field-trip September 29 to November 17, 1944. The results of the survey, with earlier data

obtained by the Department, were used to construct a fine series of maps of declination covering Australasia.

CIW magnetometer 6 and dip-circle 226 were continued on loan to Astronomer G. F. Dodwell for use in measurements in South Australia.

New Zealand. Director H. F. Baird of the New Zealand Magnetic Survey, New Zealand Department of Scientific and Industrial Research, continued the active and valuable survey-program in New Zealand using CIW magnetometer-inductor 27.

North, Central, and South America. CIW magnetometer 26 was used by the United States Coast and Geodetic Survey in extensive resurveys in the Western Hemisphere, financed by the United States Department of State.

CIW universal magnetometer 19 was loaned to the United States Lake Survey Commission at Detroit, Michigan, for use in determining magnetic declination.

Major S. Graceras, Chief of the Division of Geodesy, Military Geographic Institute, Uruguay, is using CIW magnetometer-inductor 28 in a survey of 60 field-stations in Uruguay.

OBSERVATORY-WORK

The activities of the Section of Observatory-Work continued under the direction of Johnston, assisted by Scott and Miss Balsam. By far the greater part of the time during this report-year was devoted to work relating to the war. Wait continued investigations relating to atmospheric electricity. Torreson (from January 1 to June 30,1945), with the assistance of Mrs. R. M. Crow, was engaged in preparation of manuscript reporting the atmospheric-electric results obtained on Cruise VII of the *Carnegie.* McNish continued to be occupied with war-research work. The various members composing the staffs at the observatories are mentioned under the heading "Operations at observatories."

The magnetic, earth-current, and Ionospheric programs were continued at the Watheroo, Huancayo, and College observatories. The observations were analyzed upon receipt at the Washington office. Weekly summaries of magnetic and ionospheric data, predictions of maximum usable frequencies for various distances, and current forecasts of conditions affecting radio communications were supplied various bureaus and organizations of the government.

Continuous photographic records of the three magnetic elements and the heights of the ionosphere by means of fixed and automatic multifrequency transmissions were obtained at Watheroo, Huancayo, and College. Atmospheric potential-gradient, positive and negative conductivity of the atmosphere, earth-currents, solar observations by means of a Hale spectrohelioscope, and meteorological values were recorded at Watheroo and Huancayo. The cosmic-ray meter and the three-component seismograph continued in operation at Huancayo. During the spring of 1945 signal-intensity equipment was installed at Huancayo.

The reductions of magnetic data and computations in connection with the analysis of magnetic results from Watheroo, Huancayo, and College observatories were carried forward. The values of the magnetic elements for these three observatories for 1944 were completed and made available to numerous interested organizations. The mean annual values of the magnetic elements for all days of 1943 and 1944 for Watheroo and Huancayo are shown in table 1; those for College, Alaska, are given under "Operations at observatories."

The collection of data from a network

of world magnetic observatories for use as a criterion of geomagnetic activity was continued as in previous years. Those »observatories cooperating supply indices of activity (range from o, very quiet, to 9, extremely disturbed) for each three-hour period during the Greenwich day. Reports of activity-indices were received from 29, 28, 27, and 27 magnetic observatories for the years 1941 to 1944, respectively.

tabulated all the K-indices received from world observatories for the three years 1941-1943. The mean indices were computed and tabulated. Final summaries were prepared for each of the years. A short paper entitled "Mean i£-indices from twenty-seven magnetic observatories and preliminary international character-figures for 1943" was prepared for the *Journal of Terrestrial Magnetism and Atmospheric*

TABLE 1

ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGRAMS FOR ALL DAYS, 1943 AND 1944

YEAR	DECLINATION, *D*	INCLINATION, *I*	INTENSITY-COMPONENTS					LOCAL MAGNETIC CONSTANT, *G*
			Horizontal, *H* (7)	Total, *F* (T)	North-south, *X* (7)	East-west, *Y* (7)	Vertical, *Z* (7)	
WATHEROO MAGNETIC OBSERVATORY								
1943	3° 04:4 W	64° 25^4 S	24718	57254	24682	--1325	--51643	35745
1944	3 01.1 W	64 25.2 S	24745	57310	24711	--1303	--51693	35782
HUANCAYO MAGNETIC OBSERVATORY								
1943	6 40.0 E	2 11.5 N	29400	29422	29201	3413	1125	29405
1944	6 34.8 E	2 10.3 N	29367	29388	29174	3365	.1114	29372

Reports of i^-indices from seven American-operated observatories, as also those from College (Alaska), Toolangi (Victoria, Australia), and Godhavn and Ivigtut (Greenland), were compiled and circulated weekly. Fifty-two issues of "Report of geomagnetic activity" (DTMCIW nos. 389-440) were prepared and furnished to organizations and individuals requiring this information.

Summary of magnetic activity for 1944 was completed, including graphing of American magnetic character-figures and mean JC-indices.

Johnston, with Miss Balsam's assistance, *Electricity.* The regular quarterly reports of American character-figures and *K-m*-dices were prepared for publication. The five international quiet and disturbed days were selected for the months of 1944*

The compilation of annual values at geomagnetic observatories of the world for publication in the form of a thesaurus was continued by Fleming and Scott.

Cooperative work in magnetism and atmospheric electricity was continued with various magnetic observatories. International magnetic standards were maintained at the Cheltenham Magnetic Observatory. The Department cooperated with the

Danish government in operating the Godhavn and Ivigtut magnetic observatories in Greenland.

Scott made a complete field-station at the Radio Station of the National Bureau of Standards, near Sterling, Virginia, during November 1944. He also assisted Vestine and Sherman in the adjustment and operation of the CIW visual-recording jFf-variometer installed there in the field-intensity building. CIW universal magnetometer 19 was standardized at the Cheltenham Magnetic Observatory.

In May 1945, Johnston and Scott, with Dalke of the temporary staff, made a preliminary magnetic survey of conditions in and near the "Quiet house" during construction of the Magnetic Laboratories of the Naval Ordnance Laboratory at White Oak, Maryland.

OPERATIONS AT OBSERVATORIES

Watheroo Magnetic Observatory, Watheroo, Western Australia. The Watheroo Magnetic Observatory is situated in latitude 30° 19/1 south and longitude 115^0 52^6 east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation. Only 6 hours of trace was lost during the calendar year 1944—this due to a failure of the recording lamp. The scale-value of the horizontal-intensity variometer was controlled, as in previous years, by monthly determinations using the magnetic method. Scale-value determinations of the vertical-intensity variometer were made daily by the electrical method.

The la Cour rapid-running magnetograph was also operated throughout the year, monthly determinations of scale-values of both horizontal and vertical intensities being made by the electrical method. The monthly scale-values for the year 1944 for both Eschenhagen and la Cour magnetographs are shown in table 2. The determinations of scale-values for declination were: Eschenhagen variometer on October 31, 1944, 1^032 per mm; la Cour variometer on November 15, 1944, 1^044 per mm.

Weekly determinations of the base-line values of the Eschenhagen variometers were made in the absolute observatory using CIW magnetometer 7 and CIW earth-inductor 2. A ^determination of the moment of inertia of magnet 7L and suspension was made during July 1944. During September 1944 complete intercomparisons were made between the observatory standard absolute instruments and CIW magnetometer-inductor 18, which has been extensively used by L. A. Richardson, of the Mineral Resources Survey of Australia. Mr. Richardson also made a magnetic survey of the vicinity of the Observatory, and the results disclosed a remarkably uniform distribution.

TABLE 2

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO MAGNETIC OBSERVATORY, 1944

MONTH	SCALE-VALUES IN 7/MM			
	ESCHENHAGEN		LA COUR	
	H (reduced to base-line)	Z (means of daily-values)	*H*	Z
January. . .	2.43	3.15	4.69	3.27
February. .	2.41	3.06	4.52	3.25
March. . . .	2.43	3.09	4.48	3.52
April.	2.41	2.96	4.64	3.39
May.	2.43	2.94	4.49	3.68
June.	2.42	3.06	4.55	3.70
July.	2.43	3.13	4.75	3.85
August——	2.43	3.16	4.89	3.78
September.	2.43	3.04	4.78	3.76
October....	2.42	3.18*	4.59	3.52
November.	2.43	3.48	4.59	3.41
December..	2.43	3.53	4.60	3.52

* Mean value of several base-line shifts.

The preliminary mean values of the magnetic elements for all days of 1944, as deduced from the Eschenhagen magnetograms, refer-

ring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, indicate annual changes as follows: declination, +3^3; horizontal intensity, +27 gammas; inclination, +0^2 (see table 1 for annual mean values).

As a criterion of geomagnetic activity, three-hour-range i£-indices, on a scale of o to 9, were assigned from the Eschenhagen magnetograms and transmitted daily to Mount Stromlo, weekly to Washington, and monthly to the Radio Research Board, Sydney. Table 3 shows the mean monthly i^-indices for 1944 for the three-hour periods.

Six magnetic storms were recorded during 1944, and table 4 gives the essential details of these disturbances.

TABLE 3

MONTHLY MEAN FOR THREE-HOUR-RANGE ^-INDICES, WATHEROO MAGNETIC OBSERVATORY, 1944

MONTH	GREENWICH MEAN HOURS								MEAN FOR MONTH
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	
January....	1.8	1.8	1.9	2.1	2.9	2.7	2.4	1.9	2.2
February. ..	1.5	1.6	1.9	1.9	2.5	2.2	1.9	1.7	1.9
March.....	2.1	2.0	2.4	2.8	2.8	2.6	2.5	2.2	2.4
April.....	1.6	1.9	2.2	2.4	2.4	* 2.3	2.2	1.6	2.1
May.....	1.4	1.6	1.6	2.0	1.9	1.8	1.9	1.5	1.7
June.....	1.3	1.7	1.9	1.8	1.9	2.1	1.7	1.8	1.8
July.....	1.3	1.6	1.7	1.8	1.6	1.7	1.7	1.4	1.6
August.....	1.7	1.9	1.9	2.1	2.1	2.0	1.9	1.6	1.9
September..	1.9	2.0	2.0	2.1	2.1	1.9	1.9	1.8	2.0
October....	1.8	1.6	1.6	2.0	1.4	2.3	2.1	1.5	1.8
November..	1.4	1.3	1.5	1.7	1.8	1.6	1.4	1.4	1.5
December ..	2.4	2.5	2.4	2.4	2.3	2.7	2.3	2.3	2.4
Year.....	1.7	1.8	1.9	2.1	2.1	2.2	2.0	1.7	1.9

TABLE 4

DETAILS OF MAGNETIC DISTURBANCES RECORDED AT WATHEROO MAGNETIC OBSERVATORY DURING 1944

DATE	RANGES		
	H (T)	*D* (')	*Z* (7)
February 7-8.....	113	20	147
March 26-27.....	154	20	114
April 2.....	320	27	>184
May 1.....	115	15	92
September 30.....	77	11	88
December 15-18*....	263	32	>197

* Aurora observed.

The continuous registration of earth-potentials using a system of electrodes, which has been described in previous reports, was carried on throughout the year. Loss of trace from instrumental causes was small although magnetic storms and damage to aerial lines necessitated the rejection of some days in the tabulations. Scalings and reductions are current and the diurnal-variation curves of the four lines give consistent results. Many poles supporting the lines were replaced by substantial white-gum poles and the wires were tightened. The batteries used for the balancing current in the recorder were installed in the lobby of the Atmospheric-Electric Observatory in March 1944 and are charged from the direct-current instrument line. The

conducting lines were regularly patrolled and defects promptly remedied.

Air-potentials were continuously recorded throughout the year and the results tabulated and reduced. Standardization observations, for the reduction of the values from the recorder to volts per meter, were made on January 24, August 7, and December 11, 1944. Some trouble during May 1944 in the insulation of the collector was remedied. Weekly calibrations of the recording electrometer were made. Table 5 gives the monthly mean air-potentials for 1944 in volts per meter, using a reduction-factor of 1.10.

Positive and negative air-conductivities were continuously recorded throughout the year and weekly calibrations made. Adjustment of the apparatus was made as required, and scalings and reductions are current. Table 5 gives the monthly mean values of positive and negative conductivities, their sums, and ratios.

The automatic multifrequency ionospheric recording apparatus was in continuous operation, the only breaks in registration being occasioned by maintenance, calibration-checks, minor repairs, and adjustments to the apparatus. Various replacements of wearing parts were made as required. An alarm circuit, connected to the interphone system, was installed in September 1944 and gives warning of any instrumental failure which causes a shutdown of the equipment. Minor repairs to the antenna systems were made whenever necessary, and all halyards were replaced by new weatherproofed rope in October 1944* Daily reports of hourly ionospheric conditions were transmitted to Mount Stromlo through the Department of Air, and copies of monthly mean hourly values were sent to the Department of Air, the Radio Research Board at Sydney, the Department of Scientific and Industrial Development of New Zealand, His Majesty's Australian Navy, and Washington, Photographic copies of ionospheric tabulations were also supplied to various organizations. Table 6 gives the mean hourly values of

TABLE 5

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS, WATHEROO MAGNETIC OBSERVATORY, 1944

MONTH	POTENTIAL-GRADIENT			AIR-CONDUCTIVITY, UNIT 10^{-4} ESU				
	No. selected days	Reduction-factor	Value* (V/m)	No. selected days	λ_+	λ_-	(X++X-)	(X+/X-)
January	8	1.24	114	10	1.23	1.25	2.48	0.98
February	4	....	120	8	1.32	1.22	2.54	1.08
March	7	....	94	13	1.70	1.58	3.28	1.08
April	21	....	73	24	1.87	1.78	3.65	1.05
May	16	....	77	24	2.12	1.96	4.08	1.08
June	24	....	62	26	2.60	2.38	4.98	1.09
July	15	....	82	24	2.20	1.77	3.97	1.24
August	25	1.12	85	29	2.08	1.64	3.72	1.27
September	25	....	89	20	1.91	1.43	3.34	1.34
October	25	....	92	27	1.79	1.48	3.27	1.21
November	16	....	100	25	1.62	1.35	2.97	1.20
December	18	....	100	26	1.46	1.35	2.81	1.08
Totals and means	204	1.18	91	256	1.82	1.60	3.42	1.14

* Using reduction-factor 1.10 as previously determined, because value observed in January Is poor.

ionospheric data for the calendar year 1944, and table 7 shows the monthly mean values for the same period. It will be noted from tables 6 and 7 that changes were made during the year in the elements tabulated; this was in accordance with the decisions reached at the International Radio Propagation Conference held at Washington in May 1944. Sealings and reductions are maintained strictly current.

The full program o£ observation and automatic recording of the meteorological elements was maintained. Coded reports on weather were prepared and transmitted thrice daily to the RAAF forecasting station in Perth, and monthly summaries of meteorological data were regularly supplied to the Commonwealth Weather Bureau in Melbourne. A daily journal of weather was kept. The reduction of the meteorological data is reasonably current. The year 1944 was very deficient in rainfall, the total being about 4 inches below the average. Table 8 shows the monthly rainfall at the Observatory during 1944.

The continued manpower shortage limited the amount of repair, maintenance, and improvement work on buïldings and site; however, all urgently necessary repairs and maintenance work were done.

W. C. Parkinson continued as Observcr-in-Charge and W. D. Parkinson as part-time

TABLE 6

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA, WATHEROO MAGNETIC OBSERVATORY, 1944

120° east meridian time 00	h'_{F_1} (km)	$h^{max}_{F_2}$ (km)	$h^{min}_{F_2}$ (km)	f (Mc/sec)	$f^{o}_{F_1}$ (Mc/sec)	4 (Mc/sec)	f_{min} (Mc/sec)	MUF* 3500 km (Mc/sec)	MUFf 3000 km (Mc/sec)	fls (Mc/sec)
00	...	327	253	....	....	3.65	....	9.8	11.3	3.1
01	...	318	248	....	....	3.61	....	9.8	11.2	3.2
02	...	311	242	....	....	3.51	....	9.8	11.2	3.2
03	...	305	240	....	....	3.39	....	9.7	10.6	3.2
04	...	301	239	....	....	3.26	....	9.7	10.1	3.0
05	...	294	236	....	....	3.14	....	9.0	10.4	2.8
06	...	280	237	....	....	3.39	....	9.6	12.2	3.0
07	...	270	247	2.03	....	4.41	....	13.2	15.0	3.7
08	...	278	280	2.52	....	5.04	0.70	15.1	16.8	3.6
09	...	295	307	2.80	....	5.43	0.79	16.0	17.6	3.S
10	219	304	318	2.97	4.19	5.63	0.88	17.0	18.6	3.9
11	212	315	319	3.03	4.25	6.07	0.91	17.3	19.0	4.1
12	213	310	310	3.05	4.27	6.38	0.91	18.0	20.3	4.2
13	214	312	308	3.04	4.25	6.53	0.91	18.3	21.1	4.1
14	219	306	300	3.01	4.19	6.57	0.88	18.9	21.0	4.1
15	221	298	287	2.89	4.04	6.46	0.81	19.1	20.6	3.8
16	...	287	273	2.58	....	6.18	0.74	18.7	20.1	3.6
17	...	280	255	2.16	....	5.72	....	17.6	19.0	3.3
18	...	280	230	....	....	5.03	....	14.7	17.2	3.1
19	...	293	229	....	....	4.41	....	12.3	14.7	2.9
20	...	307	234	....	....	4.11	....	11.2	13.2	2.9
21	...	319	246	....	....	3.87	....	10.3	12.3	2.8
22	...	325	250	....	....	3.75	....	9.7	11.9	2.8
23	...	329	255	....	....	3.69	....	9.6	11.6	3.0

* January to June only. f July to December only.

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TABLE 7

PRELIMINARY MEAN MONTHLY VALUES OF IONOSPHERIC DATA, WATHEROO MAGNETIC OBSERVATORY, 1944

Month	^{k}Fi (km)	$^{\cdots max}{}_{h}Fi$ (km)	(km)	(km)	$_{h}max\ F_{2}$ (km)	(km)	(Mc/sec)	(Mc/sec)	(Mc/sec)	(Mc/sec)	MUF 3500 km (Mc/sec)	MUF 3000 km (Mc/sec)	$f_{E}s$ (Mc/sec)
January...	326	215	218	423	312	294	2.84	4.11	4.66	0.71	13.0	....	....
February..	331	217	218	403	309	282	2.76	4.01	4.62	0.69	13.3	....	....
March.....	313	226	218	400	304	266	2.60	4.10	4.99	0.75	14.6	....	....
April.....	300	233	220	381	288	246	2.39	3.93	4.80	0.76	14.5	....	....
May.....	293	236	224	366	280	239	2.52	3.99	4.21	0.71	13.0	....	....
June.....	294	230	226	365	283	240	2.41	3.93	4.12	0.77	12.7	....	....
July.....	297	223	220	362	275	239	2.41	3.89	3.85	0.79	....	12.8	3.0
August....	...	...	213	...	289	253	2.59	4.01	4.31	0.79	....	14.0	2.9
September.	...	...	215	...	297	258	2.49	4.10	4.75	0.87	....	15.2	2.9
October...	...	...	217	...	318	276	2.67	4.27	5.17	0.87	....	15.9	3.2
November.	...	...	218	...	316	275	2.82	4.33	5.71	0.88	....	17.4	3.8
December .	...	...	226	...	340	302	2.95	4.34	5.59	0.90	....	16.3	4.3

TABLE 8

RAINFALL AT WATHEROO MAGNETIC OBSERVATORY DURING 1944

Month	Monthly total (in.)	No. days	Average for 27 years (in.)
January.....	0.01	1	0.36
February..	0.00	0	0.52
March....	0.48	2	1.04
April.....	0.34	4	0.90
May.....	2.49	11	2.20
June.....	1.40	10	3.30
July.....	4.37	15	2.91
August—	1.94	10	2.18
September.	0.58	12	1.25
October...	0.14	3	0.80
November.	0.17	4	0.30
December.	0.36	6	0,41
Totals.....	12.28	78	16.17

Junior Observer. A. Parkes was appointed as Junior Observer In May 1945. The services of one technical assistant and one clerk were made available by the Royal Australian Air Force. Two mechanics and a yardman were employed for the greater part of the report-year.

Grateful acknowledgment is made to the Department of Air for assistance with personnel and for courtesy in undertaking the transmission of records and data between Melbourne and Washington; the Commonwealth Department of Trade and Customs continued assistance In according free entry of supplies and equipment.

All members of the staff were enthusiastic and efficient, *in* spite of great difficulties, in coping with the ever Increasing volume of work, and they have successfully completed another year's accumulation of valuable geophysical data.

Huancayo Magnetic Observatory. The Huancayo Magnetic Observatory is situated in the central valley of the Peruvian Andes about 8£ miles west of the town of Huancayo at an altitude of 3350 meters (11,000 feet) above sea-level, and In latitude 12^{0} 02fj south and longitude 75° 20\4 west of Greenwich.

Automatic recording equipment functioned throughout the year to produce continuous records of the following geophysical phenomena: (1) horizontal Intensity, vertical Intensity, and declination of the Earth's magnetic field; *(2)* atmospheric potential-gradient; (3) positive and negative conduc-

tivity of the air; (4) earth-current voltages between four pairs of geographically oriented earthed electrodes; (5) cosmic-ray radiation; (6) seismic movements in the east-west, north-south, and vertical directions; (7) heights and densities of the ionospheric regions in the Earth's upper atmosphere; and (8) barometric pressure, temperature and humidity of the air, velocity and direction of wind, and hours of sunshine. In addition, field-intensities were recorded during the last two and a half months of the report-year for four selected high-frequency radio stations far distant from the Observatory.

Daily observations were made of the activity in the Sun's atmosphere (with the Hale spectrohelioscope), of nuclei-counts in the air, barometric pressure, humidity of the air, and maximum and minimum temperatures of the air.

Scale-value and base-line observations for the Eschenhagen magnetographs were made regularly as in other years, and monthly scale-values observed for the la Cour rapid-run magnetograph. The preliminary values for the annual changes from 1943.5 to 1944.5 as determined from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, —5^2; horizontal intensity, —33 gammas; vertical intensity, —11 gammas; inclination, —1^2 (see table 1 for mean annual values). Table 9 summarizes the mean monthly scale-values for the magnetographs.

TABLE 9

SCALE-VALUES OF MAGNETOGRAPHS, HUANCAYO MAGNETIC OBSERVATORY, 1944

MONTH	ESCHENHAGEN			LA COUR	
	D (7mm)	*H* (reduced to base-line) (7/mm)	*Z* (means of daily values) (7/mm)	*H* (7/mm)	*Z* (7/mm)
January	0.988	1.98	4.15	6.15	8.20
February	0.984	1.96	4.06*	6.23	8.34
March	0.986	1.97	4.07	6.10	8.48
April	0.984	1.97	4.09	6.17	7.92
May	0.986	1.97	4.13	6.39	7.54
June	0.992	1.96	4.14	6.12	7.77
July	0.985	1.96	4.26*	6.28	7.87
August	0.982	1.95	4.38	6.26	7.46
September	0.984	1.95	4.31*	6.26	7,46
October	0.983	1.96	4.31	5.68	7.92
November	0.982	1.95	4.35	6.06	7.85
December	0.984	1.95	4.34	5.62	8.00

* Mean value over several base-line shifts.

Weekly calibration-observations were made for records of potential-gradient and atmospheric conductivity; the potential-gradient reduction-factor was determined quarterly by comparisons with potentials measured on a near-by standardization plot. The preliminary mean values of the atmospheric-electric elements are shown in table 10.

Rainfall for the year was 32.00 inches, about 3 inches over the 23-year average of 29.21 inches. The maximum temperature for the year was 24?4 C in November 1944, and the maximum monthly mean was 2i?9.i C, also in November 1944. The minimum

TABLE 10

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS, HUANCAYO MAGNETIC OBSERVATORY, 1944

MONTH	No. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction-factor	Value* (V/m)	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+/λ_-)
January	1	....	52.2	3.72	3.53	7.25	1.05
February	1	1.14	46.8	3.58	3.69	7.27	0.97
March	2	....	73.4	3.36	2.84	6.20	1.18
April	6	....	54.1	3.27	3.12	6.39	1.05
May	6	1.22	55.8	3.95	4.08	8.03	0.97
June	8	....	44.9	4.28	4.37	8.65	0.98
July	8	....	45.1	3.62	4.14	7.76	0.87
August	8	1.16	55.8	2.37	2.57	4.94	0.92
September	5	....	42.3	3.87	4.44	8.31	0.87
October	5	....	59.6	4.04	4.20	8.24	0.96
November	4	1.16	53.6	4.44	4.75	9.19	0.93
December	3	....	42.5	4.15	4.96	9.11	0.84
Totals and means	57	1.17	52.2	3.72	3.89	7.61	0.97

* Using reduction-factor 1.15.

TABLE 11

MONTHLY MEAN METEOROLOGICAL ELEMENTS, HUANCAYO MAGNETIC OBSERVATORY, 1944, AND CORRESPONDING 23-YEAR MONTHLY MEANS, 1922-1944

MONTH	TOTAL RAINFALL		MAXIMUM TEMPERATURES		MINIMUM TEMPERATURES	
	1944 (in.)	23 years (in.)	1944 (°C)	23 years C°C)	1944 (°C)	23 years (°C)
January	7.30	4.97	17.74	18.65	5.82	6.96
February	5.44	4.28	16.83	18.23	5.99	6.96
March	5.3$	4.46	17.17	18.17	5.75	6.46
April	1.96	2.07	18.43	18.86	4.38	5.01
May	0.90	1.16	18.81	19.34	2.23	3.02
June	0.06	0.40	19.25	19.01	-1,42	1.76
July	0.01	0.30	19.09	18.93	-0.27	0.67
August	0.02	0.68	20.13	19.57	1.30	2.57
September	1.61	2.08	19.18	19.58	3.12	5.18
October	3.43	2.51	19,83	20.18	5.70	5.80
November	1.45	2.76	21.91	20.61	4.10	5.94
December	4.44	3.54	18.71	19.70	5,47	6.38
Totals and means	32.00	29.21	18.92	19.24	3.51	4.73

for the year was —8?6 C in June 1944, and the lowest monthly mean minimum was —1?42 C in June (an all-time low for monthly mean minima in 23 years). In table 11 are shown the monthly rainfall, monthly mean minimum, and monthly mean maximum temperatures for the calendar year 1944, as compared with the means for 23 years.

Scaling of traces and reduction of data were kept current and no effort was spared to keep all instrumental equipment in repair and proper adjustment for the production of dependable records. The weekly broadcasts of magnetic and seismological data were made throughout the year; a total of 26 scismic disturbances was reported in this manner. All monthly magnetic, ionospheric, and (recently) field-intensity data were completed in the first or second day of the following month and sent by air express to the Department in Washington. Monthly resumés of meteorological data were supplied to the Dirección General de Comunkaciones y Meteorología Aeronáutica in Lima and to the Huancayo military authorities, and in addition a number of special compilations of meteorological and magnetic data were supplied to local and other institutions and persons upon request.

The ionospheric data obtained during 1944 are summarized in tables 12 and 13.

TABLE 12

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA, HUANCAYO MAGNETIC OBSERVATORY, 1944

75° west meridian time (h)	7_{max}* F_1 (km)	(km)	$l,^{max}$* F_2 (km)	$,^{min}$ $^{h}F_1$ (km)	(Mc/sec)	(Mc/sec)	(Mc/sec)	f_{min} (Mc/sec)	4 (Mc/sec)	MUFJ 3000 km (Mc/sec)
00	...	...	293	259	....	....	5.02	....	...	15.45
01	...	...	285	254	....	....	4.56	....	...	14.33
02	...	...	283	253	....	....	3.92	....	...	13.05
03	...	...	281	256	....	....	3.28	....	...	11.06
04	...	...	281	260	....	....	2.77	....	...	9.48
05	...	...	285	267	0.84	....	2.38	0.82	...	8.01
06	...	...	283	249	1.53	....	4.05	1.01	2.8	14.56
07	243	226	290	247	2.41	3.94	6.21	1.21	3.5	20.81
08	233	215	332	302	2.87	4.23	7.18	1.43	4.7	22.35
09	217	208	375	336	3.19	4.37	7.53	1.62	5.5	21.00
10	207	205	400	356	3.3$	4.43	7.28	1.75	5.3	19.63
11	202	201	404	378	3.43	4.46	7.11	1.86	5.3	18.93
12	200	201	404	385	3.47	4.47	7.13	1.88	5.2	18.68
13	201	199	398	373	3.50	4.44	7.29	1.87	5.4	19.01
14	201	199	383	356	3.32	4.37	7.54	1.81	5.0	19.83
15	211	200	374	333	3.03	4.25	7.85	1.67	4.9	20.75
16	235	207	333	285	2.72	4.11	7.97	1.45	4.4	21.38
17	205	...	340	252	2.23	....	7.98	1.22	3.2	21.88
18	...	...	350	257	1.28	....	7.84	1.01	3.6	22.36
19	...	...	356	277	....	....	7.27	0.94	...	20.96
20	...	...	344	276	....	....	6.88	....	...	19.93
21	...	...	323	266	....	....	6.57	....	...	19.71
22	...	...	307	262	....	....	6.20	....	...	19.01
23	...	...	300	263	....	....	5.63	....	...	17.11

* January to June only. f July to December only (median values). *t July* to December only.

The new Ionospheric Laboratory, which was begun in May 1944, was completed in November and the ionospheric equipment removed from its former position to the new building. The new Laboratory houses the radio field-intensity equipment, whose installation was begun in February 1945. New alternating-current converters for these equipments were installed in the power-plant and an underground conduit was laid for power-lines to the building. The necessary antenna poles were erected and antennas installed for the field-intensity equipment.

S. Hluchan, of the temporary staff, was in residence at the Observatory, to assist in the installation and adjustment of the field-intensity recorders, from March 25 to June n, 1945; he successfully completed a heavy schedule of Installations operational tests, and observations. F. P. Ulrich, Chief of the seismological field-survey of the United States Coast and Geodetic Survey, was at the Observatory between April 7 and 10 with two Peruvian observers from Lima. He overhauled, checked, and adjusted the seismological equipment, with the assistance of members of the Observatory's staff. During April 26-28, Observer William Wiles of the Magnetic Section^of the United States Coast and Geodetic Survey, accompanied by Commander O. L- Rivera of the Peruvian Hydrographic Office and Colonel Pedro A. Delgado of the Geographical Institute of the Peruvian Army, made a study of the correlation between diurnal-variation observations made at stations in the north of Peru and records at the Observatory on the days of field-observation.

No changes in the staff took place during the year. Paul G. Ledig continued as Observer-in-Charge, except for absence on official business and vacation in the United States for over three months early in 1945; Mark W. Jones was in charge during the period of his absence. Jone§ left early in June for three months on official business and vacation in the United States. A. A. Gicsccke, Jn, and E. J. Cbernosky continued as resident ob-

TABLE 13

PRELIMINARY MEAN MONTHLY VALUES OF IONOSPHERIC DATA[3]
HUANCAYO MAGNETIC OBSERVATORY, 1944

Month	*Ft* (km)	*7 min* ^{h}Fr (km)	*imax* $^{h}F>$ (km)	^{h}F, (km)	f_E (Mc/sec)	4 (Mc/sec)	(Mc/sec)	^*min* (Mc/sec)	(Mc/sec)	MUF 3000 km (Mc/sec)
January....	220	208	362	311	2.67	4.32	6.15	1.34	t	t
February...	214	204	331	289	2.66	4.28	6.19	1.46	....	....
March.....	222	213	343	282	2.59	4.36	7.28	1.46	....	....
April.....	216	206	329	274	2.45	4.32	6.55	1.29	....	....
May.....	214	206	322	285	2.39	4.16	5.27	1.15	....	....
June.....	210	201	327	293	2.50	4.12	4.87	1.16	....	....
July.....	*	201	*	299	2.53	4.09	4.81	1.22	4.50	14.01
August.....	...	201	...	298	2.32	4.27	5.49	1.81	4.80	15.84
September .	...	204	...	285	2.41	4.39	6.36	1.74	4.45	18.34
October....	...	205	...	282	2.52	4.55	7.32	1.75	5.50	20.79
November..	...	206	...	295	2.42	4.55	7.56	1.86	4.65	21.24
December..	...	208	...	311	2.56	4.63	7.19	1.75	5.40	20.35
Means or medians	216	205	*SS6*	292	2.50	4.34	6.25	1.50	4.88	18.43

* Discontinued June 30, 1944. f Begun July 1, 1944; values *offg*$_B$ are medians.

servers, and T. Astete, V. Murga, and E. Melgar as clerical assistants. The efficient and wholehearted assistance given by all these men made possible the heavy program of scientific work as well as the construction of the new Laboratory and the installation in it of the ionospheric and field-intensity equipment.

Grateful appreciation is hereby expressed for the continuing assistance of the United States Embassy in obtaining free entry for shipments of equipment and supplies, and in providing priorities for monthly air-express shipments of data. It is also a pleasure to acknowledge with thanks the many courtesies extended to the Observatory and its personnel by the Peruvian government and its officials, as well as by many Peruvian individuals who have gone out of their way to show their friendliness.

College Observatory, Alaska. The College Observatory is located at the University of Alaska in the zone of maximum auroral activity, about 5 miles by road west of Fairbanks, in latitude 64° 51/4 north, longitude 147° 49/3 west, at about 381 meters (1250 feet) above sea-level. It is operated by the Department in cooperation with the University of Alaska.

During July 1, 1944 to June 30, 1945, continuous records were maintained as follows; (1) three geomagnetic elements of declination, horizontal intensity, and vertical intensity; (2) rate of change of geomagnetic horizontal intensity; (3) height- and penetration-frequencies of the ionospheric regions; (4) electric field-strength of radio waves from selected high-frequency broadcasting stations in the United States, England, and Japan; (5) direction of arrival and instantaneous field-strength of high-frequency radio signals. During all or part of the year seismographs were operated for the United States Coast and Geodetic Survey and also solar-radiation measuring instruments for the United States Weather Bureau. Preliminary analyses of seismograms were completed at College; these and records of solar radiation were transmitted to the respective bureaus.

Adequate control-observations and standardizations for all instruments were maintained to assure reliability of the resulting data.

The la Cour magnetograph functioned without interruption. Reductions of the records were kept current. At weekly intervals i^-index figures were telegraphed to the Washington office, and the reductions were forwarded monthly. Scale-values have differed little since installation, those for the year 1944 being 5f2/mm for declination, 18.37/mm for horizontal intensity, and 27.oy/mm for vertical intensity. The preliminary mean values for all days of the year 1944, as deduced from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, +29° 46^1; horizontal intensity, 125877; vertical intensity, +55395V-

Ionospheric observations were made continuously and summaries of the results were cabled. Reductions and calibrations were kept current and transmitted monthly. Information on local propagation-conditions was furnished the Cold Weather Test Group at Ladd Field for use in evaluation of performance of emergency transmitters. Certain changes in interpretation of ionospheric records and in method of statistical reduction were made as a result of the International Radio Propagation Conference.

The ionospheric investigations during the year emphasized the desirability of continuing this work over at least one sunspot-cycle. Further attacks were made upon the relation between magnetic, auroral, and signal-intensity changes and ionospheric phenomena. It was demonstrated that fade-outs and sporadic E-layer phenomena occurred with greater intensity during periods of large magnetic disturbance, but that neither fade-outs nor sporadic 2s-layer ionization led the other in phase with onset of disturbance.

Seasonal and semiannual changes in height of maximum electron-density were found to occur systematically especially in *F%~*

and jPi-layers, in agreement with corresponding changes at Huancayo and Watheroo.

Observations of direction of arrival of high-frequency radio signals were made by means of a Navy model spaced-loop direction-finder initially at hourly intervals and later at half-hourly intervals. Observations were made and recorded manually and transmitted at weekly intervals to Washington for analysis. Several aircraft were located and assisted to safe landings before the installation at Ladd Field in December of the Air Corps direction-finder unit. Preliminary analysis of some of the observations was undertaken at the Observatory as time permitted. The direction-finder conference in Washington, in February 1945, was attended by Seaton, and results of the work were discussed.

Direction-finder research clearly showed that a simple statistical approach to the problem of error-prediction is inadequate. By means of contours proportional to equal ion-densities from world-wide ionospheric data, success of 70 per cent was achieved in prediction of mean direction of wave-deviation. These predictions were made on the basis of calculated horizontal refraction from gradient-vectors developed from ionization-contours. Approaches to solution of the problem from the standpoint of ionospheric tilt are being undertaken.

Operation of the horizontal-intensity fluxmeter was essentially continuous until May 1945, when the buried coil-system again failed, apparently because of leakage of water into the coils resulting in low-resistance grounding of the conductors together with generation of local potentials by chemical action. The instrument, therefore, is out of service until repairs can be completed. Reports giving summaries of instrumental constants and reduction of the four largest variations for each month were transmitted at the end of each month.

The four signal-intensity recorders functioned without interruption. At the close of the year Station GSD, in England, was still being recorded, completing a four-year series of measurements. During the year Station WWV, Washington, D. C, was substituted for German and American stations and gave satisfactory results except for occasional interference. San Francisco, KGEX/KGEI, has been recorded for a year, thus furnishing a moderately long series of continuous measurements on this location. The remaining recorder has been used principally for east coast United States stations, but the results are not satisfactory because of adverse beam-directions at the transmitters. Measurements of field-strength of emergency transmitters were carried out for the Cold Weather Test Group at Ladd Field. Reductions to tabular quantities were kept current at the Observatory and forwarded at monthly intervals to the Department.

The recording with the automatic auroral camera was discontinued pending repairs at Washington during the season of 1944—1945. Analysis of the second half of the observational series obtained from the 1943-1944 season was completed.

The second part of the auroral studies for the season of 1943-1944 was completed, and in general substantiated the results of the first part. There is clearly a lack of detailed correspondence between ionospheric phenomena and visible zenith-aurora, although the gross correlation continued to be present. Beyond doubt, more refined methods of investigation are indicated for future study of the problem.

During the year the University of Alaska has continued its splendid cooperation with the Department, making available three laboratories and two offices in its main building as well as areas of the campus for additional installations. The University furnishes in addition heat, light, water, and general facilities, all without charge. Living quarters and garage space are made available at nominal charges to personnel. The active interest and support of President Bunnel! and the Board of Regents has been of great benefit to successful prosecution of our work.

Some time was spent in forwarding the University's plan for establishment of a Geophysical Institute at the University to provide facilities for postwar research in the Arctic. If the plans for the Geophysical Institute

develop, provision will be made for inclusion of much of the present research-program being undertaken by the Department.

COOPERATION WITH OTHER OBSERVATORIES

Cheltenham Magnetic Observatory, United States. The cooperative program with the Cheltenham Observatory of the United States Coast and Geodetic Survey was continued, using CIW instruments for absolute standards in horizontal intensity and inclination. Automatic daily records of cosmic-ray intensity were continued with the CIW precision meter, through the courtesy of Obscrver-in-Charge J. Hershberger.

Tucson Magnetic Observatory, United States. Through cooperation with the United States Coast and Geodetic Survey, registrations of atmospheric potential-gradient and of positive and negative air-conductivities were obtained, with the assistance of Observer-in-Charge J. H. Nelson. Table 14 summarizes the monthly and annual values of the atmospheric-electric elements.

Apia Observatory, Western Samoa. In the geomagnetic program CIW magnetometer 9 and CIW Schulze earth-inductor *1* were used for absolute observations- i^-indices were supplied.

Hermanns Magnetic Observatory, South Africa. Dr. A. Ogg continued the use of CIW magnetometer-inductor 17 for absolute observations until early June, when the instrument was transferred, after comparisons, to the Elisabethville Magnetic Observatory in the Belgian Congo for use as standard there.

Godhavn Observatory, Greenland. K. Thiesen continued the magnetic and cosmic-ray programs. i£-indices and magnetic reductions were received currently through the courtesy of the Secretary of State, Washington, D. C.

Ivigtut Magnetic Observatory, Greenland, Despite the hardships entailed in the operation of a magnetic observatory under severe climatic conditions, since the Observatory must necessarily be located at some distance

TABLE 14

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS, TUCSON MAGNETIC OBSERVATORY, 1944

MONTH	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU				
	No. selected days	Value* (V/m)	All complete days	λ+	X_	(X++X-)	(X+A-)
January	26	62.2	23	2.17	1.93	4.10	1.12
February	21	58.9	27	2.23	2.14	4.37	1.04
March	23	72.7	30	1.98	1.84	3.82	1.08
April	20	50.0	28	2.45	2.43	4.88	1.01
May	22	59.9	31	2.52	2.45	4.97	1.03
June	20	56.0	30	2.59	2.65	5.24	0.98
July	20	51.0	27	2.47	2.35	4.82	1.05
August	15	48.7	22	2.34	2.16	4.50	1.08
September	16	51.2	23	2.45	2.27	4.72	1.08
October	20	46.6	27	2.56	2.32	4.88	1.10
November	15	60.8	29	2.07	1.77	3.84	1.17
December	22	61.8	31	2.02	1.74	3.76	1.16
Totals and means	240	56.6	328	2.32	2.17	4.49	1,08

* Using reduction-factor 1.24.

from the mine-workings, S. O. Corp, Manager of the Ivigtut Cryolite Mines, obtained complete magnetic records. The company generously donated facilities, electric power, and services of personnel, ^-indices of geomagnetic activity were reported weekly through the cooperation of the United States Army Communication Services.

Christchurch Observatory, New Zealand. Director H. F. Baird continued the operation of the CIW cosmic-ray meter, i^-indices were regularly supplied.

Royal Alfred Observatory, Mauritius. CIW marine-inductor 4 continued on loan for determination of inclination at the Royal Alfred Observatory.

Teoloyucan Observatory, Mexico. Dr. J. Gallo, Director of the National Astronomical Observatory of Mexico, continued operation of the CIW cosmic-ray meter.

PUBLICATIONS ON THE "CARNEGIE" DATA

It was decided to publish, as a final volume in the series "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under Command of Captain J. P. Ault," various discussions of the equipment and operating program of the *Carnegie,* and summaries of results and of difficulties encountered and needs of future work. Thus the complete series will consist of 13 volumes, including Biology I to V, Meteorology I and II, Oceanography IA, IB, and II to IV, and Chemistry I. The printing of Oceanography IB was completed, but delivery was not possible within the report-year because of delays in binding caused by the emergency.

The master-copies for offset printing of Oceanography III and IV were 75 per cent completed on June 30,1945. Oceanography III is devoted to atmospheric-electric data obtained aboard the *Carnegie,* and discussions thereof. ,The several sections, following a preface by Fleming, are: Significance o£ atmospheric-electric observations at sea, by Gish; Instruments, observational procedure, and constants, by Torrcson; Progress-reports, by Parkinson; Abstract of log; Tabulated data, in four parts, on daily observations of atmospheric-electric elements, diurnal variations, hourly-recorded potential-gradient, and hourly-recorded air-conductivities» all compiled by Torreson; and one section of eight papers and studies by Gish, Torreson, and Wait.

The thirteenth and final volume, Oceanography IV, is entitled "Future magnetic, electric, and oceanographic surveys." It contains eight sections: The Captain's progress-reports, by Ault; Narrative of the cruise, by Paul; The magnetic work of the *Carnegie* and need for future ocean magnetic surveys, by Fleming; The *Carnegie:* its personnel, equipment, and work, by Moberg; Gravity-measurements on board the *Carnegie,* by Forbush; Note on fluorine content of ocean-bottom samples, by Shepherd; Suggestions for future magnetic, electric, and oceanographic surveys—a group of nine reports, by Peters, Torreson, Soule, Graham, and Seaton; Bibliography of publications relating to Cruise VII of the *Carnegie,* compiled by Mrs. R. M. Crow.

The thirteen volumes will have presented in detail the observational data obtained, together with full compilations of the results, and with considerable discussion and interpretatibn by the many investigators who have given so much time and enthusiastic support in the preparation of the volumes of the series. Naturally, there are many possibilities for additional discussions and classifications of data, particularly in the great mass of biological information acquired. It is felt, however, that further researches and compilations

and classification of data must be left to specialists in the various lines of endeavor, who now have available all the observational material and results with suitable notes regarding details for additional study.

Torreson, after return (January i, 1945) from leave of absence on war research, was made responsible for additional studies and final editing of completed manuscripts for the last two volumes. As he was a member of the *Carnegie's* scientific staff during 1928-1929, his organization of the material greatly advanced final preparation of the data and discussions for publication. Mrs. R. M. Crow has been responsible for transcribing all copy into a form suitable for offset printing, has prepared the layout of each volume, assembled and prepared bibliographical material, and in many other important ways has contributed to the completion of the memoirs of the *Carnegie's* last cruise. Preparation of drawings and other illustrations was by Hendrix and Green.

INSTRUMENT-SHOP

The work of the Instrument-Shop and the Cyclotron Shop during the report-year totaled • approximately 33,600 hours, of which 6900 hours were devoted to the construction, maintenance, and operation of the cyclotron, and 26,700 hours to instrumental work. Approximately 22,000 hours of the latter involved war contracts, the remaining 4700 hours being used for construction of new equipment and experimental apparatus, repairs and improvements to instruments and apparatus, buildings, and grounds, and miscellaneous items. The time for contractual obligations included 3174 hours' overtime.

A large portion of the work of the shop other than for contracts involved replacement parts for ionospheric and anemographic apparatuses at Watheroo, Huancayo, and College observatories. Minor repairs and modifications were made to several magnetometers and inductors, ion-counter, and ionization-chambers. All laboratory benches and cabinets for the Cyclotron Building were completed except those required in four rooms.

The time of the woodworking shop was devoted to packing and shipping of equipment and supplies for contracts and requisitions, and to construction in, and minor repairs to, all buildings at Washington and Kensington.

MISCELLANEOUS ACTIVITIES

There was active participation in scientific meetings, conferences, and organizations by members of the staff, of whom many served as officers and on special committees. So far as possible, contacts were maintained with geophysical organizations and geophysicists abroad and in the United States. Many activities related to aspects of the war effort, and to conferences with cooperating observatories, organizations, and individuals in the United States, Canada, and Australia.

Besides the papers and reports noted above and in the bibliography following, lectures were delivered as follows : "Structure elements of quasigroups, III," by Duffin and Pate, American Mathematical Society, Wellesley, Massachusetts, August 1944; "General historical development of ionospheric research in United States with particular reference to recent developments,[1]* by Wells, Australian Radio Propagation Committee of Radio Research Board, East Melbourne,, Australia, December 1944; **The geographic distribution of aurora," by Vestine, Philosophical Society,

Washington, D. C, February 1945; "The odograph," by McNish, Philosophical Society, Washington, D. C, February 1945.

Library. Although the war in Europe came to a close in the latter part of the report-year, there resulted no appreciable change in the international situation with regard to foreign scientific books and journals. Although reports have been received indicating a reawakening of scientific activity and publication in France and Belgium, postal restrictions have not been sufficiently lifted to permit procurement of publications from those countries. The principal scientific journals of Great Britain and the Union of Socialist Soviet Republics continue to be received. In the case of domestic periodicals, there is still a dearth of original contributions on terrestrial magnetism and electricity, attributable in large measure to the number of investigators engaged in activities bearing on the war and, to some extent, to the fact that certain researches, already completed, may not yet be made public.

The number of accessions during the year was 415 and the total number of books and pamphlets accessioned *on* June 30, 1945 was 27,955. The practice adopted in the past of cataloguing all articles in current publications of interest in connection with the investigational work of the Department was continued, thus assuring ready reference to material in the Library not otherwise easily located.

Librarian Harradon continued as co-editor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity,* giving attention particularly to foreign contributions, preparation of notes, reviews of books and reports, and the compilation of the annotated bibliographies of recent publications on cosmic and terrestrial magnetism and electricity published regularly in that journal. He also continued as Secretary of the Section of Meteorology of the American Geophysical Union.

In continuance of the project of making available in modern English outstanding contributions to the early history of geomagnetism, referred to in previous reports, two additional contributions, provided with suitable introductions, were prepared and published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity.* These are "Extracts on magnetic observations from log-books of João de Castro 1538-1539 and 1541," and "The haven-finding art," by Simon Stevinus.

The list of publications by members of the Department on December 31, 1944 showed a total of 2302. Because of the continued priorities given work connected with the war and the restrictions on mail to foreign countries, only a partial distribution of accumulated reprints could be effected. Complete distribution must be deferred until some future time.

The facilities of the Library were made available to investigators from universities and various bureaus of the government, and particularly to specialists concerned with research-problems related to the war. Interlibrary loans were continued. Information on a wide range of subjects, some of which only remotely related to the work of the Department, was supplied in response to inquiries from numerous sources. Cordial relations were maintained with other libraries and in particular the Library of Congress.

Dove continued as Secretary to the Director and remained in charge of the general correspondence files and the storage and distribution of reprints. He typed many reports and manuscripts and gave much assistance in proofreading.

Office administration. The work of the staff assigned to the Administrative Assistant again was concerned almost entirely

with the war contracts of the Department, and related to correspondence, liaison with various departments of the government concerned, orders, accounts, and personnel.

A conference was held with Dr. Annand, Chief of the Bureau of Entomology and Plant Quarantine, and his assistants Drs. Dove and Rohwer, regarding tests to be made with DDT and mosquito repellants at our station in northern Canada, and by the Hudson's Bay Company at its posts in Canada.

Moats, Miss Gottshall, and Miss Dermody of the regular staff, and the many temporary employees assigned to the Administrative Assistant, gave faithful and efficient assistance, without which it would not have been possible to accomplish the large amount of work done during the past year.

The many details of wartime shipments, inventories, statements of time and costs of work, preparation of reports and manuscripts, and secretarial work for the Director were completed by Capello and Dove. Charts, diagrams, and illustrations for many special reports and publications were prepared by Hendrix, who with J. W. Green also did much necessary photographic work. Filing and arranging of field-records were done by Miss Balsam, who with Capello maintained the catalogues of photographs and films, and index-albums of prints.

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SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1944 to June 1945.* (For previous reports[1] see Year Books Nos. 32 t° 43-)

The end of World War II will make possible resumption of the active discussion and interpretation of accumulated data by the several groups of investigators who have cooperated with the Carnegie Institution of Washington in the Committee's program. The absorption of so many cosmic-ray students in war problems again seriously curtailed progress in discussions under way, as indicated in earlier reports.

The programs of the groups at the Bartol Foundation, the California Institute of Technology, the Massachusetts Institute of Technology, and the University of California may be resumed during the coming year. Brief reports for the year ended June 30, 1945 have been received from the men in charge of groups at Fordham University, New York University, the University of Chicago, and the Department of Terrestrial Magnetism. These reports, as appended, show good progress. Dr. Korfif, of New York University, reports on research on counters, on measurements of neutrons produced by cosmic radiation, and on construction of a narrow-angle wide-aperture cosmic-ray telescope. Dr. Hess, of Fordham University, details measurements and interpretations of studies of atmospheric ionization. Mr. Forbush and Miss Lange, of the Department of Terrestrial Magnetism, report on routine handling of records. Professor Schein, of the group at the University of Chicago, reports on research on intermediate particles and on mesotron production in the stratosphere.

In spite of difficulties occasioned by the emergency of the war, it has been possible to continue with only minor interruption the cosmic-ray recordings at Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn. The desideratum of continuous and homogeneous series of data at world-wide and well distributed stations has been realized since 1936 or 1937 for four of the stations and since 1938 for Godhavn. Thus by 1949 or 1950 the records will include at least a complete sunspot-cycle for all five stations. This mass of material should be ample for statistical analyses concerning possible seasonal effects in different localities, solar-day, lunar-day, and sidereal variations, day-to-day changes, world-wide changes, geomagnetic correlations, etc. These analyses, together with data on the higher atmosphere resulting from numerous determinations above different points on the Earth's surface and parallel coordinated researches in the laboratory, will certainly improve understanding and interpretation of cosmic radiation.

A request has been received from Professor Amadore Cobas, head of the Department of Physics of the University of Puerto Rico, for the loan of a meter to record near San Juan. It may be recalled that the region of Puerto Rico was one considered at the beginning of the Committee's program; the station at Teoloyucan, Mexico, in about the same geographic and geomagnetic latitudes, was then selected instead of Puerto Rico* Because of the apparently somewhat anomalous data recorded at Teoloyucan, it is desirable, if possible, to provide equipment for Puerto Rico. The Committee is now considering

[1] For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335~349-

this matter. No other applications for grants or loans of equipment have been received.

Grateful acknowledgment must again be made to the directors and members of organizations which continued contributions of services and laboratories. Those so aiding the program are: the Danish Meteorological Institute; the National Astronomical Observatory of Mexico; the New Zealand Department of Scientific and Industrial Research; and the United States Coast and Geodetic Survey. The forwarding of supplies for maintenance of the station at Godhavn has been aided by the Consul-General of Denmark in New York and the United States Coast Guard.

W. S. ADAMS
}. A. FLEMING, *Chairman*
F. E. WRIGHT

STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS AT DEPARTMENT OF TERRESTRIAL MAGNETISM

S. E. FORBUSH AND IsABELLE LANGE

Instruments. The precision cosmic-ray meters of the Carnegie Institution of Washington were continuously operated at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-i, John Hershbcrger in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, meter C-2, P. G. Ledig in, charge; National Astronomical Observatory of Mexico at Tcoloyucan (D. F., Mexico), meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter O5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observatory o£ the Danish Meteorological Institute, meter C-6, K. Thiesen in charge.

Reduction of data. Owing to pressure of war work it was not possible to keep current the tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure.

War work engaged the full time of Miss Lange and Mr. Forbush and permitted only the routine handling of records and assistance in the maintenance of meter C-i at Cheltenham. Of the Institution's five cosmic-ray meters at the above stations, four have been in operation since the middle of 1936 or before. This continuous series of data, covering nearly a complete sunspot-cycle, should, on analysis, provide a better basis for interpreting the causes for the correlations between changes in cosmic-ray intensity and those in the Earth's external magnetic field.

STUDIES OF ATMOSPHERIC IONIZATION AT FORDHAM UNIVERSITY

VICTOR F. HESS

Measurements with the improved type of Gish-Hess ionization-meter, constructed by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, were made in the summer and fall of 1944 and *in* the spring of 1945. They were made on a wooden pier 80 meters offshore in New York, at Spray Beach (New Jersey), and at different localities in the suburbs of New York. These measurements are being continued and a complete report will be prepared later.

A special study of the *tfitct* of evacuating and refilling of the ionization-vessels with dry, filtered nitrogen was made, and it was found that a small initial drop in ionization by 0.5 to 1.0 / after refilling is due to a temporary removal of a gas-

layer from the walls. It takes several days—up to 10—to re-establish the normal ionization in the chambers.

Plotting the ionization *(q)* against ratio of surface to volume of each chamber *(A/W)* gives a straight line, the intercept of which with the ordinate of ionization allows one to deduce the actual ionization without the wall-effect.

A similar procedure was adopted for the determination of Eve's constant *(K* = number of ion-pairs produced by i gram of radium per cc and sec at unit-distance) with all three chambers. The smallest chamber shows the largest value of *K*. The results as graphed show that *K* has a linear relation to *(A/W)*, and extrapolation for *(A/W)* = o gives the value of *K* for the free atmosphere as 4.6 X 10^9 ion-pairs per gram radium, per cc and *sec* in nitrogen at normal temperature and pressure—in fairly good agreement with other methods. This new method of determining *K* was reported at the annual meeting of the American Geophysical Union on May 31, 1945, by V. F. Hess and Eva Balling.

The new ionization-meter is also very useful in determining the radium content of the human body by its gamma-ray effect. In the radium industry technicians and workers sometimes acquire a certain permanent contamination with radium amounting to several micrograms of radium. The Gish-Hess meter, when calibrated with a i-microgram radium standard preparation at different distances within a "water-phantom" of the human body, allows detection of 0.2 microgram of radium. This instrument therefore will be helpful in detecting incipient radium poisoning in workers and in studying the changes with time in the radium burden of individuals.

COSMIC-RAY RESEARCH AT NEW YORK UNIVERSITY

S. A. KORFF

During the year July 1, 1944 to June 30, 1945, it was found possible to carry on some cosmic-ray research at New York University, in spite of the heavy demands which the war effort placed on the time of all persons concerned. The investigations described below were supported in part by funds administered by the Carnegie Institution of Washington.

Research on counters. The study of the properties of Geiger counters, described in previous reports, was continued. Some experiments were undertaken to determine whether any design could be devised which would reduce the operating potential and at the same time provide an arrangement capable of obtaining coincidence-counts. A new type of counter employing a grid surrounding the central wire was developed. The central wire had a glass bead at its center. It was found that the unit operated as two separate counters within the same outer envelope. The two sections of the counter separated by the bead discharged independently, and, in addition, counts of double height were observed when the two sections discharged simultaneously. The effect of adding the grid around the central wire was to reduce the operating potential. Experiments showed that considerable economies in operating voltage were attainable by this arrangement. For example, a counter which required 1500 volts in the absence of a grid would operate successfully on about 800 when equipped with the additional electrode. This development promises to be of considerable value in those counters in which high operating potentials are a distinct drawback. The combination of the bead on the central wire and the grid is a new contribution to counter-technique.

Measurements of neutrons produced by cosmic radiation. The study of the neutron component of the cosmic radiation was continued. A new device was built, consisting of a neutron-counter and adjustable cadmium and boron shields. The shields were automatically slipped over the counter and then removed at predetermined time-intervals by a small electric motor. The apparatus is at present undergoing tests. It is planned to adapt this instrument to high-altitude work.

Construction of a narrow-angle wide-aperture cosmic-ray telescope. In previous reports we have described theoretical calculations which we have made which permit new information about the production-levels and lifetime of the mesotron to be inferred from a study of the vertical cosmic-ray intensity at sea-level and the meteorological variables in the column of air above the instrument. The device for the experimental test of the predictions is now under construction. For this purpose, a narrow-angle, wide-aperture cosmic-ray telescope is being built. This telescope will employ a large number of counters which use a bead at the center of the wire, and thus provide a coincidence-device within a single envelope. The vertical intensity of the cosmic radiation will be measured with this telescope, at the same time that the meteorological data are obtained from near-by radiosondes. This device will next be used to determine the angular distribution and thus provide the data necessary to interpret the results obtained with the large Millikan and Compton meters which integrate the intensity received from all directions.

Personnel. K. Kupferberg and F. Reines carried out the theoretical analysis of the correlations between cosmic radiation and meteorological variables. A. Krumbein is construciing the vertical telescope. Dr. B. Hamermesh is assisting with the work on neutron-counters.

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COSMIC-RAY RESEARCH AT THE UNIVERSITY OF CHICAGO

MARCEL SCHEIN

Intermediate particles. New investigations are now in progress to obtain additional evidence for the existence of mesotrons with a mass smaller than 200 electronic masses. For this purpose a special magnet-cloud-chamber apparatus has been constructed by Marcel Schein and A. J. Hartzler. By means of electronic circuits, the expansion of this chamber is controlled either by the passage of a cosmic-ray particle or by the injection of electrons into a large induction accelerator (betatron). The results of these investigations will be published later.

Mesotron production in the stratosphere. The balloon experiments on the production of mesotrons in paraffin and lead were continued by Marcel Schein, William G. Stroud, Jr., and F. Allen. The apparatus consisted of a number of counter-telescopes registering the simultaneous passage of several cosmic-ray particles through the paraffin or lead. Some of these outfits had an over-all weight of more than 60 pounds. Hence a larger number of balloons (45) had to be used to lift them into the stratosphere. The results of these experiments show that multiple mesotrons, or so-called mesotron showers, are abundantly produced by the impact of primary cosmic-ray particles (protons) upon atomic nuclei.

This process takes place, predominantly, close to the top of the atmosphere. The cross-section for mesotron production in paraffin was measured and found to be 10^{-24} cm^2 (per nucleus). The mesotrons produced are knocked out in the forward direction with an average angular spread of 9^0 to 20^0. The frequency of these processes as a function of atmospheric pressure approximately follows an exponential law, indicating that the mesotron showers in paraffin are produced rather in a single act than by successive impacts as assumed by Hamilton, Heitler, and Peng.

Results of a similar nature were obtained in lead. The number of mesotron showers found below a lead thickness of 18 cm was very abundant at high altitudes. A detailed analysis of these results is now in progress.

A simplified theory of cosmic-ray phenomena at high altitudes was worked out by I. Bloch. Starting with the idea of primary protons, the production and absorption of mesotrons was calculated as a function of altitude and latitude. The theoretical results were compared with the experimental data on the intensity of the hard component and the production of mesotrons in the stratosphere. This comparison strongly indicates that the multiplicity of mesotron production is 9 for primaries of an energy higher than 7×10^0 electron-volts. For lower energies the multiplicity decreases with energy. To account for the large number of electrons present at the very high altitudes, it was assumed that in addition to mesotrons of the usual type there exist intermediate particles of extremely low stability (with a mean life of about 10^{-9} second). These particles should then decay into electrons and neutrinos close to the point of their creation, giving rise to the high-altitude soft component.

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DIVISION OF PLANT BIOLOGY

Central Laboratory located at Stanford University, California

H. A. SPOEHR, *Chairman*

Two major research projects which were prompted primarily by the desire to make a contribution to the war effort have taken the entire attention of the staff during the past year. One of these projects is concerned with the isolation from plant sources of material showing antibiotic properties. This material was first isolated from cultures of the unicellular green alga *Chlorella,* and was designated by the name chlorellin. The relatively small yields of antibiotic material originally obtained from the culture solutions have been greatly increased by the development of methods which made possible the direct extraction of the plant cells. By this means sufficient material was obtained for preliminary examination of the chemical nature of the material showing antibiotic properties. It has been found that these properties are due to or are associated with the presence of unsaturated fatty acids in the material extracted from the *Chlorclla* cells. More important is the fact that the unsaturated fatly acids as first extracted from the fresh cells show very little or no antibiotic activity. This activity develops *on* exposure of the miiturc of unsaturated fatty acids to air and light and involves a complex oxidation reaction.

Pure, authentic preparations of a number of unsaturated fatty acids have been found to show the same behavior; namely* they exhibit no antibiotic activity until iifttr they have been exposed to air and liglii. After such treatment their anuiwrtjc activity is of about the same magnitude us ski! of preparation* obtained from *Chfo* relh* cdU. In extension of thew fimhn^, ** number of common food and fodder plants have been examined and have yielded material which, after exposure to air and light, exhibits antibiotic properties similar to those derived from *Chlorella* cells. It appears, therefore, that this phenomenon, associated with unsaturated fatty acids, is of rather widespread occurrence and that it may have extensive significance, although there remains much to be worked out regarding the exact nature of the substances and chemical reactions which arc involved in the production of this antibiotic.

The other research project prompted by the war has as its aim the development of improved range grasses for the West by employing newly discovered principles. For this purpose the attempt has been made to produce fertile, nonsegregating hybrids that would he unusually adaptable by employing as parents species from radically unlike environments. The bluegntsscs, of the genus *POJ,* have met the requirements because many of the species reproduce principally by seed developed .isexually, » that most of their offspring arc entirely maternal in their inheritance. The «eo-ssonal sexually produced seedling can be a hybrid, in turn producing a preiv»nderance of offspring flist like itself. Thus in a sfngle generation a new, highly constant form is potentially available.

Hybrids fit promise have i>cen obtained* fur example, btfivceii B?$ hlucgrass from the prairies of extern Washington ,m?i a hart?y race of KentuAy Mtiegn:*^ *itatn* Swedish LapiiCfl In *th*\s tn^:mct the jut* of the ^enus, and were thou ht to be impossible to cross. These hybrüK combine

the heredities of parents adapted to widely different climatic conditions, and also represent the combination of a bunch grass with a rhizome grass, and of a summer-active, winter-dormant species with a summer-dormant, winter-active one. From such materials it is hoped to discover types that will be better suited to environments in which the parents cannot thrive, and that will produce more feed by a better utilization of the soil and the growing season.

Many of the more promising hybrids and their parents are being tested at the Institution's two mountain stations as well as at the gardens of the central laboratory. Some are now being delivered to the Soil Conservation Service for the more extensive final testing of their potentialities.

The strictly practical aspects of the grass-breeding program have been in the nature of a demonstration of the applicability of principles recently discovered. The further production of such hybrids will eventually be the function of other agencies concerned with grazing and land use. The program is also yielding scientific results of importance, as it is complementary to previous studies on the evolution and organization of the higher plants.

The extensive investigations of desert vegetation which have been carried on for many years by Dr. Forrest Shreve with several collaborators have been terminated with Dr. Shreve's retirement. A considerable part of this work has already been prepared for publication, and it is planned to complete this task within the next year. Owing to difficulties of carrying on field work and the fact that Dr. Chaney has been on special appointment in connection with the war, the investigations in paleobotany have been considerably curtailed during the past year. Dr. Erling Dorf has spent a part of the year in a study of the occurrence of plant remains in the sediments of the Parícutin volcano in Mexico.

BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, H. W. MILNER, AND G. J. HARDIN

CHLORELLIN AND SIMILAR ANTIBIOTIC SUBSTANCES

In the report of last year were described the first attempts to isolate material showing antibiotic activity from cultures of the green alga *Chlorella pyrenoidosa.* These efforts were based upon the fact that the first indications of antibiotic effects from this source were obtained from extracts of the culture solutions. In these first experiments the culture solutions, after being freed of the algal cells, were extracted either with organic solvents, or, more practicably, by means of columnar adsorption on a special preparation of magnesium silicate. The material obtained showed antibacterial properties against both Gram-positive and Gram-negative organisms; it was obtained in yields of 0.15 to 0.3 gram per 15 liters culture solution, and for convenience of reference was designated by the name chlorellin.

For the most part the cultures were grown in a greenhouse, and the best yields of chlorellin were obtained during the summer months, when the plants were exposed to long periods of high light intensity and when the temperature of the cultures rarely reached 40° C. An extensive series of experiments was carried out with a view to excelling the yields obtained under these conditions. Various environmental factors were altered, singly and in groups, including temperature, length and intensity of illumination by the use of fluorescent and incandescent

lamps, concentration of carbon dioxide, etc. The objective of obtaining higher yields of chlorellin from the culture solutions was never attained; in fact, under many conditions the yields were exceedingly small, and the conclusion seems warranted that the highest chlorellin production in the nutrient solution occurs under conditions of high radiant-energy input. These conditions have previously been found to favor the production in *Chlorella* cells of the more highly reduced carbon compounds, such as fats and hydrocarbons. It was soon realized that the small yields of antibiotic material which are obtainable from culture solutions would necessitate the use of huge amounts of culture solutions in order to obtain sufficient material for chemical study, and that if such cultures were to be grown under artificial illumination this would entail the expenditure of a very considerable amount of electrical energy.

Because of the small yields of chlorellin obtainable from the cell-free culture solutions and because of the rather cumbersome technique involved in handling large volumes of solutions, efforts were made to obtain material showing antibiotic activity directly from the *Chlorella* cells after their separation from the culture solutions. On the average, a 15-liter unit of *Chlorella* culture produced no grams of fresh cells, 30 grams when dried, in about 30 days; considerably larger yields of cells were obtained with longer periods of growth of the cultures. From the immediate extraction of fresh *Chlorella* cells no material showing antibiotic properties was obtained, or only exceedingly small amounts. The extraction of cells which had been dried *in vacuo* at 60° C. yielded a little material with antibiotic activity, and cells which had been dried in this manner and had then been finely ground gave higher yields of active material. Moreover, when cells which had been dried and ground were exposed to the air for several days, or were heated in air to no° C. before extraction, the yield of active material was considerably increased. These observations led to the experimental demonstration that the antibiotic substance extracted from dried cells arose from oxidative reactions occurring in the dried plant material and that this reaction, or series of reactions, was stimulated by light. In order, therefore, to obtain larger yields of the antibiotic material from the *Chlorella* cells it was necessary to subject the dried cells to a preliminary process of fine grinding and exposure to air. The antibiotic material obtained in this manner was in the form of a thick yellow or brown oil. When this was subjected to saponification, an almost colorless crystalline product was obtained, melting at about 40° C. and of slightly higher antibiotic activity than the original oil.

The process of extraction of the *Chlorella* cells was further simplified by the adoption of a saponification-extraction procedure in which the fresh, or dried, cells are treated directly, at ordinary temperatures, with 80 per cent methanol containing 2 per cent of potassium hydroxide. In this process the cells undergo distintegration, resulting in the thorough extraction of the plant material. The material insoluble in the alkaline methanol is separated by centrifugation; the solution is acidified and thoroughly extracted with petroleum ether. The material soluble in petroleum ether, when freed from this solvent, is a brown, partly crystalline mass. It shows no antibiotic activity. When exposed to oxygen or air it becomes an almost colorless, crystalline mass, the reaction being definitely accelerated by light. This material now shows decided antibiotic activity. The activity is not significantly reduced by heating in an autoclave to 120° C, and only a very small portion thereof is volatile

with steam. The saponification-extraction method has greatly increased the amount of chlorellin available for experimental purposes. Several hundred grams have been prepared by this method, the production being limited chiefly by the amount of *Chlorella* cells available for extraction.

There is little doubt that the antibiotic activity of substances derived from *Chlorella* cells is the result of an oxidation reaction. In the one case this oxidation occurs in the killed and dried plant material; in the other case it occurs after lipoidal material has been removed from the cells and has been freed of the solvent used for its extraction. It is impossible to say to what extent an oxidative reaction of this nature occurs in the living *Chlorella* cells. The indications are, however, that there is very little antibiotic material in the living or freshly killed cells and also that comparatively little of such material accumulates in the nutrient solution in which the cells are cultured. As a consequence, only relatively small amounts of the antibiotic are obtainable from the cell-free culture solutions by means of the columnar adsorption method. If, however, cultures are killed by pasteurization (53—56° C. for 4 hours) and are then exposed to light and air, the amount of antibiotic recoverable by adsorption is greater than that recoverable from similar pasteurized cultures maintained free of air, that is, in an atmosphere of carbon dioxide. As yet, it has not been established with the desired chemical certainty that the antibiotic material derived from the culture solutions is identical with that obtained by extraction of the cells and subsequent oxidation. In all probability we are dealing with mixtures of very similar compounds, the separation of which is difficult, as has been found to be the case with several other antibiotic substances.

From the information gained through the study of the material extracted from the cells it has become evident that the antibiotic material is of lipoidal nature; it is apparently accompanied by a fat-soluble pigment.

The material first obtained by means of the saponification-extraction method is easily soluble in petroleum ether. After exposure to oxygen and light it is less soluble in this solvent and its solubility in methanol and in water is increased. Partition between petroleum ether and 80 per cent methanol makes possible the extraction of much of the active material in methanol, but because of complex mutual solubility relations, it has not been possible to attain a complete separation of the active material from inactive components by this means. Nor have other methods been found to attain this goal.

The material obtained by the saponification-extraction method is in all probability a mixture of unsaturated fatty acids. Combustion analyses" substantiate this opinion and also show that exposure to oxygen and light results in material of higher oxygen content than the original extract. For example, an original, inactive extract, on analysis, showed the following composition: 77.35 per cent carbon, 11.66 per cent hydrogen, and 10.99 P$^{er\ cent}$ oxygen; after exposure to oxygen and light the analysis was as follows: 73.29 per cent carbon, 10.86 per cent hydrogen, and 15.85 per cent oxygen. It should be emphasized that these results represent the analysis of a mixture and that probably only a portion thereof has antibiotic activity.

Further indication that we are dealing with a mixture of fatty acids is obtained from the distillation of the material before exposure to air and light. This material is readily distilled at pressures of 5 to 8 microns and 65° to 220° C. Only a very small fraction fails to distill, and there is no evidence of decomposition. All dis-

tilled fractions approximate the composition of an unsaturated fatty acid on the basis of combustion analysis. The material which has been exposed to air and light, and which shows antibiotic activity, contains a larger proportion of oxygen in the distilled fractions. The amount of material which fails to distill is larger, and this also contains a larger proportion of oxygen than the corresponding residue of the unexposed material. The distillation of the exposed material is accompanied by some decomposition, and there is indication of the formation of easily volatile substances through the splitting of larger molecules.

Additional evidence of the unsaturated nature of the material extracted from *Chlorella* cells is gained from its behavior on catalytic hydrogenation and from its iodine number. The product obtained by saponification-extraction, before it has been exposed to air and light, readily undergoes hydrogenation. Thereby a considerable portion of the product is converted into stearic acid. The hydrogenated material shows no antibiotic properties; nor is any antibiotic substance formed when the hydrogenated material is exposed to air and light. The product obtained by saponification-extraction has an iodine number of 172. After hydrogenation, only an insignificant amount of iodine is absorbed. The neutralization equivalent of the hydrogenated material is 362.

By contrast, the material obtained by saponification-extraction which has subsequently been exposed to air and light, and which has thereby taken on antibiotic properties, absorbs about 30 per cent less hydrogen. This hydrogenated product contains only small amounts of stearic acid and, in contrast with its parent substance, shows little antibiotic activity. The product exposed to air and light has an iodine number of 107. After hydrogenation it has an iodine number of about 10- The neutralization equivalent of the- material exposed to air and light is 384 and, after hydrogenation, 394. A positive correlation was found between antibiotic activity and the Kreis rancidity reaction of these products, though it has not yet been established to what particular compound or group of compounds this reaction may be due. Nor is it certain that this parallelism will be maintained in the more highly purified products showing antibiotic activity.

In view of the fact that the cumulative evidence regarding the chemical nature of chlorellin showed definitely that unsaturated fatty acids were involved, a number of such acids of known constitution were treated in the same manner as were the *Chlorella* extracts and the resulting products were tested for antibiotic properties. For this purpose the following unsaturated fatty acids were examined: linoleic, elaidic, (3-eleostearic, and 3-licanic acids. None of these showed any antibiotic activity before exposure to oxygen and light. After they had been exposed to this treatment, in the solid or oily state, they all gave definite antibiotic reactions when tested in the same manner and in the same concentrations as used for the chlorellin tests. On the other hand, stearic acid, a saturated fatty acid, showed no antibiotic activity either before or after exposure to oxygen and light. In this connection it is not without interest that carotene, an unsaturated hydrocarbon, also develops antibiotic activity on exposure to oxygen and light, although the reaction proceeds more slowly than is the case with unsaturated fatty acids.

It is evident, therefore, that various unsaturated fatty acids, which are common constituents of naturally occurring vegetable fats, behave in a manner very similar to that observed in extracts of *Chlorella* cells. The results obtained thus far indicate that antibiotic material of the nature

of chlorellin can be produced from a variety of unsaturated compounds and that the antibiotic activity is probably not due to a single oxidation product. It was realized, of course, that the oxidation of unsaturated fatty acids results in the formation of peroxides, including hydrogen peroxide, and that the latter has bactericidal properties. Preparations of chlorellin and fatty acids exposed to oxygen and light were treated with thiourea or with thiourea and potassium iodide in order to destroy labile peroxides which might be present. By this treatment the antibacterial activities were not reduced significantly, a fact which indicates that not much of the activity can be due to labile peroxides.

These investigations were largely based upon the observation that cultures of *Chlorella* are autoantibiotic, that is, such cultures produce substances that are inhibitory to their own development. It was in the belief that this autoantibiosis may prove to be heterantagonistic, and because purely autotrophic microorganisms had not been studied for the production of antibiotics, that these investigations were pursued. Since the antibiotic properties of the preparations obtained from *Chlorella* appear to be due to unsaturated fatty acids or at least to be associated with these compounds, it seemed important to determine whether similar preparations could be obtained from the lipid extracts of other plants. Such has, in fact, now been found to be the case. By the use of the same methods of extraction as employed with *Chlorella,* extracts showing very similar properties and having approximately the same antibiotic activities have been obtained from a variety of plants. The same phenomenon was observed, namely, that the first extracts of the plants showed no antibiotic activity, but that this was produced on exposure of the extracts to oxygen and light. The plant tissues examined include chlorophyll-bearing as well as pigment-free tissue. The plants from which such preparations have been made were: the green leaves of alfalfa, ailanthus, spinach, sunflower, flax, also cabbage, turnips, carrots, the fruit of avocado, and baker's yeast.

The antibiotic activity of the various preparations of chlorellin was measured by the Oxford cup test technique, the organism for routine tests being *Staphylococcus aureus* (Food and Drug Administration No. 209). Similar tests using other bacteria showed that chlorellin is active against *E. coli* and several strains of *Shigella dysenteriae.* Streptococci were but little affected. Dr. Sidney Raffel, who kindly supplied us with most of the bacterial strains used for these assays, is also testing the activity of chlorellin against various other pathogenic bacteria both *in vitro* and *in vivo,* but these investigations are not far enough advanced to warrant report at this time. The use of infected animals in assaying antibiotics is a specialized and exacting technique demanding talents somewhat different from those available in our own laboratory; consequently we consider ourselves fortunate in having the advice and wholehearted cooperation of Dr. Raffel and Dr. Winsor Cutting on this phase of the work.

It may prove to be of considerable interest that the antibiotic here described, which was first obtained from cultures of *Chlorella pyrenoidosa,* and which for convenience was designated as chlorellin, has proved to be very similar to pyocyanase, the first antibiotic, recognized and isolated over a half-century ago from *Pseudomonas aeruginosa.* Although pyocyanase has for some time been the subject of extensive investigation, its chemical composition has not been definitely established. There are, however, a number of points of similarity between chlorellin and pyocyan-

ase which may make a comparative study, of the two antibiotics a profitable undertaking. They are both heat-resistant; their solubility in organic solvents is very similar; in both, unsaturated fatty acids are definitely associated with the antagonistic action toward a variety of microorganisms. It is conceivable that the tremendously complex interrelations involved in microbial antagonism could in a measure at least be clarified on the basis of the chemistry of the substances responsible for these antagonistic reactions. Biological antagonism is a natural phenomenon, doubtless occurring throughout the entire biocoenose of which man is a part. The urge on the part of man to obtain therapeutic agents capable of suppressing bacterial pathogens is natural and of the greatest importance. Yet it is also important to know to what extent man is unwittingly protected from bacterial infection because of antibiotic substances which are ingested with his food or which the body manufactures or which are the result of old sanitary customs. It would seem to be quite as important to know something about the natural protective agents, that is, man's own antibiotics, as to discover means of combating bacterial organisms after they have invaded the body. The former would be at least an important part of scientific hygiene.

From this point of view the unsaturated fatty acids, which are common constituents of many plants, are deserving of more careful study. The chemistry of this group of compounds has been well developed, so that a vast body of scientific knowledge is available. It is possible that the antibacterial action of this class of compounds may be of a highly specific character, as appears to be the case with chaulmoogric acid. Although as compared with penicillin, for example, the antibiotic activity arising from the unsaturated fatty acids has thus far been found to be of relatively low potency, the mixture of fatty acids obtained from *Chlorella* cells has not been resolved, and only a modest beginning has been made in the study of individual components. It is possible that the antibiotic properties associated with unsaturated fatty acids may make them useful prophylactic agents in the form of soaps and cleansing agents.

EXPERIMENTAL TAXONOMY

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The range-grass program, initiated in 1943 in cooperation with the Soil Conservation Service of the U. S. Department of Agriculture, has advanced to a point where its practical and scientific potentialities can be evaluated with reasonable clarity. The primary objective has been to produce through hybridization new grasses of value under conditions of the open range, and to explore new approaches to the breeding of forage grasses. This is being accomplished by obtaining nonsegregating hybrids with increased climatic tolerance from crossings between remotely related species from contrasting climates.

Poa, or bluegrass, was chosen because its species are important for forage in almost all parts of the world, and because many of them produce their seed largely asexually. Only a small percentage of the seed is formed as a result of fertilization, so the great bulk of it produces offspring just like the mother plant. Hybrids between such species likewise produce their seed largely asexually, and so are nonsegregating and fertile. The small per-

centage of offspring arising from fertilization includes the hybrids, which for this reason are rare. This disadvantage is counterbalanced by the fact that the hybrids do not segregate once they are obtained. The superior hybrids can therefore be selected in the variable first generation, as each individual of this generation is a potential starting point for a new, distinct, and practically constant race.

Poa is also well adapted for large-scale attempts at combining the genomes of species fitting very different environments, for its forms are found in most of the environmental niches within the temperate and arctic zones. Scientifically, it is attractive for a study on speciation in a group that is evolutionarily so mature that reproduction is largely asexual, and also for an exploration of certain important aspects of ecological genetics.

Of no less importance is the fact that the practical application of scientific principles is being tested through this program. Plant breeding is applied evolution. Fundamental to the intelligent planning of a breeding program is an understanding of the evolutionary relationships within the groups to be bred, but these relationships are largely elucidated through the crossings. The scientific and practical objectives are therefore interwoven.

Spontaneous crossing has undoubtedly taken place in *Poa* through the ages, and some of the artificial hybrids resemble certain of the taxonomically critical species in western North America, suggesting that the latter may have arisen through hybridization. This does not mean, however, that the possibilities have been exhausted, for spontaneous crossing is limited to such species and races as happen to grow and flower together, but the breeder can cross races that would never occur together in the wild.

About 180 hybrid individuals were obtained among 38,000 seedlings grown from 26 crossings made in 1944. These represented 21 strains from 9 species and 3 sections of *Poa*. This number of hybrids is in addition to the 13 obtained among 4500 seedlings from the 1943 crossings. Also, 3 spontaneous intersectional hybrids were discovered.

Most of the hybrids are between species belonging to very different sections of the genus. They differ greatly in vigor, some individuals exceeding either parent. The yield of good seed also varies, but in a surprising number of cases, as many as 15,000 to 50,000 seeds per plant were obtained. In the more promising hybrids the percentage of good seeds varies between 35 and 90, a range of fertility which is similar to that observed in the parental form. Such wide hybrids could not have yielded so much had their seed been produced by fertilization; therefore, the results strongly indicate that they, like their parents, set most of their seed asexually, and that they will be constant.

It is also now obvious that in these crossings between extremely remotely related species, the vigor of the hybrids and the frequency of their occurrence depend upon how well the genomes of the parents fit together. The most vigorous hybrids do not always arise from the most vigorous parents. Also, two plants that yield a low percentage of hybrids in other combinations may produce a high percentage when crossed together. The hybrid frequency varies between 0.06 and 4.95 per cent, with a mean of 0.46 per cent.

BREEDING STOCK

The breeding procedure is relatively simple in a group having the evolutionary maturity of *Poa*, in which the entire genome, rather than the individual gene, has become the evolutionary building

block, and the hybrids do not segregate. It consists in fitting together the available genomes into successful new combinations that combine the desirable characteristics of widely distinct species. For this purpose it is important to have a diversified stock from which to select the genomes.

About 4500 plants representing 160 new strains of 23 species of *Poa* have been started in the gardens of the Carnegie Institution at Stanford University this .year. Some of these potential breeding stocks were obtained through our collections in California; others were received through the courtesy of the Division of Forage Crops and Diseases of the Bureau of Plant Industry, representing strains from widely different parts of the United States and of the world; still other seeds, representing the Rocky Mountain region, were received from Dr. B. F. Harrison, of Brigham Young University, Provo, Utah, and Dr. C. L. Porter, of the University of Wyoming. The evolutionary relationships and characteristic reactions of these races will be studied. Two growing seasons are required for most of the forms to come to full maturity.

The species of *Poa* that offer the greatest promise for breeding belong to two contrasting sections of the genus. One section consists of the bunch-grass Poas of western North America, including the members of at least the sections *Nevadenses* and *Scabrellae* of Hitchcock's Manual. Here are found some of the largest Poas, but they are specialized in their habitat requirements and are very modifiable, hence are unsuitable for introduction in a wide range of climates. They are usually winter-active and summer-dormant under the climatic conditions at Stanford.

The members of the other group are the rhizome-developing species of the *Pratenses.* They are generally winter-dormant and summer-active. This section is worldwide in distribution, with many local species and at least one that is cosmopolitan, *Poa pratensis* L., the Kentucky bluegrass, one of the most tolerant and least modifiable species known. A form of it from a subarctic bog at 68° north latitude has been growing successfully in the heavy dry soil at Stanford, 30° farther south. A strain from the Athabasca region of western Canada grows vigorously at Stanford without irrigation or summer precipitation. The wide range of tolerance and the slight environmental modifiability of *Poa pratensis* and its relatives make them suitable for agriculture, and it is hoped that some of this adaptability can be transmitted to their hybrids with the bunch grasses.

The *Poa* investigations will be limited largely to these two sections, whose species and races offer a striking array of differences in form and in seasonal periodicity related to the environment.

POA HYBRIDS

•The technique employed and the objectives guiding the crossing experiments were described in Year Book No. 43 (pp. 73, 75). Mass pollination in cages is used, and the hybrids are distinguished from the nonhybrid seedlings of maternal type in the young seedling stage. The extreme rarity of the hybrids makes it necessary to grow large numbers of seedlings, which are pricked out into flats and spaced accurately to facilitate methodical examination. The hybrids can be detected in the 8- to 12-leaf stage, when 2 to 3 months old, and most of the numerous nonhybrid plants can then be eliminated.

Several crossings were made this year between species that ordinarily flower at different seasons. Such was the case in the crossing of the California bluegrass, *Poa*

scabrella (Thurb.) Benth., which flowers in February and March, and the Canada bluegrass, *Poa compressa* L., which is activated by day length and flowers at Stanford in June. It was found that *scabrella* seedlings will flower about three months after sowing, and so by regulating the planting time it was possible to use *scabrella* for crossing with *compressa* and other late-flowering species. Likewise, the earliest strains of *pratensis* were held dormant in cold storage at the Bellingham, Washington, station of the Soil Conservation Service. Plants thus delayed could then be used for crossing with P. *nevadensis* Vasey and the latest-flowering strains of P. *ampla* Merr. Flowering in *ampla* is delayed when the plants are kept in the greenhouse, probably because of reduced light intensity. Such plants were used for crossing with *compressa,* which otherwise blooms later than *ampla* at Stanford.

Reciprocal crossings were made systematically for the first two years. No hybrids, however, were obtained on *pratensis* as the maternal parent, and very few on any member of the *Pratenses.* It was at first thought that this finding might be due to the dominance of *pratensis* characters in juvenile stages, making difficult the discovery of the hybrids among the *pratensis* seedlings. Older hybrids, however, are readily recognized as distinct from *pratensis,* yet none have been discovered among 8000 seedlings raised to maturity from seed harvested on *pratensis* after heavy pollination by *ampla* and *scabrella.* Apparently, then, hybrids occur only on the bunch grasses when pollinated by *pratensis,* and not in the reciprocal combination. This is possibly another indication of the remote genetic relationship between the two groups. Because of this finding, and in order to obtain the greatest yield of hybrids, the pollen now is carried only from the rhizome grass to the bunch grass.

The results of the crossings made in 1943 and 1944 show that in hybridizations between such remotely related species it is impossible to predict accurately which combinations will produce the best hybrids. Further exploration of the hybrid possibilities in the genus has therefore been necessary. Crossings have now been made between key climatic races of *Poa ampla* Merr., P. *scabrella* (Thurb.) Benth., P. *nevadensis* Vasey, and an alpine race of P. *secunda* Presl of the bunch grasses, on the one hand, and P. *pratensis* L., P. *Kelloggii* Vasey, P. *arid a* Vasey, and P. *compressa* L. of the rhizome grasses, on the other. These are in addition to more scattered crossings utilizing P. *Canbyi* (Scribn.) Piper, P. *nervosa* (Hook.) Vasey, P. *arachnifera* Torr.? and P. *longifolia* Trin. The 26 combinations attempted this spring raise the total number of different crossings to 59. Some 19 different hybrid combinations have already been obtained, and the new crossings can be expected to double this number.

The hybrids already obtained probably give a fairly reliable picture of the breeding possibilities in these two agronomically important sections of *Poa.* The characteristics of those that are already mature make it almost certain that desirable and constant new range types can be produced from such intersectional crosses.

A list of the hybrids growing in 1945, which are the results of the 1943 [anc]^ *944 crossings, is given in the table on page 75. The percentage of hybrids obtained is indicated for each of the 19 combinations; it is almost uniformly a low figure.

Most intersectional Fi hybrids of *Poa* are so variable that it is difficult to characterize any one combination. Three examples among the more outstanding are discussed below and include (1) *Poa ampla* X *pratensis',* (2) P. *ampla* X *compressa,* and (3) P. *scabrella* X *pratensis.*

POA HYBRIDS, 1944-1945

Crossing	No. of hybrids	Per cent hybrids
AMPLA X PRATENSIS, 84 hybrids:		
ampla, E. Washington, X *pratensis alpigena*, Lapland	7	2.30
ampla, E. Washington, X *pratensis*, Mather	57	4.95
ampla, E. Washington, X *pratensis*, Athabasca region	20	0.10
AMPLA X ARIDA:		
ampla, E. Washington, X *arid a*, Nebraska, and reciprocal	3	0.27
AMPLA X COMPRESSA:		
ampla, E. Washington, X *compressa*, Asia Minor, and reciprocal	5	0.20
CANBYI X PRATENSIS:		
Canbyi, Blue Mts., X *pratensis*, Athabasca region	1	2.04
Canbyi, Blue Mts., X *pratensis*, Great Basin race	0	(2500 seedlings)
NERVOSA HYBRIDIZATIONS:		
nervosa ? x *Canbyi* (2 crossings)	o	(1255 seedlings)
nervosa ? X *scabrella* (3 crossings)	o	(1155 seedlings)
NEVADENSIS X COMPRESSA:		
nevadensis, E. Oregon, X *compressa*, Asia Minor	4	1.18
NEVADENSIS X LONGIFOLIA:		
nevadensis, W. Idaho, X *longifolia*, Armenia	1	0.21
SCABRELLA X AMPLA, possibly 15 hybrids:		
scabrella, S. California, X *ampla*, E. Washington	3?	0.27
scabrella, Cent. California, X *ampla*, E. Washington	*6+6?*	0.98
SCABRELLA X PRATENSIS, 65 hybrids:		
scabrella, S. California, X *pratensis*, Athabasca	11	0.35
scabrella, S. California, X *pratensis alpigena*, Lapland	2	0.23
scabrella, S. California, X *pratensis*, Mather	19	1.34
scabrella, S. California, X *pratensis*, Great Basin	8	0.61
scabrella, Cent. California, X *pratensis*, Athabasca	12	0.17
scabrella, Cent. California, X *pratensis*, Great Basin	2	0.06
scabrella, Mather, X *pratensis alpigena*, Lapland	1	0.23
COASTAL SCABRELLA X HIGH-ALTITUDE SECUNDA, possibly 29 hybrids:		
scabrella 2, Cent. California, X *secunda*, Timberline	5?	2.11
scabrella, N. California, X *secunda*, Timberline, and reciprocal	24?	1.57

1. *Poa ampla* X *pratensis.* This hybrid combines the best of the bunch-grass Poas from the dry Palouse prairie region of eastern Washington and Oregon with the outstanding rhizome-producing species that usually grows in meadows. These species differ considerably in their time of flowering at Stanford, but cross fairly readily, for 84 Fi individuals have been obtained in 3 combinations. In addition, 3 spontaneous hybrids were found in 3 cultures grown from seed received from the Soil Conservation Service,

The *ampla-pratensis* hybrids generally combine the winter activity of *ampla* with the rhizomes, summer leaves, and increased rust resistance of *pratensis.* When mature, they are different from either parent and readily recognized, but like *pratensis* they do not flower before the second year.

The only *ampla-pratensis* combination

sown in 1944 was a cross between a very tall race of *ampla* from the eastern Washington prairie and the *alpigena* form of *pratensis* from a bog 2^0 north of the Arctic Circle in Swedish Lapland. One would expect these hybrids to be best adapted to climates of northern latitudes, like that of temperate Canada or southern Scandinavia. Sister hybrids are so unlike that they appear to belong to distinct species. Each one is potentially the starting point of a new constant and distinct form. Two or three of them are of promise, and are doing well even at the relatively southern latitude of Stanford. One has inherited the long, glaucous leaves, winter activity, and very large inflorescences of *ampla,* together with the soft leaf texture, partial summer activity, short rhizomes, and short culms of *alpigena.* It has also inherited some of the rust resistance of the latter. It is only about 33 per cent fertile, like its *ampla* parent, yet it was able to produce some 50,000 good seeds.

Another promising *ampla-pratensis* plant is a spontaneous hybrid of unknown *pratensis* parentage discovered among seedlings of a desirable race of *ampla* from Condon, northern Oregon. The seed was harvested on Condon *ampla* at the Pullman nursery of the Soil Conservation Service. The lone hybrid stood out distinctly from the *ampla* plants in the row. Although it is winter-active like *ampla,* it flowers about three weeks earlier, and then remains green longer. It is more floriferous, and its leaves, although somewhat shorter, are more numerous and darker green. Also, it is more rust-resistant. In loose soil it develops short rhizomes, but it would be classified normally as a bunch grass, and would pass for an improved form of *ampla.* It was more vigorous and taller than its *ampla* parent and than any *pratensis* strain grown at Stanford. Its chromosome number, *in* — 92, suggests that it has two genomes of *ampla* and one of *pratensis.* This plant, which produced some 18,000 good seeds, is 40 per cent fertile, ranking with some *ampla* forms from the wild.

Still better *ampla-pratensis* hybrids are anticipated. A cross between two highly apomictic strains, one the most vigorous form of *ampla* from eastern Washington, the other a disease-resistant form of *pratensis* from a meadow at our Mather station, has produced 57 hybrids out of approximately 1200 seedlings. These are more uniformly vigorous than any of the other hybrids, but they will not flower before next year.

2. *Poa ampla* X *compressa.* The Canada bluegrass, *Poa compressa,* is a Eurasian rhizomatous species from drier habitats than *pratensis* that has been able to establish itself widely. Hybrids between it and *ampla* combine the genomes of two fairly drought-resistant species. Five hybrid individuals were obtained between the largest form of *ampla* from eastern Washington and a form of *compressa* from the Mediterranean slopes of Asia Minor at 4000 feet altitude. Two of these resemble *compressa,* a third is a dwarf, and a fourth is sterile. These four have between 50 and 60 chromosomes, and are probably composed of one genome from each parent.

The fifth hybrid, however, is an outstanding" form. It has about 86 chromosomes, and probably arose from a diploid *ampla* ovule with *63* chromosomes and a haploid *compressa* pollen with approximately 23 chromosomes. This hybrid is winter-active like *ampla,* and during the summer it is still green after both parents have become semidormant. It has inherited the glaucous leaves of *ampla,* together with the rust resistance and short rhizomes of *compressa.* This plant, which is much more vigorous than *compressa* and compares favorably with forms of *ampla,* may

be o£ use in extending the summer grazing season in some dry sectors of the country. It is as fertile as the best, namely 85 per cent, and has produced about 35,000 good seeds in one season.

These five *ampla-compressa* hybrids, all from the same two parents, illustrate the variability to be found when species of two different taxonomic sections are crossed. In many respects, the Fi of these partially apomictic species resembles the F2 of sexual species, and it is important to have sufficiently large Fi populations to afford material for selection of superior types.

3. *Poa scabrella* X *pratensis.* The parental species, California bluegrass, *P. scabrella,* and Kentucky bluegrass,, *P. pratensis,* are complementary in their characters, and the hybrid combines the best of the two. Thus, although the *scabrella* parent is a rather weak, unimpressive species, the hybrid has unexpected vigor and gives promise of becoming one of the most successful combinations.

Poa scabrella is highly specialized to fit the climates where it is native. It is largely limited to the California Coast Ranges and the slopes surrounding the Great Valley and those of the Sierra Nevada to mid-altitudes. All its forms are distinctly winter-active and completely summer-dormant. After May or June there is no sign of life until new leaves develop in the cool fall even before the first rains come. Forms from the outer Coast Range flower in February and March. At least three ecotypes are apparent. The one from the outer Coast Range is the most vigorous and the only one of promise for breeding. It is the only form that is able to develop a second crop of leaves after flowering i£ the weather stays cool. Under conditions at Stanford the forms from the Transition Zone in the Sierra Nevada flower 4 to 6 weeks later than those from the outer Coast Range, yet they.go dormant earlier. This relatively ephemeral bunch grass is resistant to mildew and fairly resistant to rust; also, it is very rapid in development. Seedlings will flower in 90 days. In addition to these desirable characteristics, it was realized that *scabrella* is well adapted to a southern mild climate and can furnish a genome to counterbalance those of species from northern latitudes or high altitudes.

A total of 65 *scabrella-pratensis* hybrids were obtained this year in 7 crossings, using as parents two Coast Range and one Sierran race of *scabrella,* paired with races of *pratensis* from Lapland, Canada, the Sierra Nevada, and the Great Basin plateau. The hybrids were recognized by several characters 2 to 3 months after sowing.

The *scabrella-pratensis* hybrids have inherited the summer activity and the long leaves of *pratensis,* and, judging from other hybrids between winter-active and winter-dormant species, they may also be expected to be winter-active. Such a hybrid might become dormant during cold winters or dry summers, or remain perpetually active under favorable conditions, thus providing wide adaptability to different circumstances. This hybrid resembles the *scabrella* parent in its quick development, for it flowers the first season, only 2 or 3 weeks later than *scabrella,* whereas *pratensis* ordinarily does not flower until the second year. It is much less rhizomatous than the *ampla-pratensis* hybrids, but produces more tillers than the *scabrella* parent.

Unexpectedly, the most vigorous hybrids occurred in a cross between a *scabrella* form from coastal Ventura County, southern California, and a very" mildew-susceptible form of *pratensis* from the desert plateau near Mono Lake at 6500 feet. The latter plant comes from an arid, alkaline region with a very severe winter and a hot summer, whereas the *scabrella* parent is from the coastal fog belt with a mild

winter and summer climate. A hybrid combining the genomes of such forms should have a considerable range of tolerance for different climates. All 8 of the hybrids obtained were mildew-resistant. The fertility was variable, but the best plant in other characters was 90 per cent fertile, and its three inflorescences produced some 3500 good seeds. From preliminary tests, this hybrid appears to be more productive and fertile than either parent. Its chromosome number is *in* = 70, as compared with 84 and 68 in the parents.

Not all hybrids are so promising as those in the three groups mentioned. Some are definitely weak, as for example *Poa scabrella* X *ampla.* This hybrid between members of the bunch-grass section unites the genomes of a species from the southern coast and one from the dry northern interior. The few hybrids obtained are distinctly weak, but remain green longer than *scabrella.* None have shown a tendency to flower the first year.

Another weak hybrid is *Poa nevadensis* X *longijolia.* The Nevada bluegrass, which is a close relative of *ampla,* is from montane meadows east of the Sierra Nevada and the Cascades. The other parent, *Poa longifolia,* is a coarse bunch grass from the Caucasus region, but it is unrelated to the American bunch grasses. The single hybrid obtained was only a small rosette of leaves when 8 months old, much smaller than either parental type of the same age. Obviously, the genomes of these two species do not fit together.

These divergent results indicate that a number of exploratory crossings are necessary to determine which combinations will produce the most successful hybrids. Then further crossings can be made for the purpose of combining the proper ecotypes of these species to fit the desired environmental niches. This type of breeding is relatively simple as compared with breeding by *gtnt* exchange between genomes, for in the latter case many generations are required before constancy can be attained when many exchangeable genes are involved.

Summarizing the results of the crossings, it is demonstrated that intersectional hybrids between many species of *Poa* can be obtained; that the first hybrid generation is highly variable; and that the combinations of some species are generally vigorous, and those of others are weak. Furthermore, it is possible to combine favorable characteristics of the two parents in many intersectional hybrids, and some hybrids are as fertile as their parents or even more so. High fertility in intersectional hybrids in this case should indicate that the offspring is produced without fertilization and will be constant.

TRANSPLANT EXPERIMENTS

In Year Book No. 43 (p. 77) it was mentioned that the *Poa* hybrids and the parental strains would be tested at the three transplant stations in order to determine their ecological characteristics and their fitness to different climates. Clones of parent plants and of the first hybrids were transplanted during 1944 and 1945, and recent hybrids and their parents will follow as soon as available. Other forms of critical interest will be transplanted as their importance becomes apparent. *Poa prat ensis,* for example, has now been collected at from 3000 to 10,000 feet altitude in the Sierra Nevada, and a closely related form, P. *Kelloggiij* has been obtained from coastal bluffs in Oregon. These, with forms from the desert ranges, constitute a series from very different climates worthy of being tested and classified ecologically at the transplant stations.

In addition, a nonhybrid series of variable offspring from one individual of the

giant *ampla* from Albion, Washington, was transplanted. These differ in their chromosome numbers, belonging to a slightly obscured 7 series, with *in* = 56, 63, 66, 70, 90-93, 98-100, and 126 chromosomes. There are several plants in each of the 90-93 and 98-100 chromosome groups. These numbers approximate 8-, 9-, 10-, 13-, 14-, and 18-ploid. At Stanford, these plants vary considerably in vigor, fertility, and susceptibility to disease, but all are characteristic of *ampla* and even of the Albion race irrespective of their chromosome number. *Poa ampla* normally has *in* = 63 chromosomes, 9 sets of 7, which is an unbalanced number. The parent of this series has 63 chromosomes, and no^ strain of *ampla* from the wild has been discovered with less. Therefore the plant with 56 chromosomes has lost one set of 7 chromosomes. Under the conditions at Stanford this loss appears to have been rather advantageous, for that plant is less susceptible to rust and has a seed fertility of 75 per cent as contrasted with 40 per cent in the parent. The fact that whole sets of chromosomes can be added to or subtracted from *ampla* without much effect on the morphology of the plant indicates that the same basic sets of chromosomes are duplicated a number of times, and that the species probably is highly autoploid.

The members of this autoploid series of *ampla* arose spontaneously, and the indications are that such variations may arise also in the natural populations. Since 63 chromosomes are uniformly found in *ampla* from the Palouse prairie, there is a possibility that a change in the chromosome number may be accompanied by a change in the fitness to the environment, which places the chromosomal aberrant at a disadvantage at its point of origin. The present transplant tests will indicate whether the differences in chromosome number are accompanied by a change in ecological requirements.

When the hybrids at hand and those arising from this year's hybridizations have been established at the transplant stations, there will be available for study in three climatically »very different gardens a unique series of *Poa,* consisting of many species and ecotypes and some 35 to 40 different hybrid combinations of these, as well as series of chromosomal aberrants like that mentioned. Study of this material should produce a new insight into the ecological characteristics of the basic forms, and the behavior of their genomes when combined in hybrids or changed by simple addition or subtraction of sets o£ chromosomes.

CYTOLOGY OF RANGE GRASSES

Miss Marguerite Hartung has continued the study on the chromosome numbers of *Poa* species and hybrids and on many species and strains of *Agropyron* and *Elymus.* A knowledge of the chromosome numbers of the forms is essential to an understanding of the evolutionary past and future of such groups.

Poa. The large number of chromosomes in most species of *Poa* makes their eytological investigation slow. This and the inherent difficulties in fixation and staining also make it difficult to determine positively whether the chromosomes are present in exact multiples of 7 or whether slight deviations exist. Some of the results were reported in Year Book No. 43 (pp. 74-75). The chromosome numbers of more than 115 races from 22 species of *Poa* are now determined. This has filled out gaps in our information, but has not essentially changed the picture presented in last year's report.

It is evident that in the Pacific states each species of the bunch-grass section is chromosomally relatively uniform, and all

are characterized by high numbers in multiples of 7. For example, *Poa scabrella* is usually duodecaploid, with *in* = 82-86 chromosomes; that is, its forms have approximately 12 sets of 7 chromosomes each. Occasional weaker individuals deviate, with 2*n* = 63 chromosomes, but they appear to be unimportant in wild populations. However, one vigorous population from near Clear Lake, northern California, has uniformly *in* = 63. Its technical characters are those of *scabrella*, but it has coarser stems, more congested inflorescences, and a flowering period 2 months later than the other Coast Range strains. Therefore, its origin is probably different from that of the others. Likewise, a 70-chromosome race has been found in *Poa ampla* and in P. *nevadensis*, which normally have *in* = 63 chromosomes. Aberrations like these are to be expected in partially apomictic groups where vigorous deviators and new hybrids can immediately establish themselves as constant populations.

The western American bunch-grass Poas with high chromosome numbers must have had a long evolutionary history, but very few facts that can be expected to lead to an understanding of it have so far been found. The discovery of related primitive forms with low chromosome numbers would furnish keys to the solution of this problem. But if such forms still exist, they must be very rare. The only indication in this direction is the discovery of a hexaploid form of *scabrella* with about 42 chromosomes from the western edge of the Mohave Desert. This single plant is indistinguishable from the normal 84-chromosome form. Its existence merely tends to strengthen the impression that our present-day forms of these grasses have arisen from the earlier by a multiplication of their chromosomes, that is, through autoploidy.

Poa pratensis ranks as the chromosomally most variable species of the genus, and as one of the plants most tolerant to variation in chromosome number. Forms with *in* = 49, 50, 56, 57, 67, 68, 70, 73, 74, 76, and 80 chromosomes have been found among races from the Pacific states, and *in* = 81 has been found in two races of the very closely related P. *Kelloggii* from coastal bluffs of Oregon. A fairly healthy form with *in* = 36, half the normal number, was discovered among the aberrants of the *alpigena* form from Lapland. Some local populations of *pratensis* consist of several forms that differ in chromosome number. Asexual propagation makes it possible for such forms to be perpetuated once they arise. It appears that in the higher brackets of the series, the forms that deviate from the multiples of 7 are just as vigorous as those having chromosome numbers in multiples.

In spite of this extreme variation in chromosome number, *Poa pratensis* is not a critical species taxonomically, for its forms are easily recognizable and very different from all other Poas. There are no clues as to the origin of this remarkable species, from which chromosomes may be added or subtracted within the range of about *in* = 18 to 120 without its losing its identity. Its occurrence at very high altitudes in the mountains of western North America makes it certain that it is indigenous here, although some forms in agricultural areas have been introduced.

Many forms of *Poa* of hybrid origin are no doubt present in the vegetation of western North America. Some of these intermediate forms have been named as species; others have not yet been noticed. The crossing experiments have shown that morphologically very distinct forms with different chromosome numbers may arise within one cross. Species of parallel hybrid origin can therefore exist under differ-

ent names in distinct sections of the country. For example, the characters of *Poa fibrata* Swallen, *in* = 64, in California, and P. *glaucifolia* Scribn. & Williams, *in* = 50, in the intermountain states, are such that both could have arisen independently from spontaneous crossings between *Poa ampla* and P. *pratensis.* Likewise, two native strains from Washington are in culture which are very different from each other, but both of which appear to combine characters of *Poa ampla* and P. *Canbyi,* They have not received formal names, and although one has *in* = 63 and the other approximately *in* == 88 chromosomes, both could well be descendants from independent spontaneous crossings between these two species.

The synthesized *Poa* hybrids therefore will probably furnish some clues to the understanding of the intermediate forms that obscure the distinctions between the taxonomic sections. They point to the species of the future, whose forerunners already are elements of the vegetation, but they will not contribute much to the understanding of the makeup of the basic species from which they sprang.

Agropyron and Elymus. Another important group of forage grasses in western North America are the wheat grasses *{Agropyron)* and the wild rye *(Elymus).* Thirty individuals each of some 115 races of 19 species of these genera have been grown in the garden for two years in order to study and compare them and to determine their chromosome numbers.

These genera present a very different picture from *Poa,* for most of their species have relatively low chromosome numbers in strict multiples of 7, and they reproduce sexually. A few species are diploid, with 7 pairs of chromosomes, but most are tetraploid, with 14 pairs. Higher polyploids are uncommon; in our assemblage only one species each has 21, 28, and 35 pairs of chromosomes.

More than one chromosome number has been found in some species of *Agropyron.* This situation usually indicates that such a species is heterogeneous, and that additional methodical investigation is required to clarify its composition and the origin of its forms. *Agropyron spicatum* (Pursh) Scribn. & Smith has 7 pairs of chromosomes over most of its territory, but there is a pocket of large tetraploids with 14 pairs in eastern Washington and western Idaho. The extremely variable *Agropyron Smithii* Rydb. is predominantly octoploid, with 28 pairs of chromosomes, as noted in races from Washington, Idaho, South Dakota, Kansas, and Texas, but a form from southeastern Oregon, near the periphery of the range of the species, has only 14 pairs.

Within a natural population the species of *Poa* are relatively uniform, but *Agropyron* and *Elymus* are highly variable, although some species vary more than others. In extreme cases individual differences within one population will involve even the technical characters that are used to separate *Agropyron* and *Elymus,* which probably are very artificial genera. Great morphological variation, and poorly defined species, are characteristic of genera having closely related species which will cross rather readily, and whose chromosomes are still largely homologous and able to pair in the hybrids. Amphiploids arising from hybrids between such species would be unstable and very difficult to breed to constancy.

In view of the complexity of the *Agropyron-Elymus* group, it has been decided to limit the grass studies to the two sections of *Poa,* particularly since progress in hybridizing members of this genus has been greater than anticipated.

ACHILLEA STUDIES

The study of the transplant reactions of local populations of *Achillea* is now approaching its conclusion. The materials came from frequent intervals across central California in a line with the transplant stations from the coast to the Great Basin plateau east of the Sierra Nevada. They were discussed in Year Book No. 41 (pp. 127-132), and planted at the three stations in 1942. The unique range of climates covered by this transect and occupied by *Achillea,* the strategic sampling, and the reactional patterns as recorded from the three stations lead to an understanding of the basic characteristics of climatic races, or ecotypes. The analysis of the data and the preparation of illustrations for publication are well under way.

FUTURE INVESTIGATIONS

The war temporarily interrupted a series of studies dealing with the laws that determine the hereditary and environmental relations of plants. These laws are basic to an understanding of organic evolution. Fortunately, the garden experiments have been completed. The very complete records preserved in the form of notes and plant materials can now be prepared for publication without the necessity of making new field collections. The *Poa* investigations have been conducted in such a way that they represent a further extension of this program.

These investigations on the organization of plant life, as viewed from coordinated cytogenetic, morphologic, geographic, and ecologic approaches, have extensively utilized the Madiinae, the climatic races of *Achillea,* and the selection experiment on *Potentilla glandulosu.* Each of these three groups of plants has been eminently suited to the purpose for which it was used. The usefulness of these materials for discovering basic laws governing relationship and distribution of organisms in a region of climatic and topographic diversity, and the broad scope of the coordinated investigations, are unique features of this program.

It is an obligation to bring this material to prompt publication. The two parts of "Experimental studies on the nature of species" published by the Carnegie Institution, one as publication 520, on environmental influence, and the other as publication 564, on amphiploidy and autoploidy, deal with two phases of our program. The intervening field is to be treated in publications on the evolutionary dynamics of the Madiinae, on the climatic races of *Achillea,* and on the genetics of ecotypes.

The grass program, which extends the field to speciation in a group of asexually reproducing (apomictic) plants, was largely built *on* the principles learned in these still unpublished investigations. It has had three interlocking objectives. One is the development of improved range and forage grasses. At best, the necessarily limited output of such materials can be expected to contribute only a small part to the solution of the very complex problem of improving the range lands. Once the utility of these methods of producing superior grasses is demonstrated, this phase of the program obviously belongs to agencies other than those devoted to basic research.

The second and more important objective is the development of new principles in the practical breeding of range and forage grasses, in this case combining species fitted to very contrasting environments to obtain hybrids with greater tolerance, and speeding the production of new forms by utilizing nonsegregating hybrids.

The third objective is to arrive at an understanding of the laws that govern the evolution of forms in a group of apomictic

organisms. The other two objectives depend on this one, the attainment of which is clearly within the domain of basic research.

Our plan is to proceed with the preparation for publication of the Madiinae investigations, the selection experiment, and the studies on climatic races, while continuing the experimental work on *Poa.* Under this arrangement, facilities at the stations now partially vacated by the other programs become available for *Poa,* the data on which can be assembled while the other records are being analyzed.

GUEST INVESTIGATIONS

Dr. Th. Dobzhansky, Research Associate of the Cárnegie Institution from Columbia University, utilized facilities at the Mather transplant station during the summer of 1945 for experiments related to the genetics of native populations of *Drosophila pseudoobscura.* Dr. G. L. Stebbins, Jr., of the University of California, also spent some time there during the summer, analyzing wild populations containing intergeneric and interspecific hybrids of *Agropyron, Elymus,* and *Sitanion.* Mather is strategically located for studies on the distribution of plants, for forms common to higher and lower elevations, and of northern and southern distribution, frequently grow together here and a number will hybridize.

Professor W. E. Lawrence, of Oregon State College, spent two summer months during 1945 at the laboratory at Stanford studying the geographic distribution of *Achillea* throughout the Pacific coast states. As no thoroughly dependable morphological characters have been found to distinguish all forms of *Achillea borealis* Bong., which is hexaploid, from *A. lanulosa* Nutt., which is tetraploid, the only safe way of determining their distribution is to count the chromosomes. In California, the hexaploids extend from the coast to the foothills of the Sierra Nevada and have developed three or four major ecotypes over this area. Higher in the Sierra and eastward they are replaced by the tetraploids. Lawrence finds that in Oregon the tetraploid presses to within a very short distance of the coast, replacing all hexaploids inland, but leaving room for the maritime ecotype of the hexaploid species, which extends north to the coast of Alaska and the Aleutian Islands.

DESERT INVESTIGATIONS

FORREST SHREVE

Shortly after the establishment of the Division of Plant Biology a program was formed for a regional investigation of the desert areas lying in Arizona, southeastern California, and the Mexican states of Baja California and Sonora. This is a sharply marked area with essential unity in its climatic and biological conditions. In geographical and botanical literature it has long been designated as the Sonoran Desert. The Desert Laboratory of the Institution was located on the inner edge of this area and about midway between its northern and southern limits. The Sonoran Desert program provided for a complete enumeration of the higher plants, more exact determination of their areas of distribution, and fuller knowledge of their habitat requirements and ecological behavior, as well as for a study of the types of vegetation found in the area, their distribution and relationship, and their relation to the differences of climate and soil that were known to exist in the more widely separated parts of the area of 126,000 square miles.

Field work was begun in 1932 and carried on actively for five years, being supplemented later by several visits to areas of importance which had not previously been readily accessible. Work on the vegetation was carried out by Dr. Shreve and Dr. T. D. Mallery, and the study of the flora was in the hands of Dr. I. L. Wiggins, of Stanford University. Large plant collections were made by Dr. Wiggins and he has devoted much time to the study of material collected in the area by early workers. Because of the fact that there has been no previous compilation of the flora of the Sonoran Desert or the Mexican parts of the area, it has been necessary for Dr. Wiggins to make a critical study of almost every group of plants found there. The adoption of a natural rather than a political area has also made it necessary to determine the precise locality in which each of the older collections was made.

The principal differences of vegetation in the several parts of the Sonoran Desert are chiefly attributable to restriction of rainy periods in Baja California to the winter and early spring months, the occurrence of biseasonal rains in the northern parts, and the increasing prevalence of summer rains toward the south. The vegetation of Baja California is marked by the occurrence of several common large plants which are either confined to that peninsula or found only very locally on the mainland. The size and unique character of some of these plants, as *Idria, Pachycormus, Yucca valida,* and *Pachycereus Pringlei,* have given Baja California a reputation for unique vegetation which is scarcely borne out when consideration is given to the less favorable habitats and to the very large number of characteristic plants which are common to this and other parts of the Sonoran Desert. Where the desert borders the Pacific coast it is of a type very distinct from that found inland, but it enjoys extremely little amelioration of the arid conditions through its proximity to the sea. The almost constant strong ocean winds join with the aridity in causing a very low and open plant covering.

The region of biseasonal rainfall is one in which the control of soil moisture by topographic conditions is marked. The broad plains support a very uniform shrubby vegetation which is low in stature and made up of a small number of species. The coarser soil of bajadas, pediments, and the slopes of hills and mountains supports vegetation which is taller, more dense, and made up of a much larger number of species. The southern part of this desert area, lying in the state of Sonora, and the inner edge of the area, lying near the foothills of the Sierra Madre, support a heavier vegetation than is found in the north. The flora of the southeastern part of the Sonoran Desert is greatly enriched by the occurrence of many trees and shrubs which here reach their northern limits. A few of these are characteristic plants of the thorn forest which extends south from the southern edge of the desert. In this region the rainfall is greater than it is in the Colorado and Gila valleys, and its increase with increasing altitude is greater.

The Sonoran Desert program has, in effect, been an extension of the earlier work of the Desert Laboratory, carrying the investigation of the Tucson region to the distributional limits of the plants which had been studied there, and using the knowledge of the plants and conditions of the Tucson area as aids in interpreting the ecological features of the more remote parts of the desert area.

In 1937 the program of desert work was extended to include the more elevated areas lying east of the continental divide in western Texas and the Mexican states of Chihuahua, Coahuila, Durango, Zacatecas,

and San Luis Potosi. This area has been designated the Chihuahuan Desert, although field work has revealed that the most characteristic part of the area, and the one in which the agencies of aridity have apparently been longest at work, lies in the state of Coahuila.

The Chihuahuan Desert lies mainly above 3500 feet in elevation and includes some very arid areas together with others in which there is summer precipitation approaching that of the central part of the Sonoran Desert. The winter temperatures are much lower than those in the coldest parts of the Sonoran Desert. The Chihuahuan Desert is distinguished by the occurrence of numerous large and small undrained basins which have either a central saline playa or a deep soil with a heavy stand of coarse grass, and by the prevalence of limestone outcrops and hills of a type which erodes very slowly under arid conditions.

The study of the flora of the Chihuahuan Desert has been carried on through the cooperation of Dr. I. M. Johnston, of Harvard University, who had already done considerable work in the deserts of Chile and Argentina. Dr. Johnston made large collections between 1938 and 1941, and has been favorably situated at the Gray Herbarium for study of the older collections from northern Mexico. He has detected a relatively large number of new species in the area, has thrown new light on the floristic affinities of the flora of the basins and mountains of northern Coahuila, and has found critical study and revision necessary in several groups of plants. Dr. Johnston has published papers embodying descriptions of new species, and in 1943 and 1944 published five installments of an annotated list of the plants of Coahuila and adjacent states, covering the families from the Polypodiaceae to the Nyctaginaceae.

The distribution of vegetation in the Chihuahuan Desert is mainly controlled by the character of underlying rock and soil and by the major topographic features. Only at elevations of 1000 to 2000 feet above the surrounding plains does the influence of climatic conditions become important in differentiating the vegetation. In spite of floristic differences, there is a strong similarity between comparable situations in the northern and southern parts of the desert. Trees are far less frequent than in the Sonoran Desert, and shrubs and such semishrubs as *Atriplex* are characteristic. Large cacti are relatively uncommon, but small ones are extremely abundant. Extensive areas have open or heavy stands of *Yucca* or *Dasylirion.* Also the smaller semisucculents *Agave* and *Hechtia* are found in extensive stands, particularly on limestone. In all parts of the Chihuahuan Desert above 5000 feet there are many areas with an open sod of perennial grasses.

There are no parts of the Chihuahuan Desert in which the ground is as thickly covered with diversified groups of striking plants as in many localities in Sonora and Baja California. Only in Zacatecas and San Luis Potosi does the occurrence of tall yuccas, *Acacia Farnesiana,* and large platyopuntias and agaves give striking evidence of the somewhat ameliorated conditions which exist along the southern edge of the Chihuahuan Desert.

The preparation of material for companion publications on the flora and vegetation of the Sonoran and Chihuahuan deserts has made progress during the past three years, in spite of other urgent demands on the time of the participants, and the ultimate completion of the results of the projects should be possible within the next two years.

PALEOBOTANY

RALPH W. CHANEY

Completion of the study of an Eocene cactus by Dr. Chaney is the only concrete yield of the period during which he has been engaged upon an emergency war assignment. Modern members of the Cactaceae are highly specialized; in the case of the tribe *Opuntieae,* which the fossils closely resemble, this specialization of vegetative structures makes possible their existence in arid or exposed environments. Discovery of similar plants in rocks assigned to the Eocene epoch, when modern flowering plants were first becoming dominant and widespread, is therefore of interest as indicating an early development of this structural adjustment to desert conditions. This record of a prickly-pear type of cactus, to which the generic name *Eopuntia* has been assigned, extends the known age of the Cactaceae back some fifty million years to the early part of the Tertiary period, the period preceding that in which we live.

The Green River formation of Utah and adjacent states contains an abundance of plant remains. Most of the conifers and angiosperms are preserved as impressions, which show the surface characters of leaves, stems, and fruits in great detail but supply little information regarding their internal structure. Our specimens of *Eopuntia,* representing stem joints and attached fruits, show on their surfaces linear markings which are not characteristic of similar living cacti. It is therefore particularly fortunate that one of the stem joints has been so preserved that not only the external but the internal characters may be observed. When studied from within, these linear markings are seen to represent vascular strands of a siphonostele, a type of stem still occurring in certain primitive genera of the Cactaceae, but superseded by the more specialized dictyostele in modern *Opuntieae.* These earliest members of the cactus family, though having the flattened, fleshy stems of living prickly pears, were at an unspecialized level of vascular development consistent with their great antiquity. In several features of their fruits, the ancient cacti of Utah also show more generalized structures than their modern descendants. The bases of the fruits are narrowed and stemlike, vascular tissues are well developed, and areoles are numerous on their distal ends. These characters of the fruits, like the stelar structure of the stem joints, suggest an ancestral relationship with modern *Opuntieae,* and an intermediate position between *Opuntieae* and the more primitive tribes *Peres\ieae* and *Cereeae.*

The Green River flora as a whole contains many genera which now live in regions characterized by warm-temperate climate, with well defined dry seasons. Such an environment appears to have been present in eastern Utah during the Eocene epoch, and to have provided living conditions suited to this oldest known cactus.

The current eruption of Paricutin is providing an opportunity to continue the study of conditions under which many fossil plants have been preserved in the western United States. Widespread vulcanism during the Tertiary period provided the topographic setting and the sediments which facilitated the burial of stems, seeds, and leaves of ancient trees and shrubs, and their subsequent transformation into fossils. A clearer picture of the past can be drawn if we have an understanding of factors concerned in the burial and preservation of plant remains in contemporary deposits. Under the combined auspices of Princeton University and the Carnegie In-

stitution of Washington, Dr. Erling Dorf has spent a month at Paricutin volcano, in a study of the occurrence of plant remains in volcanic sediments. His preliminary report indicates that (1) leaves, stems, and fruits of plants buried during the eruption have been little if any altered as yet; (2) there is abundance of remains of pine and oak, but other trees such as alder, linden, and cherry are poorly represented although they are numerous in the region; (3) plant remains have been well preserved only where buried close to their parent trees or shrubs; (4) subaerial ash deposits contain more abundant and better-preserved material than stream and lake deposits; (5) these deposits are already being destroyed by erosion; (6) the best situation for the ultimate preservation of the record of this Mexican forest will be in valley ash deposits buried by lava to protect them from erosion.

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DEPARTMENT OF EMBRYOLOGY

Baltimore, Maryland

GEORGE W. CORNER, *Director*

This annual report, the fourth to be submitted since the entry of our nation into the war, is accompanied by the smallest review of published work since the Department of Embryology first got well under way. Two members of the regular staff of investigators have been away on war duty. A group of workers normally active in peace times, consisting of visiting investigators, temporary members in the status of fellows, and local scientific workers making use of the laboratory's facilities, has been almost completely scattered by the war. The Director and other members of the staff have been distracted by emergency duties and by the general disturbance of the times.

The small output of the year, in published research, does not however represent all the activities of the Department. The accumulation and preparation of human embryos has continued, and in fact the year has seen a notable growth in the number of well preserved embryos cut into perfect serial sections by Dr. C. H. Heuser, Curator of the Embryological Collection, and his technical assistants. In an effort to provide Dr. G. L. Streeter with ample material for his special project described below, a score or more of embryos of the fourth and fifth weeks were prepared for study. The specimens thus newly made available for morphological research, representing the period when many of the important organs begin to take form, make a permanent addition to our resources.

Mr. O. O. Heard, the senior modeler, working in collaboration with Dr. Heuser, devoted much time to the perfection of a new technique of microtomy intended to reduce the distortion of tissues caused by the pressure of the microtome knife. His new knife, circular in form, is made to rotate as it passes through the tissues and thus produces a slicing cut. Considerable mechanical effort is necessary to produce a truly circular knife and to keep its edge in good condition. In the course of this work Mr. Heard has acquired a great deal of information, both practical and theoretical, about the nature of a useful knife-edge for microtomy. This will doubtless be published in due time and is now being put to use. Other members of the staff have been able to maintain their research programs along the lines mentioned in previous Year Books, with results that will be publishable in due course. We have continued to put about half the facilities of the monkey colony at the disposal of a research group from the Johns Hopkins University School of Hygiene, in the conduct of a study in tropical medicine requiring the use of monkeys under the skilled care which our animal-house staff is qualified to give.

Dr. Louis B. Flexner, who has been Technical Aide to the Committee on Aviation Medicine of the National Research Council, has been released from most of the demands upon his time made by that work, and will resume on a larger scale than before his studies on the physiology of developing tissues. Dr. S. R. M. Reynolds, major in the Army Air Forces, has been released from the army. There are hopeful signs that the group of investigators outside the formal membership of the staff will soon be reconstituted. Postwar plans of the Department involve no

large deviation from the program which was set forth by the Director in the annual report for 1940-1941 (Year Book No. 40). The war has delayed the work but has not altered the fundamental problems of human development.

EMBRYOLOGY AS A COOPERATIVE SCIENCE

During the period, now ending, of national concentration for war, scientists have found themselves called upon as never before . for cooperative action. A trend, created by the needs of modern science and already noticeable in recent years, toward group research by associates trained in different branches has been greatly accelerated by the war. The public is now learning through the newspapers and magazines of the group projects that sprang into existence under such organizations as the Office of Scientific Research and Development and the National Research Council. Some of the practical achievements of group research are already apparent. Among the gains brought about by this war, in partial compensation for its destruction and misery, surely not the least is this cross-fertilization of the various sciences, which results not only in immediate practical advantages, but also in new thinking about fundamentals. The synthesis of ideas thus achieved is not lost even if in times of peace the pendulum swings again necessarily toward individualistic research.

Professional scientists are therefore in a mood, at present, to take stock of the services their respective branches may render to others. A few reflections on this question, as concerns a laboratory of mammalian embryology, may be useful in forecasting our own work in the future.

The science of the development of the higher animals, and especially of man, has necessarily been largely descriptive and has mostly dealt with events so intricate., so much unlike the things man can do with his hands and mechanical tools, as to banish any thought of controlling them. The embryologist could only observe, depict, and describe, although the phenomena thus revealed have been of such profound significance as to claim the attention of able minds to embryology as a pure science. Embryology could not give immediate birth to applied science as physics gave birth to locomotives, flight, and electronic devices. Its chief practical service, rendered to the art of the physician, has been to provide a background of explanation and understanding for many otherwise puzzling facts of normal anatomy as well as of structural anomalies and defects. This service is often so subtle that it is not appreciated by ultra-practical minds. Presumably an operation, for example for congenital hernia or cleft palate, could be done successfully without knowledge of the embryology of the region; but the surgeon who has the responsibility of repairing such lapses of development, if he understands how they came about, operates with added assurance and comfort of mind. This is well understood by the wisest surgeons, as is evidenced by the time many of them have spent on embryological studies. To cite a case close at hand, we are preparing to publish in an early volume of the Carnegie Contributions to Embryology a painstaking investigation of the development of the arteries of the brain, made by Dorcas H. Padget, of the staff of the distinguished neurological surgeon Walter E. Dandy. Dr. Dandy's interest in this subject was aroused because he observed anomalies of the cerebral arteries at the operating table and he thought it worth while to subsidize a study of their origin.

The staff members of the Department of Embryology, like embryologists in other cities, are not infrequently called to the hospital clinics to take part in the scientific analysis of cases involving embryonic defects. Whether or not the embryologist contributes to a cure, the patients are fortunate to be in the hands of physicians who want to understand their problems from the most fundamental aspect.

At any moment, of course, the facts of a so-called "pure" science may suddenly be found to have practical importance. This has been strikingly true of one division of mammalian embryology: the investigation of the reproductive cycle, i.e., the integration of function of ovaries, uterus, and other parts of the female reproductive tract, by which the maturation of the ovum, its discharge from the ovary, its fertilization, transportation to the uterus, and implantation are timed and coordinated. About the beginning of the present century the newly developing study of endocrinology and that of the reproductive cycle were brought together, with the result that the half-century has seen an enormous increase of knowledge of the hormonal control of reproduction, with practical results that are already impressive, if measured by the number of pages in the medical journals on this subject and the investment of the pharmaceutical firms in the manufacture of steroid hormones. The staff of our laboratory has already taken a part in this advance and we shall continue to work in the same field.

There are several aspects of embryology in which a similar cooperative attack is under way or impending. In recent years there has been a great advance in knowledge o£ the enzymes in animal tissues, and of other chemical and physical systems controlling such essential functions as tissue respiration and the intracellular metabolism of various organic substances. Some of these discoveries have gone so far as to localize the enzymes under the microscope, as for example the new techniques of Gomori for visualizing the phosphatases. The chemical processes of cell life are being worked out. The developing embryo offers an especially favorable opportunity for studying the chemical functions of specific tissues, for as the embryo grows, new organs and tissues make their appearance. Applying the new techniques to the embryo, it will be possible in many cases to associate the appearance, the peak activity, and the disappearance of an enzyme or other metabolic chemical compound with the unfolding organic structure.. In the long run we shall thus approach a full understanding of the physicochemical means by which the organs and tissues of the body are developed and differentiated from the simpler constituents of the fertilized *egg.* As this kind of investigation develops, the chemical embryologist will find himself in cooperative relation with other students of growth, and especially with investigators of abnormal growth, i.e. cancer and other tumors. No line can be drawn, in fact, between normal growth as in the embryo and infant on the one hand, and abnormal growth on the other. Whatever is learned from one will help in understanding the other. We have long since had an example of this fact in the work on cell growth in tissue cultures, carried on in our laboratory by Dr. W. H. Lewis and Dr. M. R. Lewis. Begun as a way of analyzing normal cell growth and development, their program became closely associated with cancer research.

Another phase of mammalian embryology in which, one may venture to predict, there will soon be notable progress through cooperation between the sciences is that of teratology, the lore of embryonic abnormalities. It has been part of our

departmental routine to preserve and study anomalous and defective embryos and to render diagnostic service to physicians as far as current knowledge goes. Better knowledge, based on experiments, has had to wait for the results of work on lower animals. Experiments on accessible embryos like those of fish, amphibians, and birds, intended to produce defects and anomalies, are a century old and have taught us much about the susceptibility of early embryonic tissues to harmful environmental conditions, e.g. excessive cold, heat, defective oxygenation, deleterious chemicals, etc. The advent of genetic analysis has taught us how defective genes can also produce disturbances of development. It has been difficult to reach the well protected embryos of mammals with such experimental weapons, but progress is being made, and a science of experimental teratology in mammals is probably not far off. The attention of * physicians and even of the lay public has recently been directed to the damage to human infants in utero produced by certain disorders of immunity caused by the "Rh" factor, and by the occurrence of the virus disease rubella (German measles) in early pregnancy. In our laboratory we have already begun an effort (admittedly unsuccessful thus far) to analyze the rubella problem by experiments on monkeys.

Enough has been said to show that investigators of the embryology of man and the higher mammals not only are following a so-called pure science, but are more and more in a position to contribute their knowledge to cooperative study of problems that are of vital practical importance. During the war it was frequently necessary to explain to selective service boards and similar public officers (people not at the moment officially interested in theoretical science), in the small blank space of a questionnaire, what the Department of Embryology considered itself to be doing for the national effort. The statement, which fortunately seemed acceptable, was that we are carrying on our share of the research on which the maternal welfare and "better baby" programs are based. This explanation, of course oversimplified, will serve to show that we are not unmindful of our opportunity to render service to the public through medical application of embryology. There will, however, always be a place in this Department, especially in the unharassed times of peace, for research workers, if such there be, who disregard all thought of application and usefulness to study the development of the human body simply because it is ineluctably fascinating. If in some future day the embryologists learn how to get at the smallest units of life and split and recombine them, as physics has reached inside the atom, the resulting changes (which will be as cataclysmic as the atomic bomb, for good or evil) will have resulted from the work of the cloistered theorists of earlier years.

Discoveries about the embryonic development of man and the other primates place the embryologist in cooperative relationship also with students of biological theory, philosophy, and even religion. The relation of man to the other animals is greatly illuminated by the study of his development. This is an old story which had its lurid chapters in the days of conflict over evolution. Now that the animal affinities of man are accepted, the embryologist is able to make a sober contribution to the details of primate evolution. Mammalian embryos not only possess incipient anatomical organs and systems like those of adults, which may be studied for evidences of resemblance and dissimilarity as in ordinary comparative anatomy; they also possess a set of organs not present in the adult, namely, the placenta and the

embryonic membranes and cavities of the chorion, amnion, allantois, and yolk sac. These organs differ extraordinarily from species to species, and thus they are of very great importance to the investigator who seeks to know how one animal or group of animals is related to another. It happens that in man and the other primates there are enough differences in the placentas and membranes to give us light on the old Darwinian question, whether man's eldest living relatives are to be found among the anthropoid apes or the monkeys. Given time, means, and sufficient ingenuity, we have much to learn from an extension of our program of embryological study, especially the study of the earliest stages of embryonic development, to the infrahuman primates of Africa, Asia, and America.

The understanding of man's place in the animal world, gained from such studies as these in association with other branches of comparative zoology, necessarily influences the whole structure of human education, lawmaking, and philosophy.

RESEARCHES, COMPLETED AND IN PROGRESS

DEVELOPMENTAL STAGES OF HUMAN EMBRYOS

Dr. G. L. Streeter continues actively his program of classification of human embryos. This undertaking was fully explained in Year Book No. 42. Its aim is the description and depiction of human embryos in such manner that successive stages of development can be recognized by obvious characteristics, both external and internal. By this means embryologists will be able to indicate the stage of development of any embryo by reference to Streeter's numbered stages, thus obviating all sorts of difficulties inherent in the comparison of objects which differ, as they develop, by so many variables at once. The descriptions of stages XV to XVIII are now well advanced and will be published in volume XXXII of the Contributions to Embryology.

Stage XV, including embryos of age estimated as 30-32 days, is characterized by detachment and closure of the lens vesicle. At this and the two following stages, the development of the bronchus is useful for the comparison of sectioned embryos; in stage XV the secondary bronchi are distinguishable as swellings on the primitive bronchi. Stage XVI (32-34 days) is readily detected by the appearance of the first retinal pigment. The secondary bronchi are clearly recognizable. In stage XVII (34-36 days) the retina is heavily pigmented. The secondary bronchi begin to branch. The calyces of the renal pelvis appear. In stage XVIII (36-38 days) the first semicircular canals of the internal ear (vestibular apparatus) are seen. Jacobson's organ is distinct in the nasal region.

The essence of Dr. Streeter's plan is thus to select, describe, and depict characteristic structural details at each stage. A fact thus revealed, perhaps not unexpected theoretically, but very striking as brought out by this research, is the high correlation between the various organs of the body as to time of first appearance and stages of development. If, for example, in a well preserved embryo the eyes are just beginning to show retinal pigment, then it is certain that secondary bronchi will be present in the lungs. If any organ lags behind, there is something wrong, and this is generally evidenced by multiple deviations. In a brief review of Dr. Streeter's work only a few of the characteristics which he has studied can be mentioned;

his successive chapters must be read to appreciate the march of developmental events.

VERY EARLY HUMAN EMBRYOS

The collection has been enriched by the receipt from our collaborators Dr. Arthur T. Hertig and Dr. John Rock of several embryos of the late second and the third week, in addition to those reported in previous Year Books. These valuable specimens have been sectioned by Dr. C. H. Heuser, aided by the technical staff, and together with ample photographic records are preserved in the collection of the Department.

THE RATE OF ABNORMALITY IN EARLY EMBRYOS

This past year has seen the completion of preliminary studies by Dr. Hertig and Dr. Rock, at the Free Hospital for Women in Brookline, Massachusetts, on a series of one hundred fertile married women on whom a therapeutic hysterectomy was performed in known calendar relation to the next expected menstrual period. The investigation was supported by the Carnegie Corporation of New York, by the Carnegie Institution of Washington through this Department, and by the Milton Fund of Harvard University. The surgically removed uteri were carefully searched for the presence of young fertilized ova, either free in the uterine cavity or implanted on the endometrium. During the seven years of this study, nineteen such specimens were found. These form the Hertig-Rock collection of very early human embryos, already well known to readers of these annual reports, in which many of the individual specimens have been discussed as they were added to the Carnegie Collection in this laboratory. Several of them have been published in full and they arc already beginning to find their way into the textbooks of embryology.

Dr. Hertig and Dr. Rock, reviewing their work for this report, state that the nineteen embryos range from a specimen 4 days of age (a segmenting ovum found free in the uterine cavity) to one 16 days of age, a well imbedded ovum with early, simply branched chorionic villi. Eleven of the nineteen specimens are judged to be perfectly normal and encompass the stages of embryologic development from that of a recently implanted blastocyst (7V2 days) to that of an early villous ovum (16 days). The remaining eight are pathological in one way or another, their abnormalities including such diverse factors as faulty segmentation, absence of the embryonic disk, extreme hypoplasia of the trophoblast, and shallow implantation of an otherwise normal ovum.

It is apparent from these figures that the index of fertility in married women of proved fertility, with at least one recorded coitus during the estimated time of ovulation preceding the hysterectomy, is 19 per cent. Equally apparent is the fact that a high proportion, 42 per cent, of these early pregnancies would probably have failed to reach term. Indeed, it is doubtful whether the abnormal segmenting ovum of 4 days would have implanted and, if it had, whether it would have caused the next expected menstrual period to be missed. Of the seven pathological ova that were implanted, it is doubtful whether the two most abnormal forms would have more than briefly delayed the next expected menstrual period. Thus it is apparent that many fertilized human ova, as is the case with lower animals, are destined to abort before the fetal stage is reached. Certainly, many of the abnormal forms encountered in this study have their pathological counterparts in ova spontaneously aborted by patients during the early months o£ prcg-

nancy. Therefore, these early abnormal forms of pregnancy serve to teach us something about the pathogenesis of human abortion, a subject about which little is known at present. This is so because the specimen from a spontaneously aborting patient is relatively so mature that it is impossible to trace accurately the sequence of events leading to the premature expulsion of the nonviable ovum.

During the past year, two of the specimens mentioned above were recovered from the last thirteen patients of the series. Both specimens were abnormal with respect to their embryos, although the chorions were normal. The younger specimen (Carnegie no. 8299), estimated to be about 12 days of age, shows a disoriented germ disk (embryo), of which the cephalic end points directly toward the trophoblast, while the caudal end, at the site of the potential body stalk, is free in the chorionic cavity. It is unlikely that a good body stalk or umbilical cord would have formed. This may be the early stage of the frequently found type of pathologic ovum which invariably aborts and whose embryo is either nodular or stunted and is attached to the trophoblast by a defective body stalk.

The older specimen (Carnegie no. 8290), an early villous ovum about 13 days of age, likewise shows a serious defect of its embryonic disk, the primitive ectoderm being disoriented with respect to the underlying primitive endoderm and its associated yolk sac. It appears as though the dorsal part of the premature embryo had slipped horizontally with respect to the ventral part, an abnormality which would probably interfere with any proper axial differentiation of the future embryo.

Continuing their report, Dr. Hertig and Dr. Rock state that regardless of whether their tentative interpretation of the relation of such defective early embryos to subsequent defects in the aborting ovum is correct or not, the fact cannot be gainsaid that here are a series of intrinsically defective ova whose environment is apparently normal. Hence this series offers additional evidence of such a condition as "germ plasm defect," unsatisfactory and all-inclusive though the term may be.

During the past year, the detailed description of one of the 7½-day ova and the 9½-day ovum (Carnegie no. 8020 and no. 8004) has reached galley-proof stage, and its appearance in the Contributions to Embryology is expected in the near future. In addition, plastic sheet reconstructions of two ova (Carnegie no. 8155 and no. 8171) have been prepared in anticipation of completing a detailed description of these two specimens for early publication.

ATTEMPTS TO FERTILIZE HUMAN OVA IN VITRO

Dr. John Rock reports that during 1944-1945 he has continued his efforts to fertilize and initiate cleavage of human ovarian eggs. This work, primarily supported by the Milton Fund of Harvard University, has also depended upon facilities provided for the discovery of early human embryos (discussed in the previous paragraphs) supported by the Carnegie Corporation of New York and more recently by the Carnegie Institution of Washington through the Department of Embryology.

A year ago (see bibliography), Dr. Rock and his associate Mrs. Menkin reported on the fertilization of three such eggs. During the past year, 103 follicular eggs in the preovulatory phase have been recovered from operative patients. The eggs were cultured in serum and 76 of them were exposed to spermatozoa, but none were successfully fertilized. Forty-nine of the eggs were cultured, before exposure

to sperm, in serum to which had been added a small amount of hyaluronidase. English investigators (Rowlands and McLean) had found that this enzyme would break down the gel of the corona radiata, allowing the sperm to penetrate the egg. Thus far, Dr. Rock has not found this to be of much assistance, but he plans to try a larger variety of techniques.

EMBRYOS OF THE BABOON

In an earlier paragraph of this report it has been pointed out how we may get clues as to the evolution of man by comparison of the embryos of the various primate species with one another. The value of such comparative study has long been recognized by the Department. It possesses, through the efforts of Dr. C. G. Hartman, a noteworthy collection of embryos of the rhesus monkey described in a recent monograph by Dr. C. H. Heuser and Dr. G. L. Streeter. A beginning has been made also with respect to anthropoids, two early embryos of the chimpanzee being in the collection. In 1942 the Department enjoyed a long visit from Dr. Joseph Gillman, of the University of the Witwatersrand, Johannesburg, South Africa. Dr. Gillman possesses extensive knowledge of the breeding habits and physiology of reproduction of the baboon *{Papio porcarius)*, and required only more extensive facilities for collecting, housing, and breeding animals to enable him to collect early embryos. As the result of plans developed during his visit, the Trustees of the Carnegie Corporation of New York made a grant late in 1942 from their British Dominions and Colonies Fund (to be administered through this Department) to provide facilities for such an enterprise. The effort has now begun to yield results, for during the year 1944-1945 Dr. Gillman has sent five embryos of *Papio porcarius*, all younger than one month old. These are being photographed and sectioned, and promise to yield much information about early placentation and the formation of the embryonic membranes. It is a most interesting fact, in view of the studies of Hertig and Rock, mentioned above, on the proportional incidence of early abnormality of human embryos, that one and possibly two of the first three Gillman baboon embryos are pathological. Such early abnormalities are as valuable, in their way, as normal specimens, provided a sufficiently large series can be assembled to permit proper comparison of normal and abnormal types.

PHOSPHATASE IN THE OVARY; FATE OF THE THECA INTERNA

Dr. George W. Corner has completed the preliminary stages of an investigation of the distribution of the enzyme known as alkaline phosphatase in the cytoplasm of ovarian cells of various species. This enzyme, as its name indicates, has the property of splitting phosphate ions from the compounds of phosphoric acid, in an alkaline environment. It is widely distributed in the organs and tissues of the body. In bony tissue it is obviously concerned with the metabolism of calcium by its action,on calcium phosphate. In tissues like the ovary its function is less obvious; probably it is concerned in the metabolism of phospholipids. Dr. Corner's attention was turned in this direction by a recent publication of the Chicago histopathologist Gomori, who devised a method of demonstrating the presence of alkaline phosphatase in microscopical sections. Gomori included the ovaries of a few species among the tissues which he studied in cursory fashion. Because he found that in some animals the theca interna and the rnembrana granulosa of the Graafian follicle

differ in their content of alkaline phosphatase, there seemed to be a possibility of using the method to trace the fate of the theca cells in the formation of the corpus luteum, and thus to contribute to the solution of an old problem.

In brief, the result was that in the domestic sow the fate of the theca interna can be clearly followed, because the theca interna is rich' in phosphatase and the granulosa lacks it. The theca cells, thus traced, persist throughout the formation of the corpus luteum and become scattered among the granulosa lutein cells. This confirms a description of the origin of the corpus luteum of the sow, published by Corner in 1919, which has been disputed. In the several other species studied, all possible variations of the distribution of phosphatase between theca interna and granulosa are found; in the rhesus monkey, for example, both these layers are rich in phosphatase; in the rabbit the enzyme is plentiful in the granulosa and absent from the theca interna. The method cannot therefore be used in these species to trace the theca cells after rupture of the follicle. This puzzling difference between species, however, may ultimately afford an explanation of the function of the enzyme, by revealing the association between phosphatase and other constituents of the ovarian cells.

INJURIOUS EFFECT OF LIGHT UPON DIVIDING CELLS IN CULTURES CONTAINING FLUORESCENT SUBSTANCES

Certain substances have the property of fluorescing, that is, of emitting radiations when themselves radiated, for example with light rays. The emitted radiation is generally of longer wave length than the exciting radiation, and is thus of different color. This phenomenon accounts for the peculiar glow of solutions of eosin and the bluish color of ordinary machine oil seen in strong daylight. It is more vividly displayed by various fluorescent substances when observed in the dark under the invisible rays of ultraviolet light. It has long been known that animal and plant tissues containing fluorescent substances are injured by light. A few years ago renewed attention to this subject was stimulated by the discovery that cancer cells growing in tissue cultures containing eosin were more sensitive to light than normal cells growing in the same cultures.

Dr. Margaret Reed Lewis has analyzed this phenomenon of photosensitivity of living cells in the presence of fluorescent substances by growing chick embryo cells in culture media containing various fluorescent substances, namely chlorophyll, dibenzanthracene, methylcholanthrene, eosin, and neutral red. Attention was centered on the dividing cells because it has been found previously that dividing cells in growing cultures are more sensitive than resting cells. Dr. Lewis found that the fluorescent substances named above, when added in suitably dilute amounts, were not toxic to the process of cell division as long as the cultures were kept in the dark, but when a strong light was passed through the cultures the cells quickly became damaged. The mitotic spindles and chromosomes and also the cytoplasm were injured. If the exposure to light was prolonged, the cells died. Cells showing only a slight injury were able to recover when the cultures were returned to the dark.

These effects were apparently not due to the light emitted from the activated fluorescent substance, for the cells continued to grow normally when irradiated by light that had been passed through eosin or neutral red solutions outside, but very close to, the culture slides. It appears that the cells were damaged by changes

brought about in the medium during the activation of the fluorescent material.

INDUCTION AND TRANSPLANTABILITY OF SARCOMATA IN RATS

Dr. Margaret R. Lewis, working in collaboration with Dr. Helen Dean King at the Wistar Institute of Anatomy and Biology, has completed an extensive study of the biological factors governing induction and transplantation of malignant tumors (sarcomata) in rats. The two workers made use of the carcinogenic substances dibenzanthracene, benzpyrene, and methylcholanthrene. These substances, when injected subcutaneously into rats, produce cancer of the connective tissue, that is to say, sarcoma. The experiment involved such injections into large numbers of rats of various genetic strains, and subsequent transplantation of the induced tumors into other rats of the same various strains. The object of the work was to discover whether the differences between the strains, evidenced in physical characteristics, growth rate, behavior, and reaction to stimuli, would affect the character and growth of the induced tumors or of the implanted tumor grafts. The strains used were the "King A" inbred albinos of the Wistar Institute, gray Norway rats of the Wistar Institute, three crosses between these, and nine different mutant strains of diverse origin. In all, nearly 10,000 rats were used.

Every one of the rats in thirty litters from the fourteen strains survived the carcinogenic injection and developed a sarcoma. The tumors thus produced behaved somewhat differently under different circumstances of sex and strain; they developed earlier in males than in females, and grew more slowly in gray Norway rats than in the other strains.

The transplanted tumors also behaved differently under different circumstances. They were, as would be expected, more transplantable to rats of their own strain of origin than to the other strains. Tumors that originated in the highly inbred King A rats were 100 per cent transferable to rats of the same strain and to two of the crosses with Norway rats. When inoculated into the other strains, however, they did not behave alike. Some grew in some of the other strains, some did not; in other words, there was a tendency to be strain specific. Tumors that originated in rats of less inbred strains grew much less frequently in the rats to which they were transplanted. One strain, the "curly" mutant, was highly resistant to the growth of sarcomata transplanted from rats of its own and of other strains. Tumor grafts grew faster when implanted into young rats than into old rats. Growth of the grafts was not influenced by coat color.

In summary, the sarcomatous malignant tumors of rats induced by carcinogenic agents proved to be subject, as regards their growth, to biological influences which are associated with different hereditary history (strain) of the rats into which they are transplanted.

FAILURE OF PURIFIED PENICILLIN TO RETARD SARCOMA

In March 1944 Mr. Ivor Cornman, who had been working at the Wistar Institute under the guidance of Dr. M. R. Lewis, published the finding that the growth of sarcoma tissue in tissue culture is inhibited by penicillin. The penicillin used in his experiments was a partially purified sample. Dr. M. R. Lewis proceeded to try the effect of the sodium salt of penicillin upon sarcoma, using mice of the Bagg inbred strain implanted with a sarcoma native to the strain. Ample doses of the penicillin, which was highly purified, failed to inhibit the growth of sarcoma *in vivo.* Dr. Lewis

next tested penicillin upon sarcoma cells growing in tissue culture, using both a highly purified colorless sodium salt and a less pure yellow sodium salt. The latter, in the higher of the concentrations used, killed the tumor cells and damaged the normal cells. This part of the experiment confirmed the observations of Cornman. The highly purified penicillin salt, however, failed to inhibit the growth of sarcomatous and of normal cells. Dr. Lewis concludes that the factor present in the less purified sodium salt of penicillin is lost from the highly purified product.

TRANSCAPILLARY EXCHANGE OF SODIUM IN NORMAL AND SHOCKED DOGS

Previous annual reports of this Department, in Year Books No. 41 and No. 43, reviewed a series of studies by Dr. Louis B. Flexner and various collaborators on the transfer of substances across the placenta from mother to fetus, and from blood to tissues across the blood capillary walls of the body in general. The methods used in these important studies were applicable to one of the most serious of war problems, namely traumatic shock. Dr. Alfred Gellhorn, who was working with Dr. Flexner before our entrance into the war, undertook studies on the physiology of shock in our laboratory under a grant from the Committee on Medical Research of the Office of Scientific Research and Development. A summary of the work has now been published by Dr. Gellhorn, Dr. Margaret Merrell, of the Johns Hopkins University School of Hygiene, and Dr. Robert M. Rankin. These workers compared the rate of exchange of sodium chloride from blood to tissues in normal animals and in animals placed in a state of surgical traumatic shock under anesthesia. The movement of the salt was followed by using radioactive sodium chloride ($Na^{24}Cl$) as explained in previous Year Books. The investigators ran into a certain amount of difficulty owing to the complications of the problem. Their work disclosed, for example, that the curve describing the rate of transfer of sodium chloride from blood vessels to tissues is complex and can only be understood by assuming that there are two rates at which the salt passes back and forth between plasma and extravascular fluids, presumably due to differences in different parts of the body.

After full mathematical analysis of the results it is shown that in shocked, untreated animals the total number of milligrams of sodium exchanged across the capillary walls per unit of time is about 50 per cent of the normal. When the animals are treated by replacement therapy with saline solution or serum, the defective rate of exchange is not improved, in spite of temporary better clinical appearance of the animals.

This finding, namely of a lessened transcapillary movement of sodium, is not easily reconciled with current theories of traumatic shock which postulate an increase of capillary permeability as fundamental to the diseased state.

DIFFUSION AND POPULARIZATION OF RESULTS

As already mentioned, the Director's Terry Lectures, given in March 1944 at Yale University, have appeared in book form under the title *Ourselves unborn.* In this volume, many of the problems in which this Department has been interested are reviewed for the educated general reader. Dr. Corner also published during the year, by request of the editor of *Parents' Magazine,* a journal issued under the auspices of several university groups, a popular article on human sterility from the

standpoint of the scientific investigator. Dr. Heuser, Dr. Burns, and Dr. Corner each lectured by invitation once or twice during the year to the students of Johns Hopkins Medical School.

A significant demonstration of the usefulness, outside our own walls, of our large collection of embryological materials is given by the latest textbook of human embryology, an excellent work by W. J. Hamilton, of St. Bartholomew's Hospital Medical College, London; J. D. Boyd, of the London Hospital Medical College; and H. W. Mossman, of the University of Wisconsin {*Human embryology*, Cambridge [England], Heflfer, 1945). Dr. Boyd and Dr. Mossman have been visiting investigators at the Department of Embryology in past years, and are therefore directly familiar with the resources of the Department. More than 90 of the 364 illustrations in the new textbook are drawn from the embryos of the Carnegie Collection or from articles by workers connected with the Department. It is a pleasure to note that Professors Hamilton, Boyd, and Mossman dedicate their book to Dr. George L. Streeter jointly with Professor T. H. Bryce, of Glasgow.

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DEPARTMENT OF GENETICS

Cold Spring Harbor, Long Island, New York

M. DEMEREC, *Director*

During the war, because of the nature of our work, staff members of this Department were not called upon to participate in war research to any considerable extent. The Department carried out two war research contracts, one with the War Production Board and the other with the Office of Scientific Research and Development. In addition, several members participated in other research related to the war emergency. The objective of our work under WPB contract was the development of a strain of *Penicillium* yielding a high content of penicillin. This work was successfully carried on by E. Sansome, M. Demerec, and H. E. Warmke; and a high-yielding strain, now used in production, was selected from among mutants induced by X-ray treatment. The contract with OSRD, which is still in effect, deals with the genetic aspects of resistance in bacteria. For two years Warmke cooperated with * the Bureau of Plant Industry of the U. S. Department of Agriculture in research aimed at the development of strains of fiber hemp with reduced marihuana content. He also participated in breeding studies on the rubber-producing Russian dandelion *(Taraxacum \o^-saghyz)*. Kaufmann, in collaboration with Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland, investigated the effect of ultraviolet radiation on the mammalian eye, with the purpose of developing standards for prevention of industrial hazards. Demerec and Potter took part in research at the Biological Laboratory, under contract with the Chemical Warfare Service, relating to the production and properties of aerosols. For one phase of this work, MacDowell supplied mice from his colony. Since 1943 Fano has been active at the Ballistic Research Laboratory, Aberdeen, Maryland, first on a part-time basis and later as a full-time worker. The Department cooperated with the Office of War Information by preparing for its Genetics News Letter monthly statements giving abstracts of important papers and brief summaries of other developments in the field of genetics.

Several members of the Department were taken into military service. In the Army Air Forces Dr. J. S. Potter served for a brief period as a captain, Louis R. Stillwell, Jr., and Robert Holl are serving as officers, and Dr. R. A. Miller is working as a corporal in a research laboratory.

In October 1944 Dr. Oscar Riddle retired from the Institution, but he remained with the Department until August of 1945 in order to complete his manuscripts. In September 1945 he became visiting professor of the Department of State in Brazil, Uruguay, and Argentina. Riddle came to the Department from the University of Chicago in 1912, as a Research Associate of the Institution. He brought with him the late Professor C. O. Whitman's pigeon material, and spent his first few years at Cold Spring Harbor in editing Whitman's work for posthumous publication. In 1914 Riddle was appointed a staff member of the Department. During his entire stay here he worked almost exclusively with pigeons and doves as experimental material; and his primary interest was in problems of sexuality, reproduction, and internal secretions. Although his approach was physiological, he was always aware of

genetical applications; and on many occasions he was able to trace physiological differences to differences in genetic constitution of the birds. When in 1932 he discovered a new hormone, prolactin, the emphasis on chemical aspects of his problems became greater. From that time on a chemist was included among the workers in his group; and this has had a significant effect on the work of the whole Department, broadening the general range of interest of the group. With Dr. Riddle's retirement the members of the Department have felt the loss not only of their oldest colleague, but also of a good friend and a sympathetic adviser.

Dr. H. E. Warmke left the Department in August 1945, to organize a Department of Plant Breeding at the Institute of Tropical Agriculture in Puerto Rico.

Much of the effort of Riddle and his associates during the year has been concentrated on analysis and summarization of data obtained in long-term investigations. The manuscript of a small volume on the subject of carbohydrate and fat metabolism in pigeons has been completed. The results of the twenty-four-year study on the relation of endocrincs to constitution in doves and pigeons have been summarized in the more extensive forthcoming volume "Endocrines and constitution in doves and pigeons." McDonald and Riddle have finished their studies on the effect of reproduction and estrogen administration on the partition of the various calcium, phosphorus, and nitrogen components of pigeon plasma. The nonultrafikrable calcium was found to exist in three forms: *(a)* colloidal calcium phosphatc, *(b)* calcium bound to the phosphoprotein, scrum vitellin, and *(c)* calcium Ixmm! tii the plasma proteins other than vitcllin. Increments in *(a)* and *(b)* accounted for all the increases in nonultrafiltrable calcium resulting from endogenous or administered estrogen. The calcium-combining capacity of the phosphoprotein, serum vitellin, is apparently 8 to 9 times greater than that of the other plasma proteins. All the changes in the various components that occur in the plasma of female pigeons at or near egg production can be duplicated by the injection of estrogens; and estrogens are effective in mature and immature, normal, parathyroidectornized, and hypophysectomized pigeons of both sexes. Thyroxine, when administered simultaneously with estrogen in equal amounts by weight, prevented the marked estrogen-induced increases in plasma calcium, phosphorus, and neutral fat. It did not measurably inhibit the ability of estrogen to promote formation of endosteal bone or growth of the oviduct. McDonald has continued her studies on the alcohol solubility of the plasma proteins. These have shown that serum albumin (and, to a lesser extent, some of the globulin fractions) is highly soluble, in the range of pH below its isoelectric point, in 95 per cent ethanol. Hollander and Riddle have noted the occasional onset of nongenetic partial melanism in adult female pigeons of essentially wild-type coloration. This partial melanism was associated with only slight exposure to sunlight and enlargement of the parathyroids. It appeared after one or more molts. The blackening, when it did not involve entire feathers, produced transverse bands on the feathers, not longitudinal streaks such as are typical of mosaic effects. Parathyroid enlargement and defective ossification of the bones were shown to occur regularly in young pigeons reared on a mixed-grain diet in the absence of direct sunlight (vitamin D deficiency). Melanism, however, was not found in these squabs.

MacDowell has found that the Cold Spring Harbor albino strain of mice (Balb) has a relatively high susceptibility

to spontaneous leukemia, although the resistance of this strain to all causes of death is so great, and the appearance of leukemia is so delayed, that this marked susceptibility was not recognized until a special study was recently completed. Dr. Gasić came to this laboratory as a Fellow of the John Simon Guggenheim Memorial Foundation from the University of Chile, Santiago, to test upon leukemic growth the efficacy of different steroid hormones, which had been found by Dr. A. Lipschiitz, of the Chilean National Health Service, to have a striking influence on fibrous tumors in guinea pigs. Using a virulent line of transplanted mouse leukemia, Gasić found that death was delayed slightly (less than one day) in mice treated with pellets of testosterone propionate, but that desoxycorticosterone and progesterone had no effect on the time of death. Gasić has pointed out that many of the features of the alarm reaction of Selye are shown by mice dying with highly virulent transplanted leukemias. Biesele has found that normal chromosome size varies with age in the rat. According to the tissue, there is an increase, a constancy, or a decrease. Similarly, in normal lymphatic tissue of C58 mice there is an ontogenetic decrease in size of chromosomes, but in the transition to spontaneous leukemias and from them to long-transplanted leukemic lines there is an increase in size of chromosomes, which occurs gradually rather than by aa abrupt doubling. Chromosome size in leukemic cells is influenced by the sex of the host and can be modified by means of male sex hormone.

Kaufmann has continued his analysis of the mechanism of chromosome breakage and recombination by treating spermatozoa of *Drosofhila* with combinations either of X-rays and ultraviolet rays or of X-rays and near infrared rays. Ultraviolet radiation of wave length 2537 A, when it penetrates spermatozoa previously exposed to X-rays, effectively reduces the frequency (as compared with the controls) of chromosomal rearrangements that are detected by analysis of salivary-gland chromosomes. Near infrared radiation likewise, under certain conditions of treatment, will reduce the frequency of chromosomal rearrangement; but the effect is not directly on the regions of X-ray-induced breakage, as with the ultraviolet radiation, but on those processes that make spermatozoa that were not mature at the time of treatment available for transfer in copulation. When treatment with near infrared radiation precedes X-ray exposure, the chromosomes are effectively sensitized to breakage by the X-rays, as is indicated by the higher frequency of detectable rearrangement as compared with the controls. On the basis of the extensive data (about 3750 pairs of glands) collected in these and other studies, Kaufmann has re-examined the question of chromosome recombination, and now reports that, so far as the X chromosome of *Drosophila melanogaster* is concerned, the degree of randomness of recombination varies according to whether the breaks occur in euchromatin or in heterochromatin.

Demerec has developed a special technique for detecting in *Escherichia coli* mutants resistant to bacteriophages, which involves applying the phage to the culture in the form of a fine aerosol. With material treated with ultraviolet radiation of wave length 2513 A, evidence was obtained that the increased mutation rate induced by irradiation persists over a considerable period of time, presumably through a number of cell divisions. Luria has detected two types of resistance to penicillin in *Staphylococcus.* In one type the bacteria are resistant because they secrete penicillinase; in the other type there is no evidence for an inactivator of penicil-

lin. Mrs. Witkin has found that difference in resistance to ultraviolet in *E. coli* is due mainly to a difference in the ability of bacteria to initiate division after irradiation. Demerec has devised a method for treating adult *Drosophila* with aqueous solutions of various chemicals by keeping the flies in an atmosphere containing an aerosol of the solution in question. Observations made by Dr. Jack Schultz, of the Lankenau Hospital Research Institute, on flies treated with aerosols of various dyes indicated that the material was present in the crop and digestive organs of the flies and, in some instances, in the testis.

Th. Dobzhansky, Research Associate of the Institution, has been investigating the rapid evolutionary changes discovered in natural populations of the fly *Drosophila pseudoobscura* in certain localities in California. These changes seem to be connected with the annual climatic cycle: some genetic variants become more frequent in the populations during the summer and other variants during the spring. The causative agent that operates here is natural selection; some variants are more favorable in spring and others in summer environments. This is interesting in itself, because very few well established instances of observable changes produced by natural selection are known. What makes the case of *Drosophila pseudoobscura* unique is that the changes observed in nature can be reproduced in part in the laboratory. For this purpose, artificial populations of flies of this species are set up in specially constructed "population cages," and samples of these populations are taken and examined from time to time. The most significant result to date is that in population cages kept at higher temperatures (25° C.j or summer room temperatures) changes are observed which coincide both in direction and in speed with those taking place in natural populations during the summer. At lower temperatures (16^0 C.) the composition of the populations in the population cages remains constant. This shows that the advantages or disadvantages that a genetic variation may produce in an organism are greatly dependent on even relatively small changes in the environment: at 25° C. some of the variants involved in these experiments are much superior to others in the struggle for survival, whereas at 16^0 C. all seem to be equally viable. Now, natural populations of at least some organisms are composed of mixtures of numerous genetic variants, with different environmental optima and different responses to changes that may occur in the milieu in which they live. This fact permits us to understand the remarkable adaptability shown by species of many organisms, within short intervals of time as well as in geological time, which is one of the most important phenomena of evolution.

Warmke has continued his investigations of polyploidy and sex in *Melandrium.* He has found that the spontaneous breakage of the Y chromosome observed previously is associated with bridge formation, particularly at the second meiotic division. By studying plants with various types of Y-chromosome deficiency, which arose from the spontaneous breakage, he has been able to resolve the process of male development into three separate steps: (1) the initiation of maleness, (2) the completion of maleness, and (3) the suppression of femaieness. The first of these processes is controlled by a gene or genes near the centromere of the Y chromosome, the second by a gene or genes near the top of the differential arm, and the last by a gene or genes near the end of the homologous arm. These steps appear to be qualitatively distinct from one another.

During the fall of 1944, McClintock spent a period of ten weeks at the Bio-

logical Laboratories of Stanford University and undertook a preliminary investigation of the chromosomes of *Neurospora*. Recent investigations with fungi have demonstrated their superiority as genetic materials, but little has been done to coordinate the genetic studies with studies of chromosomal conditions. If the full advantages of fungi as genetic materials are to be realized, a knowledge of chromosomal conditions and behavior is requisite. Many genetic investigations would be simplified and our understanding greatly enhanced if concomitant cytological analyses could be made. The brief study of the chromosomes and their behavior in *Neurospora* has suggested not only that some fungi are superior genetic materials, but also that they may be adequate and in some respects superior cytogenetic materials. The observations of *Neurospora* included determinations of chromosome number, absolute and relative sizes of chromosomes, centromere positions, internal organization of the chromosomes, zygote formation, and chromosome behavior in the two meiotic mitoses and the equational mitosis that follows, as well as scattered observations of several chromosomal translocations. Several phenomena of considerable theoretical interest were noted; in particular, the contracted state of the chromosomes at the time of synaptic association. On returning to Cold Spring Harbor, Dr. McClintock resumed her studies with maize. These studies are aimed at the production of mutations in a specific segment of the chromosomal complement. If our knowledge of the mutation processes is to advance, some methods should be devised for the induction of specific mutations, and some understanding should be obtained of the phenomena associated with the origin of these mutations. Previous investigations with maize have suggested a possible method. The very special behavior in successive nuclear divisions of a recently broken end of a chromosome was utilized as the mutation-inducing agent. In these studies, the short arm of chromosome 9 was the particular segment of the chromosomal complement under investigation. Theoretical considerations had indicated that it should be possible to obtain a number of new mutations located at various positions throughout the full short arm of chromosome 9. To date, 69 mutations have been located in the short arm of chromosome *g*, but they represent only 7 distinct types because of the repeated occurrence of the same mutations. New phenomena of chromosome behavior and new mutants with provocative phenotypic expressions have appeared as a part or an adjunct of these experiments.

Because of the increasing pressure of his duties at the Ballistic Research Laboratory, Fano could not continue to act as scientific adviser for the Survey of the Human Resources of the State of Connecticut. Therefore Dr. Ruby Jo Reeves Kennedy, of the Connecticut College for Women, New London, Connecticut, has taken his place as scientific adviser; Miss Mabel A. Matthews, Director of the Social Service Department of the Mansfield-Southbury Training Schools, is in charge of the project.

Dr. S. G. Stephens is spending a year with us as a Research Associate of the Department. Dr. Edgar Anderson, of Washington University, St. Louis, Missouri, and Dr. William L. Brown, of the Pioneer Hi-Bred Corn Company, Johnston, Iowa, spent about three weeks in June and July working with Dr. McClintock. A number of geneticists worked during the summer at the Biological Laboratory, in close contact with our Department. These included Max Delbriick, of Vanderbilt University; Myron Gordon, of

the New York Zoological Society; Ernst Mayr, of the American Museum of Natural History; Jack Schultz, of the Lankenau Hospital Research Institute; and C. C. Tan, of the National University of Chekiang, China.

CYTOGENETIC STUDIES OF MAIZE AND NEUROSPORA

BARBARA MCCLINTOCK.

INDUCTION OF MUTATIONS IN THE SHORT ARM OF CHROMOSOME 9 IN MAIZE

In the past, many methods have been used to induce mutations. The majority of these methods do not give rise to specific mutations or to mutations confined to specific regions of the chromosome complement. Instead, a random assortment and distribution of mutations are obtained. A better understanding of the factors involved in the mutation processes would be possible if specific mutations associated with specific regions of the chromosomal complement could be effected. Recent investigations with maize have suggested several approaches to the problem of induction of specific mutations. One of these will be considered in this report. In previous reports, the repeated induction of the mutants *pyd* (pale-yellow seedling), *wd* (white seedling), and *yg* (yellow-green seedling and plant) has been described. Their origin has been associated with the behavior in several successive nuclear divisions of a recently broken end of a chromosome. This behavior has been called the chromatid type of breakage-fusion-bridge cycle. The *pyd* mutant appeared when the chromosomal complement was deficient for a small terminal segment of the short arm of chromosome 9; the *wd* mutant appeared when a slightly longer terminal segment was missing. The mutant phenotype *bz* (bronze) has likewise appeared following the production of a specific internal deficiency, as previously described. From this and other types of evidence, it has been concluded that specific mutations will arise as the consequence of specific minute deficiencies. If the breakage-fusion-bridge cycle could give rise to a number of different internal minute deficiencies, and if the short arm of chromosome 9 were subjected to this process, various new mutants other than *pyd, wd, yg,* and *bz* should appear, each related to loss of a specific minute segment within this arm. The methods used to isolate the mutants *pyd, wd, yg,* and *bz* were selective. Therefore, a random sample of mutants which might be produced as the consequence of the breakage-fusion-bridge cycle did not appear. During the past year, nonselective methods have been used to determine whether the expected new mutants actually are being produced.

Cytological observations of the breakage-fusion-bridge cycle," as well as theoretical considerations, have indicated that this cycle will result in the production of internal deficiencies. Occasionally, a chromatid bridge in an anaphase figure is broken at more than one place. If a chromatid bridge breaks in three places, two centric chromosomes with a single broken end and two acentric fragments, each with both ends broken, will be formed. It is possible for the two fragments to enter one telophase nucleus along with the centric chromosome. If, in this nucleus, a particular type of fusion of broken ends occurs, a centric rod chromosome, with an internal deficiency and an acentric ring fragment can be produced (following fusion of the two broken ends of the proximal fragment to form an acentric ring, and fusion of one broken end of the distal fragment with the broken

end of the centric chromosome). If the remaining free broken end of the centric rod chromosome healed and no longer underwent the breakage-fusion-bridge cycle, a chromosome with an internal deficiency might subsequently be isolated. Sufficient cytological evidence has accumulated to support the assumption that this is one method of origin of internal deficiencies. Theoretical considerations suggest a second method for obtaining internal deficiencies. Many investigators have considered the anaphase chromosomes to be multiple, that is, composed of two or more sister strands. It is probable that effective doubleness at anaphase is present in some cells or tissues and not in others. Should a chromatid bridge at anaphase be composed of two sister strands, breakage need not occur at comparable positions in the two strands. Should the breakage be unequal, the chromatin composition of the two sister strands entering a nucleus would not be comparable. They could differ by various duplications or deficiencies. If, in the following telophase, fusion occurred between the two broken ends of the unequal strands, the chromatin components between the two centromeres would consist of two dissimilar instead of similar segments. A chromatid bridge and breakage of this bridge would follow in the next mitotic division. Should the resulting newly broken end heal permanently, it might be possible subsequently to isolate a chromatid with an internal deficiency. The type and extent of deficiency would depend on the positions of breakage in these two divisions. This process would give rise to internal deficiencies without fragment formation. Again, theoretical considerations have suggested that the *chromosome* type o£ breakage-fusion-bridge cycle (see previous reports) should result in chromosomes with internal deficiencies ranging from minute to extensive. Therefore, both the chromatid and the chromosome type of breakage cycle have been utilized in an attempt to produce and isolate new mutations confined within the short arm of chromosome 9.

To isolate new mutants produced by the *chromatid* bridge cycle, F2 progeny derived from Fi plants that had received a recently broken chromosome 9 from one parent were examined. To isolate new mutants produced by the *chromosome* bridge cycle, the selfed progeny of individuals that had received a newly broken chromosome 9 from each parent were examined. In many cases, the constitution of the short arm of the chromosomes 9 with healed broken ends had been considerably altered during the period of the breakage cycles. Large as well as small duplications or deficiencies frequently were present. Many of these altered chromosomes 9 did not pass through the gametes to the next generation. Whenever the pollen grains and eggs carrying the chromosomes 9 with altered short arms were capable of effecting fertilization, the selfed progeny could include individuals homozygous for these altered short arms. Should an alteration, when homozygous, result in a changed phenotype, individuals with a distinct mutant character would appear in the progeny. Considerations of space and labor confined the search for new mutations mainly to the kernels and the seedlings. A number of new mutants appeared in these progenies. The most clearly defined of these mutants were selected to determine whether or not they were located in the short arm of chromosome 9. Only 3 of the distinctly new types of mutant have been sufficiently analyzed to indicate their positions in the short arm. These are a small-kernel mutant *(sm{)*, a spotted-leaf mutant *(spl)*, and a pale-green mutant *(pg)*. The *sm* and *spl* mutants

are located in the distal third of the short arm, whereas *pg* is located between the mutants *sh* and *wx.* Many new *pyd* and *wd* mutants and a few new *yg* mutants appeared in these cultures. Although 69 mutants arising from newly broken chromosomes 9 have been tested, they represent only 7 distinct phenotypes because of the repeated occurrence of the same mutations. In the published linkage group of chromosome 9, 7 spontaneously arising mutants have been placed in the short arm. The symbols for these are: *Dt, yg, C, sh, bz, bp,* and *wx.* The newly broken chromosomes 9 have given the 7 mutants *pyd, wd, yg, sm\, spl, bz,* and *pg.* As has been stated previously, the *yg* and *bz* mutants derived from the broken chromosomes 9 are allelic to the 2 mutants, *yg* and *bz,* that arose spontaneously in genetic cultures.

An interesting type of chromosomal behavior has appeared in three of the broken-chromosome cultures mentioned above. In each culture, one of the broken chromosomes 9 is continually being lost from cells during development. This loss is not due to bridge formation or to ring chromosome behavior, but appears to be caused by the inability of the two halves of this chromosome to migrate to opposite poles in some of the somatic anaphase figures. The rate of loss varies widely from plant to plant. Within a single plant, changes in rate occur; this is made evident by the presence of distinct sectors each with its own rate of loss. To date, only a cursory examination of the nature of this phenomenon has been made; it warrants further study. In addition, some of the mutants appearing in these cultures are individually provocative. Several show variegation characterized by a change from mutant to normal-appearing tissues. For any one plant, a distinctive or basic rate of change is apparent, but this basic rate differs from plant to plant. Sectors with changed rates of variegation appear in all plants, especially in the later-appearing tissues. It is significant that twin sectors accompany many if not most of the alterations in rate; this is expressed by the appearance of a sector of tissue having a greatly increased rate of variegation immediately adjacent to a sector of tissue having a much reduced rate of variegation.

PRELIMINARY STUDIES OF THE CHROMOSOMES OF THE FUNGUS NEUROSPORA CRASSA

During the fall of 1944, a period of ten weeks was spent in the Biological Laboratories of Stanford University, where genetic studies are being conducted with the fungus *Neurospora.* The purpose of this visit was to obtain some knowledge of chromosomal and nuclear behavior in *Neurospora crassa.* Although fungi have assumed an important role as genetic materials, little has been done to coordinate the genetic studies with a study of chromosomal conditions. As genetic investigations with fungi progress, the necessity for correlative cytogenetic analyses will become increasingly evident. It was a pleasure to have the opportunity of examining *Neurospora* in this laboratory. Progress was greatly accelerated by the availability of large numbers of stocks, both wild-type and mutant, and by the generous and cooperative support of the members of the department.

The observations were confined to the chromosomes and nuclei of the ascus. They included observations of chromosome numbers, absolute and relative sizes of the chromosomes, centromere positions, internal organization of the chromosomes, zygote formation, chromosome behavior in the two meiotic mitoses and the equational mitosis which follows, and scattered observations of several chromosomal translocations. In the short time available, no

one of these topics could be adequately considered. Nevertheless, this over-all survey has suggested that some fungi may be adequate and, in several respects, superior material for cytogenetic studies.

The haploid number of chromosomes in *Neurospora crassa* is 7. Each chromosome of the complement is distinguished by its relative length, the position of its centromere, and its internal organization. The longest chromosome is approximately 2.7 times as long as the shortest. The second-longest chromosome, chromosome 2, has a nucleolus organizer located close to the end of the short arm. The organizer region functions to produce a nucleolus in a manner similar to that observed in many other organisms. Because of its location close to the end of one arm of this chromosome, a minute satellite is formed. Throughout the various nuclear cycles, the relative lengths of the chromosomes of the complement are maintained. Therefore, absolute lengths need be given only for the longest chromosome. In the third division in the ascus, which is cquational, this chromosome may be only 1.5 microns long. At the full mciotic prophase extension, it may be 15 microns long. Chromomere patterns were observed at this latter stage; each chromosome appears to have its characteristic pattern. Centromere positions were adequately determined for the two longest chromosomes, and approximate positions were obtained for the other five chromosomes. ' Two heterochromatic segments were observed and located adjacent to the centromere, but the chromosome or chromosomes carrying these heterochromatic segments were not Identified.

Fusion of two haploid nuclei to form the zygote nucleus occurs in the very young ascus. The two sets of chromosomes in this zygote nucleus then commence the activities associated with meiosis. The behavior of the chromosomes in the early meiotic stages is of considerable theoretical interest. During meiosis in most organisms, homologous associations commence when the chromosomes are in a very elongated state. In the *Neurospora* strains most intensively studied, this occurs when the chromosomes are greatly contracted. Following nuclear fusion, the chromosomes contributed by each nucleus undergo what appears to be a typical prophase contraction without visible evidence of splitting, until, in some strains, the chromosomes are almost as short as those of the metaphase of the third division in the ascus. In this highly contracted state, the homologous chromosomes commence their synaptic associations. Before the chromosomes have reached this state, fusion of the nucleoli contributed by the two nuclei usually has occurred. Actual physical association of the homologues usually begins at one or both ends and continues along the chromosomes. In many nuclei, synapsis is completed for some pairs of chromosomes before the members of the other pairs have approached sufficiently close to each other to commence actual contacts. It is not clear from these studies whether the approach of homologous chromosomes toward each other is directed or whether it follows from random movements of the chromosomes in the nucleus. It is of considerable theoretical interest to determine the range of the synaptic force which brings about homologous associations of chromosomes. It is suspected that the young asci of *Neurospora* might be readily cultured. Because of the relatively large volume of the nucleus and the small size of the chromosomes in these asci, continuous observations of the behavior of these chromosomes in the living nuclei might he possible.

Following the synaptic phase, the associated homologous chromosomes begin to elongate until, as stated above, the longest

chromosome may reach a length of 15 microns. Diplotene sets in rather suddenly following the completion of elongation of the synapsed chromosomes. The period from diplotene to metaphase I is passed through very rapidly. At diakinesis, typical chiasmata may be observed leading to rather orthodox, even though small, metaphase I bivalents. Although the nucleolus becomes smaller during the prometaphase stage, it is still present at metaphase. Chromosome 2 remains attached to the nucleolus by its organizer region. Anaphase I appears to be essentially typical except for the presence of the nucleolus. The nucleolus may be dragged toward one pole or stretched between the poles because the nucleolus organizer of one or more chromatids of chromosome 2 still remains attached to it. The nucleolus becomes detached before telophase sets in. At telophase I, and likewise at telophases II and III, the centromere regions of all the chromosomes form an aggregate that lies at the apex of a distinct protrusion of the nucleus (the beak). No true resting nucleus is formed. Instead, the chromosomes uncoil, the individual arms of each chromosome extending into an elongated nucleus. A new nucleolus is formed and remains attached to the nucleolus organizers of chromosome 2. Contraction of the chromosomes initiates prophase II. This continues until the two dyad chromosomes are in the form of short, parallel rods, each showing a conspicuous centromere region. Metaphase and anaphase II are essentially typical. At telophase II the centromere regions are again aggregated at the apex of the beak of the nucleus; the chromosomes uncoil and the two arms of each chromosome extend into the nucleus as individual strands. They remain in this condition until the following prophase. The extent of elongation of the chromosomes appears to be similar to that observed in the meiotic prophase. In each nucleus, a new nucleolus is formed at the position of the nucleolus organizers of chromosome 2. Prophase III is initiated by contraction of the arms of the chromosomes. The metaphase and anaphase of division III proceed as a typical equational mitosis. The resting stage of nuclear organization follows telophase III. Shortly after spore delimitation, a mitosis occurs in each ascus. This is also a typical equational mitosis. In essential details, divisions I and II are typically meiotic. Division III is essentially a somatic mitosis, except that the chromosomes retain their identity as elongated strands from the telophase of division II to the prophase of division III. The time of effective splitting of the chromosomes for this division is of some theoretical interest.

Because many of the mutations in *Neurospora* have appeared following X-ray and ultraviolet irradiation, it was suspected that various types of chromosomal translocation might likewise have been induced by these treatments. Three irradiation-induced mutants, whose genetic behavior suggested the presence of some chromosomal abnormality, were selected for examination. A translocation between two nonhomologous chromosomes was found in each case. Intensive studies of these translocations were not undertaken, but the preliminary observations have suggested the usefulness of some translocations for attacking special problems.

POLYPLOIDY INVESTIGATIONS

H. E. WARMKE, HARRIET DAVIDSON, AND GERMAINE LECLERC

The work of this laboratory during the past year has been largely devoted to a study of spontaneous breakage of the Y chromosome in *Melandrium* and to an investigation of the number, position, and mode of action of the male genes made available for study by such breakage. The beginnings of these studies were mentioned last year, at which time certain contradictory observations were noted. Now these apparent contradictions have been resolved, and the essential facts stand out clearly.

These studies had their inception with the discovery that the chief male-determining genes in *Melandrium* are located in a single chromosome, the Y. This knowledge, and the development of inbred plants of the constitution 2A XXY, made possible an analysis of maleness in *Melandrium* similar to the analysis of femaleness made by Dobzhansky and Schultz, Pipkin, and others in *Drosophila;* that is, a determination of whether sex is controlled by a single or by many male-determining genes, and something of the location of this gene or genes in the Y chromosome. No similar investigation of maleness has been made previously, on either plant or animal material, so far as we are aware.

BREAKAGE OF THE Y CHROMOSOME IN 2A XXY PLANTS

Cytological examination of plants with broken Y chromosomes shows that fragments are constant in size in all parts of a given plant. This evidence, together with the absence of sectorial chimeras, indicates that the breakage does not occur somatically, but is a meiptic phenomenon. This inference was borne out by the discovery of meiotic bridges, involving the Y chromosome, apparently in sufficient numbers to account for the observed incidence of breaks.

These bridges, however, are not of the usual type, which results from crossing over in heterozygous inversions. The bridges observed in 2A XXY individuals of *Melandrium* appear to be restricted largely to the second division, and are not accompanied by acentric fragments. Though the exact cause of bridge formation is not clear, it appears to be associated with asynapsis of the Y chromosome. There is a close correlation between the amount of asynapsis and of bridge formation, and the number of broken Y chromosomes recovered.

When the Y chromosome fails to synapse with either of the X's, it behaves as a univalent at meiosis. If it is not on the spindle at the first division, and is by itself, it may form a separate micronucleus; or, if it happens to lie near one of the poles, it may become incorporated in one of the daughter nuclei. In this latter case it splits longitudinally at the second division, and the two chromatids separate normally. If, however, the asynaptic Y comes to lie on the first-division spindle, it divides somewhat later than the other chromosomes but nevertheless one whole division cycle ahead of normal. The sister halves of such a precociously dividing Y chromosome may become incorporated in the telophase nuclei of the first division; or they may not have separated in time to be so included, and in this case they form small accessory nuclei. In either event they behave abnormally at the second division. Having already divided at the first division, they do not divide again at the second; instead they become laggards, are not under the control of their centromeres, and are variously distributed on the

spindle during the second division. These laggards, when caught by the spindle forces, are stretched and, it is believed, form the bridges which break and give rise to the observed Y fragments.

NUMBER, LOCATION, AND MODE OF ACTION OF MALE-DETERMINING GENES

As the result of selling 2A XXY plants, the normal offspring—2A XXY (male-hermaphrodite), 2A XX (female), 2A XY (male), and 2AXYY (supermale)—are obtained, and in addition two abnormal hermaphrodite types appear. These are: (1) a type in which the female structures are highly developed, essentially as well developed as in 2A XX females and with normal stamens; and (2) the type described last year, in which there is a complete failure of stamen development shortly after meiosis. These segregants are easily distinguished from the normal types, and cytological examination has shown them to be associated with breaks in the Y chromosome. The first type occurs when the homologous (synaptic) arm of the Y is deficient. Deficiencies may range in size from a short terminal loss to one which appears to include the entire or nearly the entire homologous arm. It is interesting that the degree of abnormality is not proportional to the length of the deficiency; once a small terminal segment is lost, this phenotype appears, and larger losses do not cause more pronounced effects. One can be certain in such cases that the homologous arm, and not the differential arm, is the deficient one, by the fact that deficiencies in the homologous arm cause complete asynapsis of the Y chromosome. The asynaptic Y, as noted above, behaves as a univalent and is obvious in all figures. The segment that pairs with the X thus appears to be terminal and quite short; losses of as little as one-fourth or one-fifth of the arm prevent synapsis.

The second abnormal type of segregant, in which male development is arrested short of completion, with resultant male sterility, appears when there is breakage of the differential arm of the Y chromosome, or combined differential and homologous breakage. As with deficiencies in the homologous arm, a small terminal loss in the differential arm is sufficient to evoke the effect, and larger deficiencies do not increase this effect. Plants that have lost as little as one-fourth of the differential arm are male sterile and indistinguishable from plants that have lost most of both arms. The Y, in extreme cases of this latter type, may be represented at meiosis by only a small spherical fragment, smaller in diameter than the normal width of a chromosome, and in somatic mitosis by a fragment shorter than the smallest autosome. These fragments, down to the smallest, retain their centromeres and are carried through the mitotic growth divisions to every cell of the plant; only in rare cases and with the very smallest fragments is there evidence that somatic loss may occur.

The above observations are interpreted as indicating that maleness in *Melandrium* is not controlled by a single gene, or by an extremely large number (as is the case with femaleness in *Drosophild).* Specifically, there appear to be at least three genes or *gene* complexes in *Melandrium* that operate in the development of maleness, and more may well appear as more deficiencies are discovered. First, there is one near the centromere, and present in the smallest observed fragments of the Y chromosome, which *initiates male development.* Plants which lack this proximal part of the Y, as when it is lost somatically or is not originally present (2A XX types), are normal females; when this proximal segment is present stamens do develop, but just past meiosis. Second, there is a gene (or group of associated genes) near the

end of the differential arm of the Y that *completes male development.* When the entire differential arm is present full male development results, but when as little as one-fifth of the arm is absent in terminal deficiencies, male development stops where the male-initiating influence left-off. Third, there appears to be a gene or region in the terminal fourth of the homologous arm of the Y which *suppresses femaleness.* Whether this is in the pairing segment or not is uncertain. When the entire Y chromosome is present (in addition to two X chromosomes), female structures are poorly developed; in only a small percentage of the blossoms are ovaries sufficiently well developed to set capsules with seed. When the homologous arm is deficient—that is, when this particular region is removed—female development is complete, and every blossom produces seed-filled capsules. Thus experimental evidence indicates that this part of the Y chromosome acts when present as a positive suppressor of the female-determining regions in the X chromosomes.

Basically it is important to know whether the genes controlling these three steps in male development are qualitatively different and control different reaction systems, or are only quantitative stages in a common over-all process. At least a partial answer to this question is now possible, because of evidence obtained from two newly derived types of plants. These are plants with two sets of autosomes, two X chromosomes, and two deficient Y chromosomes.

One of these types had two Y fragments comprising the proximal region (the region necessary for the initiation of male structures), but none for male completion or female suppression. These two Y fragments, though unquestionably exceeding a complete Y in total amount of chromatin, did not combine to produce complete maleness. These plants were phenotypically indistinguishable from plants with only a single proximal Y fragment; they were male sterile because of incomplete male development.

A second and somewhat similar type has recently been synthesized; it has two Y fragments, each lacking the distal part of the homologous arm, that is, the female-suppressing region. These plants, though having two male-initiating segments and two male-completing segments, still are not able to suppress femaleness. It would thus appear that the genes governing these three essential steps in male development are qualitatively distinct from one another in their action and cannot be substituted one for another in a quantitative fashion.

THE GENE

M. DEMEREC AND S. E. LURIA

ULTRAVIOLET IRRADIATION AND MUTATIONS IN ESCHERICHIA

Experiments with ultraviolets and X-rays were undertaken as a part of the program for studying the origin of bacterial resistance to various agents (Year Book No. 43). In experiments conducted by M. Demerec in collaboration with Miss M. Crippen and Miss N. McCormick, strain Br of *Escherichia coti* was treated with ultraviolet radiation of wave length 2513 A, and the rate of mutation from B to B/i—that is, to resistance to bacteriophage Ti—was observed.

Bacteria were plated on Petri dishes and incubated. The controls begin to divide after about 50 minutes, and the bacteria treated with ultraviolet radiatioh after about 2 hours. Once they start to divide, the division periods are regular, one every 20 minutes. Therefore, if the number of bacteria put on each plate is known, the

number at subsequent periods can easily be estimated. Phage sprayed as an aerosol does not disturb the position of bacteria on a plate. It will eliminate all sensitive individuals, and the resistant ones.will remain to form colonies. The number of mutations that has occurred during a certain interval can readily be determined by finding the number of resistant colonies at the beginning and at the end of the interval. The advantage of this method of applying phage is that the positions of bacteria are not changed. If mutation occurs early in the interval, a mutant bacterium will divide and produce several resistant bacteria, but all of them will be close together and will form only one colony.

In one set of experiments, the control series showed a mutation rate of about i to 2 X io^{-8}, which is similar to that observed previously in untreated material. In a series treated with a dosage which kills about 98 per cent of bacteria, the mutation rate among bacteria immediately following treatment was about 2 X io^{-6}; among bacteria developing during the first 2 hours of incubation (one cell generation after treatment), the rate was about 4 X io^{-6}; among those developing during the interval between 2 and 3 hours (2d and 3d cell generation) after treatment, it was about 2 X io^{-6}; and among those developing during the interval between 3 and 4 hours (4th to 6th generation) after treatment, it was about 3 X io~\ Results of another series of experiments indicated that the mutation rate reaches its normal level after the bacteria have passed through ten to twelve divisions.

These data show that the increased mutation rate induced by ultraviolet irradiation persists over a considerable period of time, presumably through a number of cell divisions. Experiments are now under way to trace down the reasons for this persisting effect.

BACTERIAL RESISTANCE

Last year's report (Year Book No. 43, pp. 109-110) contained a summary of work on the genetic aspects of the origin of resistance to penicillin of *Staphylococcus* bacteria. Results of that work indicate that resistant bacteria occur as mutants independently of the action of penicillin, that resistance develops in steps, and that the progress of the building up of resistance is more rapid with each step.

In June 1945, an extensive research project was started, dealing with the genetics of acquired bacterial resistance to drugs and other antibacterial agents. Dr. S. E. Luria, who is on leave of absence from Indiana University, is taking a leading part in this research. In July and August he was joined by Dr. E. Oakberg, Mrs. E. Oakberg, Miss R. Arbogast, and Mrs. E. Witkin.

The scope of this project is twofold. Its aims are, on the one hand, to solve practical problems arising from bacterial resistance to therapeutic agents, and, on the other hand, to obtain fundamental knowledge about bacterial genetics—in particular, about the mutational patterns of bacteria and the underlying physiological mechanisms. The present approach to this problem is based on the analysis of the distribution of mutant individuals in uniparental populations made by Luria and Delbriick in 1943. This analysis has been applied successfully to the study of bacterial resistance to bacteriophages (Luria and Delbriick, 1943; Demerec and Fano, 1944) and to penicillin (Demerec, 1945).

The present project includes work on resistance to penicillin, sulfonamides, inorganic salts, bacteriophages, and ultraviolet radiation. The work on penicillin resistance is directed toward clarification of several complex aspects of this phenomenon. Two types of penicillin resistance can

occur. In the first type the cells acquire, by mutation, tolerance to higher concentrations of the antibiotic, without other evident physiological changes, as described by Demerec. In the second type the organisms secrete an inactivator of penicillin (penicillinase), which protects them from penicillin although they are individually sensitive. The genetic basis of this second type of resistance is still obscure. In the course of the work, a rapid quantitative test for penicillin resistance in staphylococci has been devised for use in medical laboratories.

The problem of acquired resistance to sulfonamides has met with several difficulties because of the peculiarities of the phenomenon of bacteriostasis; in particular, because of its complex dependence on the initial number of bacterial cells present in a culture. This and other aspects of the problem are being methodically investigated.

Work on bacteriophage resistance is being continued with an analysis of complex mutations involving unusual changes in the resistance pattern of bacteria. Study of these mutations is being extended to an analysis of the correlated changes in growth-factor requirements. It is also planned to attempt investigation of the cytological aspects of the problem by nuclear stainings.

The occurrence of bacterial resistance to ultraviolet radiation, discovered by Mrs. Witkin last year (Year Book No. 43, pp. 110-111), is being further investigated. Resistance seems to be due mainly to a difference in the ability of bacteria to initiate division after irradiation. Improved techniques have been developed for an analysis of this type of resistance, and for investigation of the possibility that mutations to ultraviolet resistance, besides occurring spontaneously, are also induced by the radiation itself.

DEVELOPMENT OF A HIGH-YIELDING STRAIN OF PENICILLIUM

Beginning in September 1943, Mrs. Sansome and M. Demerec, in collaboration with Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland, started experiments to produce, by means of X-ray and ultraviolet irradiations, strains of *Penicillium* that would give high yields of penicillin. Experiments were conducted on a small scale until May 1944, when a contract with the War Production Board became effective and funds were made available for additional equipment and special assistants to carry on routine tests. At that time Dr. H. E. Warmke joined the group. The work was continued at the Department until November 1944. Since early in 1944, similar work, also under contract with the War Production Board, had been going on at the laboratories of Stanford University, the University of Minnesota, and the University of Wisconsin.

Penicillin may be obtained from a culture medium when *Penicillium* is grown on its surface, or when it is submerged and aerated by shaking or by bubbling air through the medium. At the time we joined the project it was known that high surface yielders may not be high yielders in submerged cultures, and vice versa. Manufacturing experience had indicated also that submerged culturing is more efficient and economical than surface culturing. Therefore, the aim of the project was to develop high-yielding strains with submerged culturing. Since a considerable amount of equipment is necessary for complete tests of the yielding capacity of submerged strains,, it was decided to divide the work so that the irradiation and the preliminary rough screening tests to isolate possible high yielders would be carried out at our laboratory; further tests for

yielding capacity would be made at the University of Minnesota laboratory, where large shaking machines were already available; and the final tests would be carried on at the University of Wisconsin in 80-gallon tanks.

For efficient planning of experiments, it was essential to acquire certain fundamental knowledge about the reaction of *Penicillium* to X-rays. It is known that the frequency of mutations is proportional to the dosage, and also that the rate of killing of the treated spores increases with the dosage. The most efficient dosage for our experiments, therefore, was that which would produce a sufficiently high frequency of mutations and at the same time leave enough survivors.

In order to establish this dosage, the mutation rate and killing rate were determined on spores treated with 25,000, 50,000, 75,000, and 100,000 r-units. Spores were treated both dry and in saline suspension. Detailed results of these experiments are published in last year's report (Year Book No. 43, p. 113). On the basis of these results, a dosage of 75,000 r-units was selected for our experiments.

Tests were also conducted to find out whether the mutation rate or the germination rate of treated spores deteriorates when they are stored in a refrigerator. Since it was found that deterioration does not occur, it was possible to treat large batches of spores and to store them for subsequent use.

The majority of cultures obtained by irradiation of a high-yielding strain may be expected to have the same high-yielding capacity as the original strain. Consequently, the quick assay methods designed to screen out low yielders are not applicable to these cultures. What is needed is a quick assay method which will pick out the exceptional high yielders. In a search for such a quick screening method it was thought worth while to investigate the possibility that the pellets formed in shaker flasks originate from single spores, in which case the penicillin-producing capacity of single pellets could be tested directly. An experiment designed to test this possibility revealed that pellets are formed from a mixture of mycelia originating from several spores.

After experimentation with various techniques, a standard procedure for making tests was developed. Spores of *Penicillium chrysogenum* were X-rayed *on* agar slants with 75,000 r-units. The irradiation was given by Mr. L. D. Marinelli at the Memorial Hospital in New York, at an intensity of 2420 r per minute. Treated spores were spread on the surface of potato-dextrose-agar plates; and immediately after germination they were isolated into test tubes containing 2 cc. of liquid culture medium. These were put into the shaker machine, which had a 4-inch horizontal stroke and operated at 250 strokes per minute. The tubes we used had an inside diameter of 10 mm. and were no mm. long. The size of tubes and the amount of nutrient in each tube is determined by the properties of the shaker. After 5 days of continuous shaking, a sample of the medium taken from each tube was diluted 100 times and assayed for penicillin content by the cup method, using *Staphylococcus aureus* (NRRL strain B313). Tubes showing a high yield were saved and the fungus growing in them was cultured; the remaining tubes were discarded. In this way about 90 per cent of the cultures were eliminated as low or average yielders, and 10 per cent were saved as possible high yielders and were shipped to the Division of Plant Pathology, University of Minnesota, St. Paul, for further tests. All together, 504 selected strains were sent to Minnesota. One among these was the strain now known as X-1612, which yields

about twice as much penicillin as the strain 1951.B25 from which it originated. This new high-yielding strain is now used in production of penicillin.

AEROSOL METHOD FOR CHEMICAL TREATMENT OF DROSOPHILA MELANOGASTER

In the course of extensive studies dealing with the induction of mutations in *Drosophila* by means of X-radiation, efficient methods have been developed for detecting induced as well as spontaneously occurring mutations. Dr. H. J. Muller developed the most useful one, which is designed to detect lethal mutations occurring in the sperm of male flies. The great advantage of this method is that one treatment reaches a large number of mature sperms, which may easily be tested for induced changes.

For many reasons it would be desirable to have a similar method for use in studies that attempt to induce mutations by means of various chemicals; specifically, a method whereby the male gonads could be reached without excessive injury to the flies and without its being necessary for the chemicals to pass through the digestive organs, where they might undergo change.

It has been shown by Auerbach and Robson (Nature, vol. 150, p. 80, 1944) that mutations may be induced in *Drosophila* sperm by exposing males to mustard oil vapor. It appears likely that the vapor enters the gonads through the numerous tracheae present in these organs. Now, if genetic changes in the sperm may be induced by materials entering the gonads through the tracheae, then it might be possible to affect sperm by using an aqueous solution of any chemical, in the form of an aerosol consisting of very fine droplets. With the aid of experience obtained during the past three years in a problem investigated at the Biological Laboratory^ apparatus was devised for exposing flies to aerosols having droplets less than 1.5 microns in diameter.

During the summer of 1945, M. Demerec, in cooperation with Wilton E. Baty, of the staff of the Huntington High School, and Zlata Demerec, carried on extensive experiments with aqueous aerosols of thirty chemicals, including oxidizing, reducing, and wetting agents and stains. In some cases brief exposure to an aerosol killed the flies, and in other cases the flies were not injured by long exposure. Experiments are now under way to determine whether or not genetic changes were produced in the sperm of treated males.

The utility of aerosols in attempts to alter the genetic constitution of *Drosophila* by chemical means depends on their mode of entry and the disposal of the substances in the fly. If aerosols enter as gases do, through the tracheae, the chemicals contained in them have almost immediate access to the heavily tracheated gonads; if not, they may be subject to the various methods of detoxification provided by the other portals of entry (alimentary, body surface). Accordingly, it seemed advisable to observe the fate of a group of dyes, whose presence in the different organs of flies exposed to aerosols made with these dyes could easily be detected on dissection. By using dyes known to be intravital stains, the penetration into the cells could be studied. Dr. Jack Schultz, of the Lankenau Hospital Research Institute, Philadelphia, who was working at the Biological Laboratory, participated in these studies and made most of the microscopic observations.

The dyes used were the familiar toluidinc blue, neutral red, janus green, trypan blue, among the vital stains. In addition, tests were made with acriflavin, because of its known effects on amphibian sperm; with

the chromatin stains crystal violet, methyl green, and safranin O; and with the cytoplasmic and chromosomal counterstain fast green. Adult wild-type flies were subjected to aerosols containing maximal concentrations of these dyes, and observed for various periods following the beginning of treatment. The atmosphere of the culture bottle was renewed every half-hour, so that concentration of the aerosol was maintained at an approximately constant level.

These experiments, then, gave a picture of the course of entry of the dyes. Almost invariably, the first region to show the dye was the crop. Later, in the case of toluidine. blue, neutral red, and acriflavin, the stain was visible in the cells of the midgut, with characteristic differences in detail. The staining was not uniform in all cells of the gut, but bands of cells at intervals were affected, indicating either a rhythm in the release of the material from the crop, or the existence of periodicities in the receptivity of the cells to the dye. At later stages, these dyes were observed in the Malpighian tubules and—most interesting—in the pigment granules of the testis sheath and in cysts of spermatogonia (moribund?). With other stains no absorption was evident; the dye was simply passed along the lumen of the gut for excretion. The final picture in all treatments was one of excretion of masses of pigment from the lumen of the hindgut.

It appears, then, that intake occurs via the proboscis and the alimentary tract. Indeed, the proboscis itself was often seen to be colored by the dye. Tests were made to determine the intake when the flies were prevented from feeding on the surface of the culture bottles. Following a suggestion of Dietrich Bodenstein, flies were mounted, according to the technique developed by Chadwick for studying the frequency of wing beat, by an attachment to the dorsal surface of the abdomen which left the fly suspended in air with its legs and wings freely movable. Under these circumstances staining was similar to that observed in unmounted controls, although less intense. A few trials were made with flies mounted in the way described but with their front legs cut off to minimize the amount of dye obtained by licking from the surface of the body. The intake was further decreased, but still observable. The impression is therefore strong that chemicals are taken in by feeding on the film at any exposed surface, and also by swallowing aerosol.

The use of mutants that cannot fly provided evidence from a converse set of conditions. Crawling on the surface of the vessel, the mutant vestigial took in as much dye as the wild-type, or possibly more. A similar picture is presented by the mutant Dichaete, in which an alteration of the wing musculature extends the wings at right angles to the body. One additional point of interest appeared in the experiments with Dichaete: with toluidine blue, the crop rarely became inflated, the dye appearing only in the crop duct. This was not the case with other dyes—for example, neutral red—and constitutes an interesting problem on the physiology of the crop.

Whether there are other modes of ingress than by the alimentary tract was tested by the use of the mutant proboscipedia. In this mutant, Dobzhansky and Bridges showed, the proboscis is transformed into a leglike structure, with the opening to the buccal cavity completely overgrown in the extreme cases. As might be expected from the foregoing, those flies with closed proboscises showed no intake into the gut. They did, however, after being exposed for some time, show some concentration of dye near the tracheal endings around the ovary, for example; pigment could also be seen in the Malpighian

tubules. Since previous treatments had shown that aerosols of mercuric chloride kill wild-type flies, the lethal effect of this aerosol on proboscipedia was tested. The mutant flies were susceptible to approximately the same degree as the wild-type, indicating that penetration of the mercuric salt into the gut is not required for the lethal effect. It would seem, therefore, that in proboscipedia, and hence probably also in wild-type, there is some intake, of certain aerosols at least, through either the tracheae or the thinner parts of the body surface.

The occurrence of stained regions in the testis is, of course, of major interest. An attempt was made to study these more closely by the use of the white-eyed mutant, which lacks pigment in the testis sheath and Malpighian tubules; because in flies where pigment granules are present they absorb the dye selectively. In the white-eyed flies, the dye was eliminated from the cells more rapidly, when it was absorbed at all, and became evident as a diffused staining of the cytoplasm. No obvious changes in the frequency or location of stained areas in the testis were seen.

Aerosols furnish a simple technique for feeding adults with specific substances, without the introduction of the complications involved in the use of culture media. The presence of stained regions in the testis indicates that aerosols of at least some chemicals reach the germ cells. The genetic study of treated flies will show whether this technique is effective in producing mutations.

CYTOGENETICS OF DROSOPHILA

BERWIND P. KAUFMANN AND HELEN GAY

MODIFICATION OF X-RAY-INDUCED CHROMOSOMAL REARRANGEMENTS

Use of near infrared radiation. Although radiation geneticists have outlined the more general aspects of the process whereby the activating energy of ionizing radiation induces alterations within a chromosome that culminate in its eventual breakage, the sequence of molecular changes by which this end is reached remains unknown. Since breakage may be followed by recombination, it follows that the process of disruption by X-rays involves a loosening rather than a destruction of those bonds that normally serve to maintain the linear continuity of the chromosome. The experimentally induced recombination types show such patterns of realignment of parts as presumably have occurred in phylogeny, but the techniques used have failed so far to furnish a clear understanding of the methods by which these changes have occurred in nature.

Certain aspects of the cycle of chromosome breakage and recombination have been elucidated by altering the conditions, such as rate and temperature, under which the ionizing radiation was delivered. On theoretical grounds it appears possible, therefore, to modify the capacity for reattachment of the bonds loosened by the ionizing radiation if supplementary treatment is given prior to the time that new combinations are established. *Drosophila* appears to be especially well suited for experiments of this type, since irradiated chromosomes of the mature spermatozoa do not combine to form new arrangements until after the sperm has entered the egg in the process of fertilization (Year Book No. 39). Irradiated males can be kept for several days before mating, so that long intervals of time are available in which efforts may be made to alter experimentally the capacity of the regions of breakage to recombine or to undergo restitution. Any

factor promoting restitution prior to the time of recombination should decrease the number of potential breaks, and^ thereby increase the frequency with which sperms transmit in fertilization an unaltered group of chromosomes. Supplementary treatment, if it were effective in disrupting the chromosome and "sealing" the broken end, would likewise reduce the proportion of detectable alterations.

Proceeding on these assumptions, a series of experiments were initiated (Year Books Nos. 41, 42) to measure the effects of the ultraviolet and near infrared parts of the spectrum on X-ray-induced chromosomal rearrangements. The projects were carried out in cooperation with Dr. Alexander Hollaender, of the National Institute of Health, who designed the apparatus used for treating the flies. The method of biological assay involved cytological analysis of the salivary-gland chromosomes of the Fi larval progeny of irradiated fathers mated with virgin females of the same (Oregon-R) stock of D. *melanogaster.*

In the first experiments (Year Book No. 41) 4000 roentgens of X-rays were given in two equal fractions at 16-day intervals, and in the intervening period the flies were exposed to near infrared radiation for either 72, 144, or 216 hours. The near infrared radiation when used alone produced no detectable chromosomal changes in a sample of 100 pairs of glands examined; but when intercalated between the two fractions of X-ray treatment, it was effective in reducing the frequency of chromosomal rearrangements in proportion to the time of treatment. Subsequent experiments have shown that the reduction with time is to be attributed to an accelerating effect of the near infrared radiation on those processes that make available for copulation sperm that was not mature at the time of X-ray treatment.

Post-treatment with near infrared does not seem to be effective, therefore, in eliminating or modifying the potential breaks induced by X-rays. But a repetition of the fractionation experiment so designed as to test only spermatozoa that were mature at the time of treatment gave a frequency of rearrangement in excess of that observed in the X-ray controls. Inasmuch as fractionation of the X-ray dose involves pretreatment as well as post-treatment with near infrared, a series of tests was run in which exposure to near infrared preceded 4000 roentgens of X-rays. The combined data from 5 series of experiments are presented in the accompanying table.

FREQUENCY OF CHROMOSOME BREAKAGE

Type of treatment	Total sperms tested	No. with rearrangements	Per cent sperm showing changes	No. of breaks observed	Breaks per 100 sperms	Mean no. of breaks
Near infrared followed by 4000 r	721	312	43.27 db 1.84	850	117.89	2.72 =b 0.064
4000 r alone	549	169	30.78 ± 1.97	435	79.23	2.57 d= 0.075
Diff. %/S. E.			12.49/2.70=4.6			0.15/0.098 = 1.5

There seems to be little question, from these data, that pre-treatment with near infrared is a method of increasing the yield of detectable chromosomal alterations in *Drosophila.* The frequency of rearrangement and that of breaks per total sperm tested are of the same order of magnitude

as those induced in earlier experiments by a dose of 5000 roentgens of X-rays. But when a comparison is made, using the x^2 test, of the proportions of simple and complex rearrangements, they resemble a 5000-r treatment less than they do one of 4000 r. Thus the effect of the exposure of male flies to near infrared seems to be to sensitize the chromosomes of the sperm so that the number of potential breaks induced by 4000 r of X-rays, and the consequent opportunities for recombination, are increased without altering the proportions of 2-break, 3-break, and multiple-break combinations characteristic of a 4000-r treatment. A consideration of the distribution of the induced breaks indicates, moreover, that the increased yield of chromosomal aberrations is not due to selective sensitization of any one chromosome or part thereof.

Breaks that are detectable by analysis of salivary-gland chromosomes represent but a residue of the larger number of potential breaks induced by the X-rays, since some patterns of recombination lead to unbalanced, inviable nuclei in subsequent generations. An effective measure of these "dominant lethals" may be obtained by determining the proportion of individuals that die in embryonic stages. Since only about 15 per cent of the eggs hatched following an X-ray dose of 4000 r, a dose of 2000 r was used following exposure of the males to near infrared rays. The accompanying table presents data of all egg counts.

HATCHABILITY OF EGGS

Type of treatment	Total eggs deposited	Unmatched 36 hrs. later	Per cent failing to hatch
None (controls)....	7,047	478	6.8
Near infrared alone (48 hrs.).....	14,272	1,901	13.2
2000 r alone.....	9,214	4,480	48.6
Near Infrared (48 hrs.) +2000r...	9,562	5,096	53.3

Near infrared radiation of sperm, although inducing no appreciable number of chromosomal rearrangements (none among 100 sperms tested), slightly increases the percentage, in comparison with the controls, of *eggs* that fail to hatch. The end result is such as might be obtained if a small percentage of the sperm were inactivated and, although penetrating the *zgg*, were unable to ensure fertilization. We have not sectioned a series of eggs to determine whether those that fail to hatch have been fertilized, but inactivation of some spermatozoa does not account for the augmented break frequency obtained following the combined treatment, nor does differential inactivation seem probable when we recall that adult male flies exposed to near infrared rays for as long as 216 hours show no apparent physiological disturbances or reduction in viability. Another possible mode of action of near infrared radiation is the rearrangement of certain molecular configurations within the chromosome so that the bonds maintaining the linear continuity of the chromosome are uncoupled more readily by the ionizing radiation than if such pre-treatment had not been given. Near infrared radiation does increase the body temperature of *Drosophila* during the period of exposure. By means of a thermocouple designed by Dr. J. Gordon Carlson, working with Dr. Hollaender at the National Institute of Health, it has been determined that the temperature of the fly during exposure is elevated about 7^0 C. The flies used in the studies here reported attained temperatures of at least 29 to 30° C, but survived for as long as 9 days without loss of fertility. This is made possible by the design of the treatment chamber, which is fitted within a coil that carries circulating water (temperature, 19" C.) and prevents excessive accumulation of heat in the culture medium or enclosed air.

Since near infrared radiation provides a method that essentially increases the temperature range within which normal viability of *Drosophila* is maintained, its effect on irradiated chromosomes at the time of their recombination has also been measured. Females inseminated by sperm from X-rayed males were exposed to the beam of near infrared rays during oviposition. The eggs deposited by these females completed the early cleavage stages while exposed to the radiation, and gave a significantly higher frequency of chromosomal rearrangements than those held at i8° C. recommend its use in experiments designed to alter the frequency of X-ray-induced breakage (see Year Book No. 41). Accordingly, males of the Oregon-R stock of *D. melanogaster* were given 4000 r of X-rays and exposed shortly thereafter to ultraviolet radiation of wave length 2537 A for 10 minutes. To facilitate penetration of the ultraviolet rays, the abdomens of the flies were flattened between quartz plates so as to bring the testes closer to the ventral body surface. Frequencies of chromosomal breakage are presented in the accompanying table.

FREQUENCY OF CHROMOSOME BREAKAGE

Treatment (X-ray, 4000 r; 2537 A, 10 mins. exposure)	Total no. sperm tested	No. with rearrangements	Per cent sperm showing changes	No. of breaks detected	Breaks per 100 sperm	Mean no. of breaks
Ultraviolet alone	146	....	.....	....	....	.....
X-ray alone	128	38	29.7 ± 4.04	108	84.4	2.84 ±0.19
X-ray + ultraviolet:						
(a)	55	8	14.5 ± 4.75	20	36.4	.....
(b)	51	8	15.7 ± 5.09	27	52.9	.....
(c)	49	12	24.5 ± 6.14	25	51.0	.....
(d)	44	12	27.3 db 6.72	33	75.0	.....
(e)	39	11	28.2 ± 7.21	24	61.5	.....
(f)	51	16	31.4 ± 6.50	39	76.5	.....
Total X-ray + ultraviolet	289	67	23.2 ± 2.48	168	58.2	2.51 ± 0.13

during the same period. (See Year Book No. 42.) These results suggest that the higher temperature accelerates those movements of the chromosomes that facilitate chromosome recombination. In this connection it is interesting to note that eggs exposed to a temperature of 28° C. show values in frequency of recombination and in the complexity of the resulting rearrangements intermediate between the 18° C. and the near infrared samples.

Effect of ultraviolet radiation of wave length 253J A, The selective absorption of monochromatic ultraviolet radiation by various components of the chromosome

The considerable variability in the frequency of chromosomal alterations obtained following the combined treatment is presumably attributable to varying degrees of penetration of the ultraviolet quanta. Nevertheless, when the total data are compared with those for the X-ray controls, the difference in the percentages of altered sperms is 1.9 times its standard error, and therefore at the threshold of significance. In respect to the proportions of various types of rearrangement observed, the results of the combined-treatment series (4000 r + 2537 A) approximate more closely those of a 3000-r X-ray treatment

than those of a 4000-r treatment alone (P = ca. 0.95 when obtained from x^2)-

Despite our inability to determine with any degree of precision the amount of energy reaching the mature spermatozoa of the testes, we feel that the data here presented indicate that ultraviolet radiation that penetrates spermatozoa previously exposed to ionizing radiation may so affect the chromosomes as to produce fewer chromosomal rearrangements than would have been obtained if ultraviolet radiation had not been used.

Whether the ultraviolet alters the chromosomes by inhibiting recombination or by increasing the amount of restitution may possibly be determined by measuring the frequency of dominant lethals. Counts of numbers of eggs that fail to hatch have been made for both the ultraviolet and X-ray controls, but data from the combined treatments are at present too meager to present a satisfactory answer to the problem.

Ultraviolet of wave length 2537 A is absorbed primarily by nucleic acids, but whether the action here reported may be attributed to absorption by the ribose nucleic acid—as Swanson (Genetics, vol. 27, 1942) suggests to explain the effects of wave length 2537 A on X-ray-induced breaks in the pollen-tube chromosomes of *Tradescantia*—or by the desoxyribose nucleic acid or other components of the chromosome remains to be determined. The spermatozoon of *Drosophila* presumably has a high content of the desoxyribose type, and, according to Schultz, is not affected by ribonucleose under conditions that permit digestion of the matrix of the salivary-gland chromosomes. Answers to problems of this type can possibly be given by an extended study of the comparative effects of ultraviolet radiation of different wave lengths.

SPONTANEOUS MUTATION RATE IN DROSOPHILA

Radiation genetics has given many clues, if not an answer, to the problem of the nature of the mutation process. Further information may be gained by analysis of various, factors influencing spontaneous mutation rates. Ten years ago N. W. Timoféeff-Ressovsky presented data showing that the percentage of mutations occurring in the chromosomes of *Drosophila* varies with the age of the spermatozoon. We have carried out similar experiments during the past year with the assistance of Miss Katherine Tulloch and Mr. B. N. Kaufmann. The frequency of lethal mutation in the X chromosome of the Swedish-b stock of D. *melanogaster* was determined by the standard C1B method. All stocks and experimental materials were kept at 22° C. Males were selected within a few hours of their emergence, stored for either 1 day, 16 days, or 32 days, and then placed for 1 day with virgin females of the C1B stock. The sperm from males 1-2 days after emergence gave 5 lethals out of 3545 sperms tested (0.141 *zt* 0.063 per cent); that from males 16-17 days after emergence, 11 lethals out of 3471 (0.317 ± 0.095 per cent); and that from males 32-33 days after emergence, 30 lethals out of 5248 (0.5716 ± 0.104). The 1-2-day and the 32-33-day samples are significantly different; together with the 16-17-day material they indicate a relation of mutation to passage of time that is essentially a linear proportionality. These data were obtained by testing mature sperms (which presumably are neither resorbed nor ejaculated while the males are stored), so that we may be measuring mutation rate in nondividing chromosomes. Other experiments bearing on this problem are now in progress.

CHROMOSOME BREAKAGE AND RECOMBINATION

In the analysis of the chromosome rearrangements obtained in the experiments outlined in the preceding pages, the positions of a considerable number of breaks have been determined. For the X chromosome more than 1400 points of breakage have been localized with respect to the lettered subdivisions of Bridges' salivary-gland-chromosome map. Details concerning the distribution of the greater part of this total were presented in Year Book No. 43. Analysis of the accumulated data has been continued, with a view to determining the patterns of recombination between these breaks and those in. other chromosomes. Data accumulated in an earlier study (Year Book No. 37) had led to the conclusion that breaks are distributed among the chromosomes essentially at random (assumedly in accordance with the random distribution of the ionizing radiation), but that the opportunity for recombination at any region of potential breakage depends on spatial relations that favor exchange within a chromosome limb (intrabrachial inversion) as compared with exchange between limbs (interbrachial inversion and reciprocal translocation). With the large body of data now available we are in a better position to ascertain whether the breaks determined by analysis of salivary-gland chromosomes represent a random sample of the potential breaks originally induced.

The breaks involved in interchanges with the X chromosome are scattered among the autosomes essentially at random with respect to length either of mitotic chromosomes or of salivary-gland chromosomes. The proportion of rearrangements restricted to the X chromosome is larger, however, as compared with exchanges between the X chromosome and the autosomes, than would be expected if recombination were at random. Moreover, the ratio of number of X-chromosome inversions to number of translocations between the X and the autosomes differs markedly according to whether heterochromatic or euchromatic regions are involved. The analysis—which up to the present has included only two-break cases, and requires further confirmation—suggests that differences may exist in the time, with respect to the movement of the chromosomes, at which potential breaks in euchromatin and heterochromatin first become available for the initiation of recombination.

The pattern of recombination within the chromosome may be measured by determining frequencies of inversions of different lengths. Considered in terms of units as large as the division, the frequencies depart only slightly from values expected if recombination were at random (P from X^2 is almost 0.03). When one break occurs in the proximal heterochromatic region (division 20), the separated ends apparently may combine with equal facility with any other available broken ends within divisions 1 to 19. Inverted sections restricted to these divisions can be measured in terms of numbers of subdivisions encompassed. Plotted against values expected on random distribution, a P of ca. 0.005 is obtained, which suggests that the data do not adequately fit this hypothesis. Of the various possible lengths (ranging from 0 to 113 subdivisions), the highest frequencies were found in the inversions of 12 or 13, of 25 or 26, and of 42 or 43 subdivisions in length. This suggests that a pattern of coiling may exist within the X chromosome at the time of recombination that increases the chances of reunion of parts separated by the distance of one full turn. This increase is slight, however, since an inversion was observed

in which both breaks occurred in the same subdivision, another as long as in subdivisions, and others of almost all intermediate lengths.

The extensive data of the present study enable us, therefore, to interpret more adequately the conclusions reached in earlier work. It is now clear that patterns of break distribution and recombination that were obscured by analysis in terms of the divisions of the salivary-gland chromosome are revealed when smaller units such as the subdivisions are considered. By plotting the distribution along the X chromosome of breaks involved in exchanges with other breaks in either proximal or intercalary heterochromatic regions, it was found that the broken ends produced by a break in heterochromatin may combine freely with all other regions within the chromosome, either euchromatic or heterochromatic. These conditions suggest that the breaks identified by analysis of salivary-gland chromosomes represent in their distribution essentially a random sample of the potential breaks originally induced. For a more complete understanding of the various factors involved in recombination, studies paralleling those here summarized will be required for the limbs of the various autosomes.

GENETIC STRUCTURE OF NATURAL POPULATIONS

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Evolutionary changes in nature are mostly too slow to be perceived within a human lifetime. This fact was recognized by pioneer evolutionists, and most biologists took it for granted until recently. Darwin pointed out that the transformations brought about in domestic animals and plants by artificial selection are relatively rapid, but he conceded that the process of evolution ín the wild is something to be inferred rather than observed. This concession need no longer be made. Under some conditions rapid changes do occur in nature. Recent work on microorganisms shows that the long-recognized phenomena of bacterial adaptation resolve into the same mutational and selectional components that bring about evolutionary changes in other organisms. Entomologists have recorded the occurrence of genetic changes in some insect pests; these changes adjust the insects to the environment as altered by man. Finally, some wild species have been shown to undergo rapid genetic changes, which are geared to the annual climatic cycle, and which represent adaptive responses to seasonal alterations in the milieu. The results of studies on a case of this last category have been mentioned in Year Books Nos. 39, 40, and 43, and they are reviewed below jointly with new data. This case has the unique advantage that the changes known to take place in nature can be reproduced in part in laboratory experiments.

SEASONAL CHANGES IN THE GENETIC COMPOSITION OF POPULATIONS

Populations of the fly *Drosophila pseudoobscura* which inhabit the Andreas Canyon, Pifion Flats, and Keen Camp localities on Mount San Jacinto, California, have been sampled repeatedly during four consecutive breeding seasons (1939-1942). Three types of third chromosome—called Standard, Chiricahua, and Arrowhead—are found commonly, and two further types rarely, in all the populations. These chromosomal types differ in inversions o£ blocks of genes. The carriers of the different types interbreed at random; inversion

homozygotes and heterozygotes occur in nature. The relative frequencies of the chromosomal types are different in the three populations. The most important fact for us, however, is that these frequencies change from month to month, the changes being cyclic. The data for the four years of observation at Piñon Flats are summarized in the accompanying table.

FREQUENCIES (IN PER CENT) OF THE THREE COMMON CHROMOSOMAL TYPES IN THE PIÑON FLATS POPULATION

Month	Standard	Chiricahua	Arrowhead	No. chromosomes examined
March	47.2	28.6	18.1	496
April	46.2	23.6	24.9	449
May	33.6	31.3	29.0	642
June	29.2	35.9	30.6	630
July-August	42.3	27.3	26.3	388
September	47.3	26.6	22.2	338
October	54.1	16.6	25.3	150
November-December	41.7	25.0	27.8	180

It can be *seen* that Standard chromosomes are frequent during autumn and winter, become less prevalent in spring, reach a minimum in June, and increase in frequency during the summer. Chiricahua chromosomes follow a path opposite to that of Standard. The behavior of Arrowhead is erratic. The population at Andreas Canyon undergoes changes qualitatively similar to those at Piñon Flats. No seasonal changes have been observed at Keen Camp, although this locality is only about 15 miles distant from Piñon and from Andreas.

As indicated in Year Books Nos. 40 and 43, these data suggest that, in the Piñon Flats and Andreas Canyon populations, the flies with Standard chromosomes are better adapted to the summer environment than flies with Chiricahua chromosomes, whereas in spring the conditions are reversed. Accordingly, natural selection augments the frequency of Standard chromosomes in summer, and of Chiricahua chromosomes in spring. In autumn and winter, the three chromosomal types are equivalent.

The data given in the table above show that the frequency of Standard chromosomes decreases by about one-third between March-April and June, and increases by about one-half between June and August-September. Although *Drosophila pseudoobscura* breeds rapidly for an insect, the time intervals just indicated can correspond to hardly more than three generations. The intensity of natural selection necessary to bring about changes so great in so short a time must be very high; i.e., the survival or reproduction rates of the carriers of the different chromosomal types must be quite different. The selection coefficients involved here must be of a higher order of magnitude than those customarily assumed by theorists to be effective in bringing about evolutionary changes in nature. This is very fortunate indeed, because high selection differentials may be verified in experiments, whereas the small ones are not detectable experimentally; this latter circumstance has been, ever since the time of Darwin, the weakest point of the theory of natural selection.

NATURAL SELECTION IN ARTIFICIAL POPULATIONS

Artificial populations with different proportions of flies having the three chromosomal types mentioned above have been kept in the "population cages" described briefly in Year Book No. 43. Suffice it to state here that the populations in such cages grow rapidly to a maximum size

compatible with the amount of food supplied, and remain more or less constant in numbers thereafter. The numbers of eggs deposited in a cage, however, are very much greater than the numbers that can develop to adult insects. Hence, the competition for survival is keen in the population cages. If the original population consists of two or more genetic types with unequal adaptive values, the strong types increase, and the weak ones dwindle in numbers. Nineteen experiments with population cages have been completed up to the present, all with flies whose ancestors were collected at Pifion Flats, California. In some experiments the composition of the natural population of Pifion Flats has been artificially reproduced, as far as relative proportions of the chromosomal types are concerned.

The data summarized in the next table (p. 130) are representative of all those experiments carried at constant or fluctuating temperatures above 21 ° C. Population cage no. 18 was started on October 23, 1944, with an initial population of about 20 per cent Standard, 36 per cent Chiricahua, and 44 per cent Arrowhead chromosomes. By late February of 1945? the proportion of Standard had approximately doubled, and that of Chiricahua had been reduced to around 25 per cent. Cage no. 19 was started on November 15, 1944, with about 38 per cent Standard, 62 per cent Chiricahua, and no Arrowhead chromosomes. By late February of 1945, the proportions of Standard and Chiricahua chromosomes had been approximately reversed. If the initial mixture contains Standard and Arrowhead, but no Chiricahua, Arrowhead is displaced by Standard. But in a mixture of Arrowhead and Chiricahua without Standard, Arrowhead displaces Chiricahua.

These changes observed in population cages are obviously analogous to those taking place in the natural population of Piñon Flats in summer—Standard displacing Chiricahua chromosomes, and Arrowhead more or less holding their own. Precisely what physiological properties of flies with Standard chromosomes make them superior to those with Chiricahua chromosomes in population cages kept at temperatures above 21 ° C. is not known; nor is it known whether or not these same properties are responsible for the differential survival of the flies in the natural populations. It may be regarded as an established fact, however, that the carriers of Standard, Arrowhead, and Chiricahua chromosomal types possess sharply different adaptive values in at least some environments. The relative frequencies of these types in populations are governed by natural selection.

Quite different is the outcome of experiments carried on at low temperatures. The relative frequencies of the chromosomal types remain constant, within the limits of experimental errors, in population cages kept at 16.5^0 C. Therefore, the adaptive values of the different chromosomal types seem to be approximately alike at 16.5 ° C, although, as we have seen, they are sharply different at higher temperatures. This result agrees very well with the known behavior of the natural populations of Pifion Flats and Andreas Canyon, where the chromosomal types remain nearly constant in frequency during autumn and winter, when the temperatures in the environment of the flies are low. During spring the natural populations undergo a different type of change; the frequencies of Chiricahua chromosomes increase and those of Standard decrease. Attempts to reproduce these changes in population cages have been unsuccessful so far. In all the experiments at the low temperature the relative frequencies of the chromosomal types remained constant, whereas at high tempera-

CHANGES OBSERVED IN ARTIFICIAL POPULATIONS KEPT AT FLUCTUATING TEMPERATURES AVERAGING ABOUT 26° C. THE FIGURES SHOW THE FREQUENCIES, IN PER CENT, OF THE CHROMOSOMAL TYPES

TIME	EXPERIMENT 18			EXPERIMENT 19	
	Standard	Chiricahua	Arrowhead	Standard	Chiricahua
October 23, 1944	19.9	36.5	43.6	.....	.....
Mid-November 1944	*33.3*	39.3	27.3	38.3	61.7
Mid-December 1944	37.7	33.7	28.7	53.0	47.0
Mid-January 1945	39.3	30.7	30.0	63.3	36.7
Late February 1945	44.3	25.7	30.0	60.3	39.7
Late March 1945	42.0	19.0	39.0	65.3	34.7
Late April 1945	46.7	23.0	30.3	*65.3*	34.7
Early June 1945	56.4	16.3	27.3	70.4	29.6

tures the frequencies of Standard rose and those of Chiricahua declined. This occurred regardless of whether the temperatures were constant or fluctuating, whether the cages were exposed to light or kept in the dark, whether fresh food was introduced into the cages at short or at long intervals.

The mode of action of natural selection *on* the chromosomal types is interesting. A mathematical analysis of the data has been made by Professor Sewall Wright, of Chicago. He found that, at high temperatures, the adaptive value of Standard/Chíricahua heterozygotes is highest, that of Standard homozygotes lower, and that of Chiricahua homozygotes lowest. Such being the case, Standard chromosomes can never replace Chiricahua completely in any population. The end result of the selection process is the establishment of an equilibrium between Standard and Chiricahua chromosome types. The relative frequencies of heterozygotes and homozygotes at equilibrium are such that the population as a whole attains the optimal adaptive level. Thus, if only Standard and Chiricahua chromosomes are present, the equilibrium is established when 65-70 per cent of the chromosomes are Standard and 30-35 per cent Chiricahua. It follows that, at high temperatures, in population cages with initial mixtures containing more than 70 per cent Standard and less than 30 per cent Chiricahua chromosomes, the frequencies of Standard must diminish, and those of Chiricahua must rise. This expectation must be tested experimentally.

THE GENETIC BASIS OF THE SELECTIVE DIFFERENTIALS

Two hypotheses may be put forward concerning the differences in adaptive value observed between carriers of the different types of third chromosome. First, the gene arrangement in a chromosome may influence the properties of the organism through position effects. Inversions of blocks of genes change the gene arrangement in the chromosome, and hence may change the properties of the body. Second, a chromosomal type may become associated, in a given population, with a certain constellation of genes. The adaptive properties of a chromosomal type would, then, be determined by the genie variants which it happens to carry.

According to the first hypothesis, the chromosomes of a given type must have similar adaptive properties wherever found.

If the second hypothesis is correct, chromosomes of the same type found in populations of different geographic origin may possess different properties. Since all the experiments so far have been done with chromosomes derived from the Piñon Flats population, neither hypothesis can be regarded as established. The second hypothesis is favored, however, by the fact that no cyclic seasonal changes in the frequencies of the chromosomal types are known at Keen Camp. The population of this locality contains the same chromosomal types as those found at Piñon Flats and Andreas Canyon, where changes do occur. Furthermore, chromosomes with different gene contents are known to be present in these populations. The experiments to be reported below show how great is the variety of these chromosomes.

Many chromosomes found in natural populations carry recessive genes which, when homozygous, reduce the viability of their carriers. The reduction may vary from a barely perceptible diminution of the viability to complete lethality. Furthermore, the effects of a given chromosome on viability are often modified very greatly by the environment (see Year Book No. 41). For example, individuals homozygous for the second chromosome no. 1015 from Andreas Canyon have a viability only slightly below normal at 16.5^0 C, but they are semilethal at 21°, and completely lethal at 25.5^0. Here, then, is a good analogy with the behavior of the different types of third chromosome; for, as we know, flies with the Standard gene arrangement have a higher adaptive value than those with the Chiricahua arrangement in summer, a lower value in spring, and an equivalent one in winter. On the other hand, homozygotcs for the second chromosome no. 975 from Andreas Canyon, or for no. 863 from Piñon Flats, arc normally viable at all three temperatures.

By means of appropriate crosses, flies were obtained which carried (were heterozygous for) both second chromosomes Andreas 1015 and Piñon 863. Such flies may transmit to their offspring either the chromosome Andreas 1015, or Piñon 863, or chromosomes compounded from segments of these two by crossing over. Ninety-six males were taken at random from among the offspring of females of the genetic constitution just indicated. The second chromosomes of these males were examined for their effects on the viability of homozygotes. When the experiment was done at a temperature of 25.5° C, 35 out of the 96 chromosomes tested proved to be lethal when homozygous. These chromosomes seem to resemble the ancestral Andreas 1015. Only 8 chromosomes gave normally viable homozygotes, resembling the ancestral Piñon 863. Of the remainder, 21 chromosomes were extreme semilethals, 13 were less extreme semilethals, and 9 gave subnormal viabilities outside the semilethal range. The 56 chromosomes that behaved as complete lethals at 25.5° were retested at 16.5^0 C. In this experiment, 47 chromosomes gave almost normally viable homozygotes. Their behavior is thus identical with that of Andreas 1015. Three chromosomes, however, remained lethal, and 6 chromosomes gave distinctly subnormal viabilities at the low temperature.

A great variety of chromosomal types with quite different reaction norms, therefore, can be produced by crossing over between two chromosomes obtained from natural populations. An even more striking example of this phenomenon is offered by the cross involving the second chromosomes Andreas 975 and Piñon 863. As was stated above, both of these chromosomes give homozygotes that are normally viable at the three temperatures tried. Yet, among 22 crossover chromosomes tested,

3 chromosomes proved to be lethal and 3 others semilethal at 25.5° C. It follows that chromosomes which are lethal when homozygous can be produced through recombination of the genes of chromosomes which normally give viable homozygotes. Such lethals, obtained by recombination, may be called "synthetic lethals."

The variety of chromosomes with different gene contents actually available and potentially possible in natural populations is evidently enormous. Even if only a few chromosomes were available to begin with, crossing over would constantly supply new gene combinations. Some of these gene combinations may be favorable in certain environments, other combinations in other environments, and still others may be unfavorable. Although it is obviously advantageous to the organism to have the favorable gene combinations retained, a gene combination formed by crossing over is just as easily dissolved by another crossing over. The dissolution may be delayed or prevented, however, if an inversion happens to occur in the chromosome carrying the favorable combination. Inversions may bind together gene combinations present in a chromosome, because they suppress crossing over. In this manner, chromosomal types that arise through inversions may acquire different adaptive properties and different selective values.

It should be kept in mind that the experiments with population cages showed that flies heterozygous for two chromosomes with different gene arrangements have higher adaptive values than do the homozygotes. It follows that natural selection, in wild populations of *Drosophila pseudoobscura,* favors gene combinations which give optimal results in heterozygous compounds with other gene combinations present in the same populations. The gene combinations that insure the highest degree of hybrid vigor are, evidently, those in the third chromosomes bound by the inversions. Now, different gene combinations may be more or less favored in localities with different environments, even though these localities may be as near each other in space as Keen Camp and Pifion Flats. The different behaviors of the Keen Camp population on the one hand, and of the Pifion Flats and Andreas Canyon populations on the other, may thus be accounted for. Further experiments are needed to settle this problem.

INTERSPECIFIC HYBRIDIZATION IN POPULATION CAGES

Drosophila pseudoobscura and *Drosophila persimilis* are two closely related species. They are almost indistinguishable in external morphology, yet are easily recognized by their chromosomes as seen in the saiivary-gland cells. Their geographic ranges are distinct but overlapping, and the two species live side by side in an extensive territory. They show a partial sexual isolation; that is, when females of both species are confined with males, of one of them, a greater proportion of conspecific than of non-conspecific females is inseminated. If, however, an interspecific mating has taken place, hybrids of both sexes are easily produced, and these hybrids seem to be as vigorous as individuals of the pure parental species. The Fi hybrid males are completely sterile. The Fi hybrid females oviposit abundantly, and, if inseminated by males of either parental species, give rise to backcross progenies. The viability of the backcross progenies, however, is more or less strongly reduced on account of a deleterious maternal effect (the *eggs* of mothers with hybrid chromosomes are somehow injured). In laboratory experiments, it is possible to transfer sections of chromosomes of *Drosophila pseudoobscura* to *Drosophila persimilis,*

and vice versa. Nevertheless, no hybrids have been so far encountered in nature, and the available evidence is against the supposition that these species exchange genes in natural populations. This is but an illustration of the general rule: hybridization in captivity is no proof of hybridization in nature.

The "population cages" offer a technique whereby conditions that obtain in natural populations can be approached more closely than is otherwise possible (no claim is being made, however, that natural conditions are duplicated). The problem, then, is: to what extent will *Drosophila pseudoobscura* and *Drosophila persimilis* exchange genes if they live together in the same population cage for several generations? Late in December 1944, 600 wild-type individuals of *persimilis* and 200 orange-eyed *pseudoobscura* were put in one cage, and 600 wild *persimilis* and 300 orange *pseudoobscura* in another cage. The first cage was placed at a temperature of 21^0 C, and the second at 16.5^0 C.

On February 3, 1945, the cage kept at 21° contained 4689 adult flies, 464 of them with orange eyes and 4225 with wild-type eyes. Since orange is an autosomal recessive gene, the orange-eyed flies were obviously pure *Drosophila pseudoobscura.* The wild-type flies may have been either *persimilis* or hybrid. The hybrid males can be distinguished from the nonhybrids by dissection and microscopic examination of their testes. Out of 170 males so examined, 10 were hybrids and 160 were *persimilis.* In the total population of the cage, approximately 5.3 per cent were hybrids and 94.7 per cent pure species. The flies were returned to the cage, which was then placed at room temperature.

On March 14, 1945, this cage contained 1321 wild-type and 486 orange-eyed flies. Two kinds of hybrids could now be expected in the cage: Fi generation hybrids formed by cross-mating of pure *pseudoobscura* and *persimilis* flies, and backcross hybrids derived from the Fi hybrid females formed in the previous generation and mated to males of the pure species. Backcross hybrids might have either wild-type or orange eyes; the Fi hybrids would be all wild-type. They are not always distinguishable by examination of the testes, but many of them can be told apart in this way. In reality, the 50 orange-eyed males dissected were all *pseudoobscura,* whereas among the 117 wild-type males 114 were *persimilis* and only 3 hybrid, probably belonging to the Fi generation. On May 2, the cage contained 133 orange and 1247 wild-type flies. All the orange males (62) were dissected, and proved to be *pseudoobscura.* Of 200 wild-type males dissected, 193 were *persimilis* and 7 were in all probability Fi hybrids.

The absence of backcross hybrids is suggestive. As was stated above, they can be obtained in laboratory experiments, although their viability is low. Their failure to appear in the population cages indicates that the lowering of the viability is lethal under the conditions of crowding and intense competition that obtain in the population cages, and probably in natural populations as well. The Fi hybrid females are mostly fertile in the laboratory, but they are likely to be completely sterile in nature. This makes gene exchange between the species impossible.

The second population cage, kept at 16.5^0 C, provides, for two reasons, a rigid test of the validity of the above conclusion. First, low temperatures frequently permit otherwise weak or nonviable types of *Drosophila* to survive. Second, the sexual isolation between *pseudoobscura* and *persimilis,* as Dr. Ernst Mayr has discovered, is very weak at low temperatures; consequently, many more hybrids will be produced. On February 3, 1945, this cage

kept in the cold room contained 2971 wild-type and 1083 orange flies. The latter were obviously *pseudoobscura.* Among the 200 wild-type males dissected, 134 were *persimilis* and *66* were hybrids. It is easy to compute that the total population of the cage consisted of approximately 76 per cent pure species and 24 per cent hybrids. On March 30, the cage had 3987 wild-type and 2634 orange flies. The 200 orange males dissected were all *pseudoobscura.* Among 200 wild-type males, 169 were *persimilis* and 31 were apparently Fi hybrids. It can be computed that the proportion of hybrids in the total population of the cage dropped to about 9 per cent. The experiment was discontinued on June 11, when the cage contained 3390 wild-type and 1937 orange flies. No hybrids were found among 200 orange males dissected. Only 17 hybrids, apparently Fi, were among 300 normal-eyed males examined. This amounts to about 3.6 per cent of hybrids in the cage population as a whole.

Apart from the production of some first-generation hybrids, apparently no gene exchange takes place between *Drosophila pseudoobscura* and *Drosophila persimilis* in population cages. The proportion of hybrids in the population of a cage does not increase from generation to generation. As a matter of fact, the cage kept at 16.5^0 C. showed a fairly rapid decrease in the incidence of hybrids with time. If confirmed in further experiments, this progressive reduction of hybridization with time will be a very important finding. For it would constitute an experimental verification of the hypothesis according to which natural selection should strengthen reproductive isolating mechanisms between populations that are exposed to hybridization and that produce hybrids with a lowered reproductive potential.

DISPERSION RATES OF DROSOPHILA PSEUDOOBSCURA

Field experiments on the rate of dispersion of *Drosophila pseudoobscura* (see Year Books Nos. 41 and 43) had to be discontinued for a time because of war conditions. They were resumed during the summer of 1945 at Mather, Tuolumne County, California, using some of the facilities of the Division of Plant Biology of the Carnegie Institution. The writer wishes to express his most sincere appreciation to Drs. J. Clausen and H. A. Spoehr, of that Division, for their hospitality at Mather. The experiments should, according to plan, take two years; results will be reported later.

MOUSE LEUKEMIA

E. C. MACDOWELL, J. J. BIESELE, G. GASIĆ, M. J. TAYLOR, AND T. LAANES

During the past year, active work on spontaneous leukemia has been confined to the maintenance of experiments previously started. This has been the necessary result of not having a histological technician or a diagnostician, and of having an insufficiency of mice. A major proportion of the mice produced by the unique leukemic strain C58 have been contributed to a wartime medical research program.

SPONTANEOUS LEUKEMIA IN STRAIN BALB

It has long been supposed from casual observation that strain Balb was largely resistant to spontaneous leukemia. The breeding period is long in these mice, and large numbers far older than the most frequent age for leukemia in strain C58 have been handled. The first actual determination of the incidence of leukemia in a given sample of Balb mice has recently

been completed, with the surprising result that, according to the diagnoses of gross autopsies, nearly 70 per cent have died with leukemia. We are grateful to Dr. M. N. Richter, of New York Post Graduate Medical School and Hospital, for confirmatory microscopic diagnoses of a random sample of 22 of these mice. The reason that this high incidence of leukemia was not anticipated is that the leukemia (as indeed all causes of death) is much later in appearing in this strain than in strain C58. This fact is indicated by the accompanying comparison of average length of life and incidence of leukemia in inbred females of three strains. This table furnishes new evidence of the independence of longevity and incidence of leukemia, a subject discussed a year ago, in that the relatively long-lived mice of strains Balb and StoLi differ so greatly in the incidence of leukemia, and in that the many leukemics in strains C58 and Balb differ so greatly in length of life.

STRAIN (FEMALES)	LEUKEMICS (%)	TOTAL NO. OF MICE	LENGTH OF LIFE (DAYS)	
			Non-leukemic	Leukemic
Balb* ...	69.3	88	632.0	692.3
Balbf.. .	68.0	25	655.5	679.8
StoLif...	15.1	33	678.9	688.0
C58f....	90.5	40	482.0	360.3

* Virgin females.

f Females which had produced young in connection with the foster-nursing experiment previously described.

STEROID HORMONES AND TRANSPLANTED LEUKEMIA

Gasić has carried out various experiments with steroid hormones and transplanted leukemia, with the purpose of investigating the possible influence of these hormones on the time of survival and the pathological picture of inoculated mice.

Pellets of hormone, pure or mixed with cholesterol, were inserted subcutaneously into normal males and females and spayed females of strain C58 at the age of one month; the spaying was done at the same time. The cholesterol and the pure hormones—desoxycorticosterone acetate, progesterone, and testosterone propionate—were generously provided by the Schering Corporation. In most of the experiments, leukemic cells of line I were used in doses diluted to 1/256 of standard, which doses are 100 per cent lethal in normal mice of this strain. These doses were given 10, 21, 32, and 60 days after the hormone pellets.

The results indicate that the mice treated with testosterone propionate 32 and 60 days before leukemic inoculation survived a little longer than the controls. In different experiments the averages were from 12 to 18 hours longer. The other two hormones showed no effect on the time of death.

Most of the effects of the hormones on the anatomical pictures at autopsy were those indicated in the literature on normal organs. In mice with pellets of desoxycorticosterone, however, the leukemic spleens were unaccountably large. And in spayed females the small hemorrhages that appear in the lungs very shortly before death from line-I leukemia were reduced in frequency and size; this effect was partially overcome by progesterone and eliminated by testosterone propionate. Histological study reveals that these pulmonary hemorrhagic spots are caused by thrombi rich in leukemic cells; but the pathological mechanism concerned, and the manner in which sex hormones act upon it, are questions for investigation.

Incidental observations showed that total body weight of females was increased by spaying, so that it surpassed that of males by 32 days after the operation. Pellets of testosterone propionate considerably coun-

teracted the effect of spaying. Progesterone has a similar but less striking effect. In leukemic mice the correlation between weights of entire body and liver was high; it was lower between body and spleen; but thymus weights showed no correlation with body weight. The spleen of the leukemic female at death weighed less than that of the male, but spaying females eliminated this difference.

ALARM REACTION

In the course of the preceding work, Gasić noted that mice of strain C58, inoculated with leukemic cells of line I, showed a severe involution of the thymus. This observation had been made previously, in experiments on immunity to leukemic cells in this laboratory. But Gasić recognized that this involution and other conditions associated with it were characteristic of a general syndrome described by Selye as the "alarm reaction," which may be elicited by a variety of deleterious conditions and substances. Selye's 1940 list of stimuli known to induce this reaction does not include malignant growths.

After a period of incubation, the inoculated animals show a clinical syndrome resembling shock: lowered temperature, lack of muscular tone and of appetite, sweating, drooping eyelids, and frequently a white lachrymal secretion. Anatomically, the chief features of the well developed alarm reaction are: hypertrophy and other gross changes of the adrenal, involution of the thymus, atrophy of the pancreas, general hyperemia, edema of the serosa, and, less frequently, ulcers and erosion of the digestive tract accompanied by hemorrhages.

The defensive importance of the involution of the thymus, under immediate control of adrenal hormones, has recently been brilliantly elucidated by the experiments of Dougherty, White, and Chase. Not only are antibodies delivered to the blood stream by a hormonal control of the thymus, but normal lymphocytes may transfer specific antibodies to, and receive them from, malignant cells of a transplanted lymphosarcoma. The appearance of the gross phenomenon of thymic involution in certain leukemic hosts raises the question of the possible part this phenomenon may play in induced resistance to leukemic cells.

In approaching the significance of this reaction for the interpretation of leukemic processes as well as for the mechanism of resistance to leukemia, Gasić has studied different experimental conditions and spontaneous cases. He has varied the genetic constitution of the host and the size of the dose of inoculated leukemic cells of lines differing in virulence, number of transfers, and other specific characteristics. In general, the strength of this reaction increases as the survival time is reduced. In spontaneous cases and early transfers, which are relatively chronic with large tumorous lesions, the alarm reaction is mostly undemonstrable. As the acuteness increases in the course of successive transfers, the leukemic lesions become progressively smaller and the alarm reaction more and more distinct. But even with an extremely virulent line of cells, the survival time may be lengthened by reducing the dose. This increases the size of the leukemic lesions and diminishes the expression of the alarm reaction. Certain combinations of genetically foreign hosts and acute leukemias show extreme alarm reactions, with minimum invasion of leukemic cells. The gross changes in adrenal and thymus are somewhat more evident in females than in males. Subsequent study will trace the alarm reaction during the processes of resisting lethal doses of leukemic cells and development of immunity. Does

a lethal dose in an immunized mouse occasion involution of the thymus, without conditions that in themselves might be responsible for death? How different are the causes of death in chronic and acute cases? Does resistance to the destructive aspects of the alarm reaction also destroy leukemic cells? Is the increase in toxic action in the course of successive transfers a result of the increasing proportion of large cells, or a change in a toxic agent carried by the cells?

CHROMOSOMES IN LEUKEMIA

In previous years, Biesele had found the chromosomes of many neoplastic tissues to be larger than, and usually about double the volume of, chromosomes of normal cells of the tissues of origin. Because the number of chromosomally carried plasmosomes in many of the resting nuclei of the neoplasms had doubled, and the frequency of polyploid mitoses in some tumors was low, it had been tentatively concluded that the enlarged chromosomes of malignant cells were structural multiples of the chromosomes of normal cells.

The new work has tested this conclusion by a study of chromosomes of leukemic and normal tissues of different ages.

In the study of chromosome size in normal tissues, some 1100 metaphase figures have been drawn from 50 albino rats of 6 age groups. The animals were provided by the Fels fund through the courtesy of Dr. E. J. Farris, of the Wistar Institute for Anatomy and Biology. Up to the present, the following scheme of variability in chromosome size has been disclosed. In late embryos chromosomes of the chief organs all measured about one-half cubic micron; the thymus chromosomes, however, were two or three times smaller. After birth the variability was greater: in lymph nodes, spleen, and intestinal epithelium the chromosomes became smaller with age, in epidermis and lung they remained constant, in kidney they increased in size, and in liver their relative increase was enormous, up to 20 times the size of the smallest thymus chromosomes. The order of tissues in adult rats, according to relative values based on average chromosome volume, is as follows: lymph nodes and spleen, 2; intestinal epithelium, 2+; epidermis and lung, 3; kidney, 4+; liver, 8. This seriation confirms one published earlier from more limited material.

These data yield a provocative insight into the nature and possible function of somatic chromosomes, especially as the two series are paralleled by others, from the literature, dealing with the over-all enzyme activities of adult rat organs and the concentrations of B vitamins, most of which are known to be associated with enzyme systems. The parallelism extends to embryonic organs. In view of the growing knowledge of the relation between gene and enzyme, it seems permissible to repeat here the suggestion that normal chromosomes, in proportion to their mitotic size, might be instrumental in the synthesis of protein apoenzymes of the cell. This would suggest a possibly qualitative differentiation of chromosomes in size and function, according to cell type and age.

These generalizations can probably be applied to the mouse. For example, livers of C58 adults, regenerating after partial surgical removal, contained chromosomes much larger than those in embryonic liver.

It is known, however, that malignant tissues often show reduced enzyme activities and vitamin concentrations. Is the presumed productive effort of the enlarged chromosomes in cancers abortive, being diverted to the benefit of the competitive altered enzyme or "cancer virus" of V. R. Potter's theory? Or is the enlargement of chromosomes in neoplasms of a different

sort from that in normal tissues, perhaps involving the less specific heterochromatin instead of euchromatin? But if the enlarged chromosomes of cancers are actually abnormally multiple in structure, each one must consist essentially of a number of smaller chromosomes, and hence the euchromatin could not have undergone the differentiational enlargement suggested as leading to big chromosomes in normal cells.

Our knowledge of the processes occurring in the enlargement of chromosomes in malignancies is augmented in several ways by the study of chromosomes in leukemia of C58 mice.

First, we find that the development of leukemia reverses the reduction in size of lymphocyte chromosomes, which normally goes on rapidly in early life but more slowly with age. Thus in spontaneous leukemias in 12 animals about 40 weeks old, the average chromosome size in the enlarged mesenteric nodes and spleens was one-third to two-thirds greater than that in 3 coeval controls (0.37 cubic micron). With respect to chromosome size the whole population of dividing leukemic cells seems to have been shifted upward, yet in this regard the leukemic populations of the 40-week-old mice were hardly distinguishable from the normal lymphocyte populations of 9 males about 2 months old. Likewise, the average chromosome volumes in the six current lines of long-transplanted leukemia were about 0.8 cubic micron, much the same as the average for the spleen of the newborn C58. Although the upper limit of chromosome size in the six lines exceeded that in the newborn spleen, there is evidence that its peer may be found in the primitive blood cells of embryonic liver. In but one leukemia, a spontaneous case in a 2-year-old hybrid female, were there chromosomes of a size (up to 2.0 cubic microns) unparalleled in the normal lymphatic tissues; but this case had other odd features, such as a great deal of aneuploidy and polyploidy instead of the usual uniform diploidy. Evidently in the majority of dividing C58 leukemia cells there are chromosomes whose size is equaled at some stage in the ontogenetic history of normal lymphocytes. Since it is possible that equality of size of chromosomes could disguise an underlying dissimilarity of structure or material, our present observations hardly give us basis for choice between J. S. Potter's concept of an altered rate of differentiation as the fundamental malignant change and the theory of "tangential" differentiation of some other oncologists.

Second, our study demonstrates that the enlargement of chromosomes in malignancies may not be absolute and irreversible, since the size of chromosomes in leukemias appears to be environmentally modifiable. In each of the six transplanted lines, the over-all mean of chromosome volumes in specimens taken from female hosts was smaller by about one-fourth than the mean for male specimens. There was some overlapping, however. That this sex difference in size of leukemic-cell chromosomes may have a hormonal basis is suggested by examination of Gasić's material. For example, in spayed females, half of which bore implanted 12-mg. pellets of pure testosterone propionate for 1 month before inoculation with leukemic cells, the average chromosome volume in leukemic lesions of the 6 animals receiving the hormone was significantly greater than that in the 7 untreated animals. The ranges of chromosome size scarcely overlapped, and the leukemic-cell chromosomes in the spayed females without added testosterone pellets were the size of normal lymphocyte chromosomes in intact males at 7 weeks.

The above observation indicates that in lesions even of highly virulent lines, cells

with small chromosomes may be leukemic. In addition, the smallest chromosomes found in the supposedly totally leukemic lesions of liver were usually but little larger than the mean size of lymphocyte chromosomes within uninoculated animals.

The third contribution made by these studies of leukemia to our knowledge of chromosomes in malignancies is the realization that their enlargement may be gradual. With the exception of the aberrant case mentioned above, the frequency distributions of metaphases according to average chromosome volume in the 60 leukemic specimens studied are interpretable as unimodal, rather than polymodal as in many cancers. The increase in chromosome volume from the normal condition through chronic spontaneous leukemia to its highly virulent transplanted derivative also promises to be a continuous one. A slow hypertrophy of the chromosomes in mouse leukemia, rather than a sudden doubling in volume such as occurs in mouse skin painted with carcinogenic hydrocarbons, would suggest that a more subtle change than an abrupt structural modification by doubling of strand number may be responsible, not only in leukemic cells but also in cells of other types of malignancy.

Direct studies of structure on the chromatid level, by uncoiling chromosomes and allowing sister chromatids to fall free of one another, are in progress. Should it be determined that the chromosomes of leukemic cells contain no more than two chromatids, as would seem likely from the earlier observations of Claude and Potter on chromatin threads isolated from leukemic cells, and that the leukemic-cell chromatid gives no visible evidence of a more complex structure than that of the normal lymphocyte chromatid, then the explanation of larger size of chromosomes in leukemic cells would have to be sought on a level other than that of the chromatids or their immediate precursors —perhaps ultimately on the level of molecular amount or kind. On this level a gradual size increase would be readily explicable, but it should not be interpreted offhand as the exact reversal of the ontogenetic diminution.

In summary, we are left with the suggestion that the enlarged chromosomes of C58 leukemia are either immature normal chromosomes or products of differentiation in an abnormal direction. If the latter view be accepted, it is not clear what form the hypertrophy has taken, nor whether the chromosomes are structurally or materially altered. The size of the chromosomes is fairly labile and responsive to certain environmental conditions. Apart from the question of leukemia, the demonstration that the size of mouse chromosomes can be influenced by means of hormones would seem to be of importance in chromosomal physiology. This is especially true in view of the suggestion that there is a differentiation of chromosomes according to cell type and age, in which the size of the chromosomes reflects their activity in some part of the manufacture of intracellular enzymes.

ENDOCRINE STUDIES

O. RIDDLE, W. F. HOLLANDER, M. R. MCDONALD, E. L. LAHR, AND G. C. SMITH

During the past year most members of this group have shared in the conduct of research, and also assisted in the preparation of manuscripts dealing with previous research. In March Air. Lahr left to become associated with the School of Dentistry of New York University. At intervals during the year Professor Hoyt S. Hop-

kins, of the Department of Physiology, New York University, rendered further assistance in summarizing the results of our extended study on heat production in doves and pigeons. Manuscripts constituting a small volume, "Studies on carbohydrate and fat metabolism, with especial reference to the pigeon," were completed in January. These studies by Riddle and associates will appear as publication 569 of the Carnegie Institution of Washington. Manuscripts dealing with our prolonged studies on races of doves and pigeons, "Endocrines and constitution in doves and pigeons," were completed later. In July, substantially the whole of our program of research was brought to a conclusion.

THE EFFECT OF REPRODUCTION AND ESTROGEN ADMINISTRATION ON THE PARTITION OF CALCIUM, PHOSPHORUS, AND NITROGEN IN PIGEON PLASMA

A partial report was made last year on the partition of those plasma components that might be capable of binding the large increases in calcium observed in pigeon plasma during periods of egg production or after injection of estrogens. These studies by McDonald and Riddle have now been completed and the results published. Changes in the various calcium, phosphorus, and nitrogen components of plasma were studied *(a)* in 75 adult female pigeons during the reproductive cycle and *(b)* in 31 normal, 4 fasted, 13 parathyroidectomized, and 4 hypophysectomized pigeons injected with estrogens. Birds of both $scxcs_y$ varying in age from 1.5 months to 5 years, were used in the latter study; 65 additional pigeons (46 normal, 13 parathyroidectomized, and 6 hypophysectomized) were used as controls.

No significant differences occurred in either ukrafiltrable calcium, ultrafiltrable inorganic phosphorus, or nonprotein nitrogen during the reproductive cycle or after the injection of estrogens. Nonultrafiltrable calcium, nonultrafiltrable inorganic phosphorus, lipid phosphorus, and protein phosphorus all increased markedly from 4 days before the ovulation of the first ovum until 2 days after the ovulation of the second (last) ovum. Similar, and even greater, increases resulted (in all the types of pigeons studied) from the daily injection of from 0.25 to 0.5 mg. estradiol benzoate for from 4 to 25 days. Small increases in protein nitrogen were noted under these conditions. Endogenous estrogens, as postulated by Riddle in 1927, are probably responsible for the increased plasma calcium, phosphorus, and nitrogen found during the reproductive cycle.

Calculations of the regression equations and correlation coefficients between the various plasma components that increased owing to endogenous or administered estrogens showed that the nonultrafiltrable calcium of pigeon plasma exists in three forms: *(a)* colloidal calcium phosphate, (£). calcium bound to the phosphoprotein, serum vitellin, and *(c)* calcium bound to the plasma proteins other than vitellin. Increments in *(a)* and *(b)* accounted for all the estrogen-induced increases in nonultrafiltrable calcium. The changes found in the partition of the latter as it increased during reproduction or under the influence of administered estrogens are summarized in figure 1. In 72 control pigeons, 36 per cent of the nonultrafiltrable calcium occurred as colloidal calcium phosphate, 12 per cent was bound to vitellin, and 52 per cent was bound to the plasma proteins other than vitellin. In 102 estrogen-treated pigeons, however, 37 per cent of the nonultrafiltrable calcium was in the form of colloidal calcium phosphate, only 8 per cent was bound to the plasma proteins other than vitellin, and 55 per cent

was bound to vitellin. Calculations of the calcium-binding capacity of serum vitellin showed that 1 gram of this phosphoprotein can apparently combine with more than 7 mg. of calcium—a value 8 to 9 times greater than that of the other plasma proteins.

trable phosphorus; protein phosphorus was responsible for 36 per cent, and nonultrafiltrable inorganic phosphorus for the remaining 8 per cent.

Benjamin and Hess (1933) noted that barium sulfate adsorbs from plasma a part of the nonultrafiltrable calcium. They

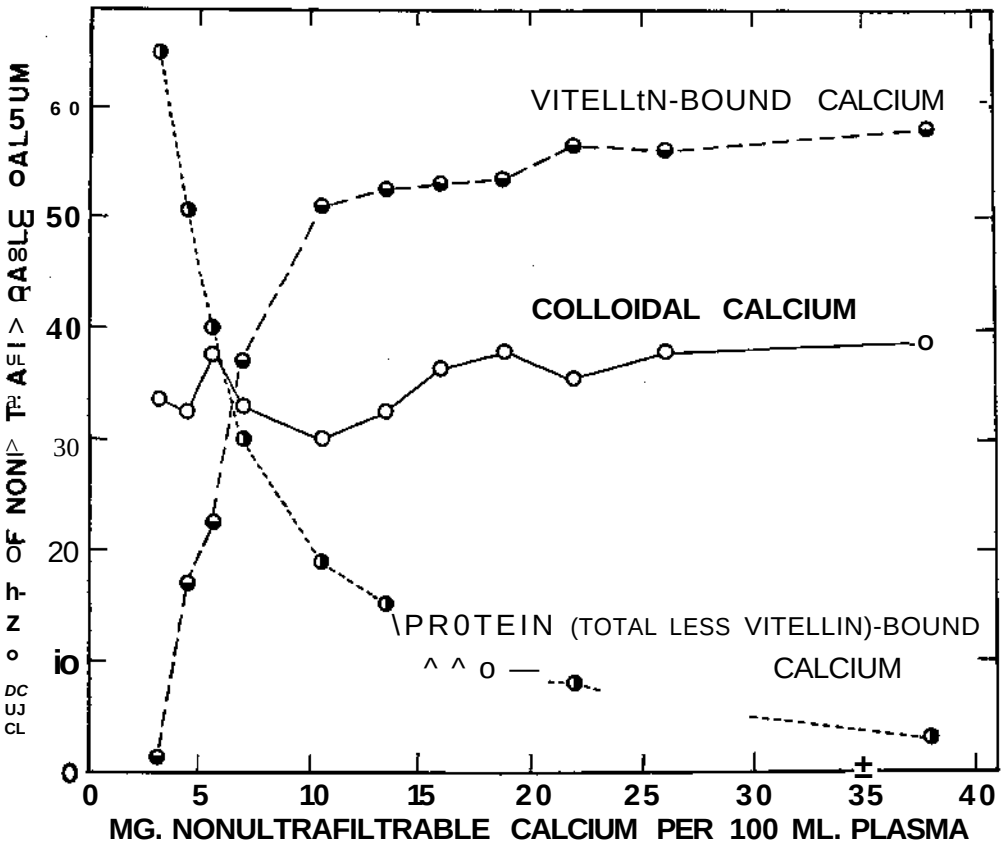

FIG. I. Analysis, on a percentage basis, of the partition of nonultrafiltrable calcium in pigeon plasma. Each point represents the average of 10 to 29 determinations.

No evidence was obtained for the presence of a phospholipid-calcium complex in the plasmas of pigeons with hypercakemia due to administered or endogenous estrogens. Lipid phosphorus accounted for 93 per cent of the nonultrafiltrable phosphorus in the plasmas of the control pigeons, but for only 56 per cent of the estrogen-induced increases In nonultrafil-

assumed that this procedure separates the nonultrafiltrabk calcium into at least two fractions: protein-bound calcium and an unknown adsorbable complex. Their procedure has been widely used in other laboratories, but the possibility that barium sulfate might also adsorb protein has apparently been neglected- Results obtained in this laboratory on 31 samples of pigeon

plasma confirmed the fact that part of the nonultrafiltrable calcium was adsorbed by barium sulfate. The latter, however, also adsorbed part of the phosphoprotein, serum Vitellin. It is therefore impossible to separate, by the procedure of Benjamin and Hess, protein-bound calcium from the adsorbable complex. There is probably a partial adsorption of all the nonultrafiltrable calcium fractions rather than a complete adsorption of one or more specific fractions.

ACTION OF THYROXINE ON ESTROGEN-INDUCED CHANGES IN BLOOD CHEMISTRY AND ENDOSTEAL BONE

Estrogens, in addition to increasing the calcium, phosphorus, and lipid content of bird plasma, also induce growth of the oviduct and formation of endosteal bone. Fleischmann and Fried (1944-1945) made the important observation that thyroxine, when administered to immature chicks simultaneously (in equal amounts by weight) with estradiol dipropionate, greatly reduces the ability of the estrogen to increase the plasma calcium, inorganic phosphorus, vitellin, phospholipid, and cholesterol, but does not inhibit the estrogen-induced growth of the oviduct.

Experiments were undertaken in this laboratory to determine *(a)* whether the results obtained with simultaneous dosage of thyroxine and estrogen in fowl could be duplicated in pigeons, *(b)* whether such treatment prevents the increase in plasma neutral fat which follows the use of estrogen alone, and *(c)* whether endosteal bone can be formed under the simultaneous administration of thyroxine and estradiol benzoate. The results obtained have been published. It was found that thyroxine prevented the marked estrogen-induced increases in plasma neutral fat, calcium, inorganic phosphorus, lipid phosphorus, protein phosphorus, and total nitrogen. It did not measurably inhibit the ability of estrogen to induce formation of endosteal bone or growth of the oviduct. It therefore seems improbable that thyroxine is a physiological antagonist of estrogens. Its inhibiting action on the estrogen-induced increases in plasma constituents is probably a secondary effect associated with increased metabolism and excretion of calcium, phosphorus, and nitrogen.

The data from these experiments afforded further proof that all the nonultrafiltrable-noncolloidal calcium not bound by the normal plasma proteins is bound by the phosphoprotein, serum vitellin. When the nonultrafiltrable-noncolloidal calcium values for the thyroxine-treated pigeons were plotted against those for protein phosphorus, all the points were found to lie on the regression line previously calculated for 104 estrogen-treated pigeons. When such data for nonultrafiltrable-noncolloidal calcium were plotted against lipid phosphorus, however, none of the points fell on the regression line calculated for 31 normal pigeons injected with estrogen.

SOLUBILITY OF THE PLASMA PROTEINS IN ALCOHOL

It was noted last year that at least one of the plasma proteins had the peculiar property of being soluble in acidified mixtures of 3 parts ethanol and 1 part ether. Further investigation of this unusual phenomenon has been possible through the courtesy of Dr. John T. Edsall, who has kindly supplied us with several of the plasma products developed by the Department of Physical Chemistry of the Harvard Medical School from blood collected by the American Red Cross. The study has not been completed, but the results thus far obtained are extremely interest-

ing. They suggest that, if investigations are made over a wide range of pH, it may be found that alcohol solubility is a much more common property of proteins than has previously been postulated.

Crystalline serum albumin was found to be highly soluble in 95 per cent ethanol or mixtures of 3 parts ethanol and 1 part ether, in the presence of small amounts of hydrochloric, nitric, lactic, acetic, or trichloracetic (but not sulfuric) acid. The effect of trichloracetic acid is especially noteworthy, since it completely precipitates albumin from aqueous solutions. Albumin precipitated by trichloracetic acid can still be dissolved by acidified 95 per cent ethanol or ethanol-ether mixtures. The range of pH in which albumin is soluble in 95 per cent ethanol extends from below pH 1.5 to about pH 4.5.

Some, but not all, of the several a (or (3) globulins were also found to be soluble in acidified 95 per cent ethanol and, to a lesser degree, in ethanol-ether mixtures. Solutions of these fractions, however, unlike those of albumin, are unstable, and the globulins slowly precipitate. The yglobulins and fibrinogen appear to be insoluble in 95 per cent ethanol in the range of pH thus far studied.

Attempts have been made to develop a method, based on the above observations, for the quantitative determination of albumin and globulin. The results to date are extremely promising. Further refinements of technique should yield a simple procedure for the analysis of these components.

PARTIAL MELANISM ASSOCIATED WITH PARATHYROID ENLARGEMENT

Melanism arising from physiological disturbance has not previously been reported for domestic pigeons. A few cases of partial, melanism have been observed in the pigeon colony of this department under circumstances that suggest the nature of the factors intimately associated with the belated appearance of this condition. Hollander and Riddle have found that, on the diet supplied to birds of this colony, a deficiency of sunlight regularly leads to enlargement of the parathyroids and also seems to be concerned in the occasional onset of partial melanism. This melanism had the following characteristics: *(a)* it was observed only in adult female pigeons of essentially wild-type coloration—gray-blue with black bands on tail and wings; *(b)* it was definitely partial rather than complete; *(c)* it first appeared after one or more molts; *(d)* when the blackening did not involve entire feathers it produced transverse bands on the feathers, not longitudinal streaks such as are typical of mosaic effects.

Five cases of this type of nongenetic partial melanism were observed in adult female domestic pigeons. One similar case was observed in an old male hybrid *(Zenaida* X *Zenaidura)* dove after it became unable to fly. Two physiological conditions, slight exposure to sunlight and enlargement of the parathyroids (3 to 6 times normal), were known to be associated with all these six cases of melanism. It is considered probable that these conditions were also responsible for previously reported instances of melanism in caged wild birds. In two instances, plucked melanistic feathers were replaced by normal feathers following the administration of a concentrate of cod-liver oil (vitamin D).

Parathyroid enlargement was shown to occur regularly in young pigeons reared on a mixed-grain diet in the absence of direct sunlight (vitamin D deficiency). Grossly defective ossification of the bones (rickets) of many such pigeons was also noted. These conditions have been observed repeatedly by others in fowl.

Rachitic squabs never have shown melanism even when their parathyroids were very large. A more prolonged deficiency, or an element of aging, therefore, seems to be necessary for the appearance of melanistic feathers. Something more than chance is probably responsible for the fact that this type of melanism has not been observed in a male pigeon. It should be noted that the male's supply of calcium and vitamin D is not subject to the special drains and losses that necessarily accompany *egg* production in the adult female.

INTERSEXUALITY IN MALE EMBRYOS OF PIGEONS

A transient intersexuality in male embryos of certain species of birds has been reported by various investigators. The species in which this condition has been observed include the fowl, English sparrow, blackbird, and pheasant, hawks, and ring doves. This anomaly involves a temporary development of ovarian cortex on the left testes, but usually not on the right testes, of genetic male embryos. Lahr and Riddle investigated the question whether this type of intersexuality exists in the pigeon, and also made a comparison of the conditions found in normal breeds of pigeons with those existing in the special strain of hermaphrodite-producing pigeons developed in this laboratory.

Ovarian cortical tissue is present on the left testes of all pigeons examined at the 14th and 15th days of incubation. In testes from normal races of pigeons (33 cases), ovarian tissue showed degeneration between the 14th day of incubation and the end of incubation (18 days); in such testes the ovarian tissue disappeared completely at or before the time of hatching.

Testes derived from embryos of the hermaphrodite strain (28 cases) differed from those of normal type in showing a delay in the time at which atrophy of the cortical tissue begins; this atrophy was first observed, in 2 of 7 cases examined, on day 17. This tissue had disappeared in only 1 of 4 embryos at day 18, and in only 3 of 6 embryos examined at 5 days after hatching. Birds that retain large amounts of ovarian tissue at and after hatching are presumably the ones that have been observed to possess a left ovotestis and (or) a left oviduct in adult life.

MISCELLANEOUS

Dr. Hollander has prepared various papers or items for publication. The titles of these communications will be found in the bibliography for this year or next year. One of these papers provided an extensive review of "Mosaic effects in domestic birds"; another study, conducted on the flock of pigeons personally maintained by Dr. Hollander, resulted in the paper, "A lethal achondroplasia in the pigeon."

Mrs. Smith has developed and published a technique for the complete removal of the parathyroid glands of pigeons. Several studies conducted in this laboratory during the past two or three years on medullary bone formation, and on factors affecting calcium and phosphorus levels in the blood, have required an extensive use of this technique. Riddle, Rauch, and Smith earlier found that the parathyroid tissue of certain pigeons (e.g., Carneaux) lies wholly external to the thyroids; in these animals, therefore, parathyroidectomy is of special interest, since it involves no injury to or reduction of thyroid tissue.

ENDOCRINES AND CONSTITUTION

Manuscripts describing the results of Riddle's twenty-four-year study of the relation of endocrines to constitution in doves and pigeons have been completed. Several of the more important results of that study have been indicated in Year Books of the past eighteen years. The

additional facts that have emerged under a final analysis of the data cannot be properly considered here; they are presented in one or another of the eighteen chapters which provide a full account of one of the Institution's most prolonged experimental studies. The present statement, however, will refer to one result that hitherto was unsuspected, and will in addition discuss briefly the nature and significance of the entire study.

An unusual "selection" experiment, conducted principally on twenty-four pairs of ring doves (and on their progeny), will be discussed further in later paragraphs. The final data show that at least two of these twenty-four derived dove progenies, or "races," differed from other races with respect to a sex difference in body weight. Normally, male doves are heavier than females; but the present tests led to the establishment of two races in which this condition did not exist, and also to the establishment of still other races in which this sex difference was more marked than in other races. It should be stated that these differences were not consciously sought, but were a by-product of other selection. Since various measurements were made continuously on all the races (progenies), the data thus obtained might be expected to provide information concerning the relation of endocrine status to the presence or absence of this sex difference in body weight. This expectation was fulfilled only in small measure. Good, though perhaps inadequate, evidence indicated that races which show no difference in body weight have the highest rate of heat production and therefore probably a high level of thyroid function; again, races with unusually large sex difference in body weight had unusually low rates of heat production. Less consistent evidence indicates that in races which show no *sex* difference in body weight the females attain sexual maturity at a more advanced age than do the females of races which exhibit a sex difference in body weight.

The primary purpose of the study now completed was to learn whether certain of the individual differences of doves could be established as racial characteristics, and, if so, whether hormonal differences are associated with one or another of such racial differences. It would seem that facts derivable from a study of this kind should have nonnegligible implications in regard to both individual and racial differences in man. In the long and complicated task of recognizing, measuring, and evaluating human constitutional differences—as in the similar and, we believe, better-performed task concerning human origin—it seems clear that experimental animals must be expected to supply some basic principles and much indispensable information. A variety of reasons led to the acceptance of doves and pigeons as species especially suitable for one such study. For example, the degree of mongrelization present in each of these species is apparently comparable with that in the human population of an American city, and many findings relating to constitutional factors in these birds are probably applicable to man. Support for that early view has accumulated during the twenty-four years that have elapsed since the present study was started.

During the progress of this study it became evident that we were, in fact, then dealing with physiological and structural inequalities of related groups of individuals (races). It should be observed that the word "inequalities," not "differences," is used in the preceding sentence. Since physical conditions could here be virtually leveled—substantially equalized—and since social, educational, and related influences are wholly improbable in this material, it

is concluded that the highly important distinction between "inequalities" and "differences" is implicit in the results of this investigation.

Whether the segregated groups should be called "races," "breeds," "stocks," or "types" is immaterial. It is wholly probable that numerous humans carry and transmit genetic factors predisposing to the extremes of most or all of the several traits studied in doves. And the strong presumptive evidence that similar segregates are (theoretically) obtainable within *Homo sapiens* is not contradicted by any valid evidence of which the writer is aware. The results of the present investigation thus provide direct experimental support for the view, now prevalent among anthropologists, that the products of endocrine glands do much to shape the anatomical variants with which their measurements usually deal. These results also lend support to those few anthropologists who conclude that it is not alone "underprivilege which makes the underdog." Widespread genetic inequalities of individuals and groups characterized the organisms here subjected to tests.

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NUTRITION LABORATORY

Boston, Massachusetts

THORNE M. CARPENTER, *Director*

The activities of the Nutrition Laboratory during the past year have been devoted almost exclusively to investigations on war research projects under a contract of the Office of Scientific Research and Development with Harvard University. These studies are conducted in cooperation with the Harvard School of Public Health. The investigation that was started on January i, 1943 was finished during the past year. Several other projects have been completed or are rapidly approaching completion. Three reports have been prepared for the Office of Scientific Research and Development. With the resignation of members of the staff and the almost complete absorption of the remaining staff members in the war researches, all other scientific activities have ceased. With formal conclusion of the Laboratory's work in immediate prospect, a review of its contributions during the past thirty-eight years is made part of this report.

The Nutrition Laboratory was established in 1907 with Dr. Francis G. Benedict as Director, and he continued in this capacity until 1937, when he retired. The building was completed early in 1908 and active work on construction of apparatus and the carrying out of investigations began at that time.

The primary purpose of the Laboratory was to conduct fundamental scientific investigations in vital activity with special reference to the laws governing total metabolism, heat production, heat elimination, and heat regulation. Although the undertaking was designated as the Nutrition Laboratory, the main part of its work has not been, in nutrition as popularly understood, but has consisted in fundamental studies on basal metabolism and heat production as a basis for determining the requirements of energy in nutrition to meet the needs for heat for body processes and muscular activity. Only occasionally have prescribed diets, digestibility studies, and analyses of foods been employed. Special studies on food composition have occasionally been made, such as analyses of Bengali foods, foods of the Maya, foods of the Navajo Indians, and the common everyday extra foods eaten at other times than regular meals.

From the beginning, emphasis has been laid upon exchange of information with workers in other countries. Periodic trips were made to Europe, to become acquainted with investigators in similar lines of work, to gain a more intimate knowledge of their researches, and to acquire newly developed apparatus that would be useful in investigations in the Laboratory. Information regarding experimental work in progress in the Laboratory was imparted freely to other workers, and on several trips series of lectures were given gratuitously on the latest studies in the Laboratory. Foreign workers were invited to spend the greater part of an academic year at the Nutrition Laboratory as research associates. The funds for most of these were provided by special grants from the Institution, and occasionally by grants from other organizations. Many other workers came to the Laboratory for periods of varying length to become acquainted with the various forms of apparatus and the problems on which the Laboratory was engaged. Many American investigators

also, who participated later in cooperative studies, came to the Laboratory to be trained in the apparatus and techniques.

Cooperation with other workers and other institutions and universities has had a prominent role all through the investigations of the Laboratory. In the first year of active construction of apparatus, 1908, a cooperative study on the metabolism of diabetes mellitus in man was begun with Dr. Elliott P. Joslin, of the New England Deaconess Hospital. This cooperation with him and with his colleagues was carried on almost continuously until 1943. Other cooperative investigations are mentioned below.

A major part of the activities of the Laboratory has been the development and testing of various types of apparatus for the measurement of heat production, heat elimination, respiratory exchange, and surface and internal body temperature. The earliest project was the construction of four respiration calorimeters for human subjects for special purposes, and more particularly for periods shorter than 24 hours. The comparison of direct and indirect calorimetry was an outstanding problem; it was found that the measurement of respiratory exchange in short periods gave a reliable measure of heat production, and consequently the use of calorimeters was gradually diminished. The necessity for a more sensitive type of calorimeter for measuring rapid changes in heat elimination such as might occur in studies of heat regulation led to the development of the emission respiration calorimeter for animals in 1916 and for humans in 1920. At the time of writing, with the finding that direct calorimetry is no longer necessary for the majority of problems in total metabolism, only the emission calorimeter for humans is still in functioning condition.

From the beginning the development of respiratory apparatus for measurement of very short periods was also an object of investigation. This resulted in an apparatus by which reliable results could be obtained in as short a period as one-quarter hour. This apparatus has been simplified more and more, and now devices based on the principles involved are widely used in thousands of clinics and hospitals for determination of basal metabolism of human patients. Various types of apparatus were also originated for determining the respiratory exchange of animals of various sizes and species. The standard European types of apparatus for measurement of total metabolism were obtained. For many years one of the most important phases of the work of the Laboratory was the study of the use of these apparatus—also of apparatus devised in American laboratories—and of their technical difficulties, reliability, and accuracy, in comparison with the apparatus originated in the Laboratory.

Most of the earlier respiration apparatus devised in the Laboratory were based on the closed-circuit principle. In 1922, however, a gas analysis apparatus was developed which permitted the analysis of atmospheric air and air coming from open-circuit respiration apparatus with an extraordinarily high degree of accuracy. Thereafter, more and more the open-circuit principle of measurement of respiratory exchange was applied, particularly in studies on animals of various sizes, and in studies where exact information was needed on the respiratory quotient as an index of the character of body material and the rapidity with which true basal condition was obtained, and on the effect of food on the character of the metabolism. The use of the open-circuit principle with gas analysis made possible the measurement of total metabolism of

animals with which the use of the closed-circuit system would have been impracticable.

The necessity for establishing standards of basal metabolism of normal human subjects of both sexes was early recognized, and this project constituted one of the major activities of the Laboratory. Gradually large enough numbers of adult human subjects were studied so that standards were devised based on height, weight, age, and sex instead of body surface. This accumulation of measurements also furnished material for derivation of basal metabolism standards in other ways by other workers. It is now customary for students of basal metabolism to use the Nutrition Laboratory standards as well as other standards for the estimation of the normality and abnormality of basal metabolism results. The studies on the normal basal metabolism were also extended to comprehensive series on human subjects from birth to old age, so standards are now available for all ages of both sexes of humans. Special researches were made on the conditions that may affect basal metabolism, such as position of the body, temperature, vegetarian diet, athletic activity, environment, season, fatigue, and the neutral bath. As several members of the staff either have been on the staff for a number of years or were available for periodic measurements, information has been obtained on the progressive effects of age on this factor.

In 1912, a notable study was made of the total metabolism, heat regulation, and balance of energy and of materials in a 31-day fast of a human male subject.

In 1913, an extensive program on the physiological and psychological effects of ethyl alcohol was inaugurated, and for a number of years this constituted a substantial part of the activities of the Laboratory. Even after the advent of the prohibition law the study of the physiology and chemistry of alcohol in man and animals was continued in special researches.

In 1917-1918, a comprehensive investigation was made of the physiological and chemical aspects of a group of young men of the International Y. M. C. A. College in Springfield who underwent undernutrition for an extended period. This resulted in considerable information on the ability of young men to carry on the physical and mental activities of normal life on a submaintenance diet.

The finding in 1925 that the basal metabolism of Oriental women living in the United States was lower than that found for American women led to an intensive and cooperative campaign on the study of race metabolism. A special apparatus was devised, compact and easily transportable, for the determination of basal metabolism in field studies and anthropology. Workers from other laboratories were trained at the Nutrition Laboratory and subsequently carried on studies of the basal metabolism of races in various parts of the world. The studies included the blacks and browns in Jamaica, the Maya in Yucatan, women of various races in southern India, the aborigines of Australia, natives of Manchuria, types of Chinese in eastern and western China, and various races and mixtures of races in the Hawaiian Islands. The results have been brought together in a large number of publications on race metabolism and have shown clearly that some races have a definitely higher metabolism and some a lower metabolism than that of the Caucasian race.

It was early recognized that our information regarding quantitative and qualitative aspects of the factors that go to make up the total metabolism of man could be supplemented by studies of the metabolism of animals. The research on

undernutrition in man in 1917-1918 led to a study of the possibility of the subsistence of cattle on a submaintenance diet, followed by an investigation of the subsequent realimentation. In the latter part of 1918 work was begun in cooperation with Professor E. G. Ritzman, of the University of New Hampshire, on this problem in the study of the total metabolism of undernourished steers. In 1922 similar work was done with fasting steers. This cooperative effort proved most profitable and was continued until 1938. Steers, cows, horses, sheep, goats, and pigs were used in research on the basal metabolism and the effect of food ingestion on total metabolism in both qualitative and quantitative aspects, and on the effect of season, of variations among breeds, and of external environment. These researches have been supplemented by studies on surface and internal body temperature under differing environmental conditions.

Researches on the basal metabolism of a great variety of animals have been conducted, usually covering a number of years. Rats were studied at Columbia University in cooperation with Professor H. C. Sherman and Professor Grace MacLeod, and at Yale University with Professor L. B. Mendel. Studies at the New York Zoological Park on wild animals in captivity included birds from the 600-gram bittern to the 17-kilogram cassowary, and cold-blooded animals from the gopher tortoise to the 132-kilogram tortoise as well as lizards, snakes, and pythons of various weights and sizes. At the Laboratory, valuable information was gained from a research project on the woodchuck, which forms a link, so to speak, between the warm-blooded and the cold-blooded animals in that at various periods it is in a condition like that of warm-blooded ones, and during hibernation it simulates the cold-blooded ones. The investigation concerned its total metabolism, the qualitative aspects of its metabolism, and its heat regulation during periods of normal activity, of going into hibernation, and of change from the hibernating state to the state of normal activity. The basal metabolism and heat regulation of the rabbit was extensively studied; other animals investigated there were canaries, sparrows, wild rats, frizzled fowl, and mice. The basal metabolism of the chimpanzee was studied at the Yale Anthropoid Experiment Station, Orange Park, Florida; that of the rhesus monkey, at the Department of Embryology of the Carnegie Institution, in cooperation with Dr. G. L. Streeter and Dr. C. G. Hartman; that of various races of doves and pigeons, in cooperation with Dr. O. C. Riddle at the Department of Genetics of the Institution. An investigation on the total metabolism of a 4-ton elephant was supplemented by several researches on various phases of the physiology of the elephant, using single elephants and groups of elephants.

In all these investigations on the basal metabolism and the various factors affecting it, special stress was laid on the necessity for finding the point of thermic neutrality—that is, the environmental temperature at which the metabolism was lowest—and on the complete absence of muscular activity. These two factors have not always been recognized in studies by other investigators.

The total heat production of any animal is, in general, made up from the combustion of the three groups of food components, proteins, fats, and carbohydrates. When these are burned in the body, each group produces a characteristic ratio between the volumes of carbon dioxide given off and of oxygen consumed. This ratio is called the respiratory quotient. When

the total respiratory exchange is l^nown, and the nitrogen in the urine due to the destruction of protein is known, it is possible to compute the amounts of the three substances burned in a given period. As a contribution to our information regarding the source of the substances furnishing the fuels for combustion that make up the total heat production, a knowledge of the respiratory quotient is of the utmost importance. The development of the gas analysis apparatus in 1922 made possible a more exact determination of the respiratory quotient and of the various factors affecting it in both animals and man than had previously been feasible. The finding, early in the studies with the simple sugars, dextrose, levulose, and galactose, into which the carbohydrates of the diet are for the most part resolved in digestion and absorption, that the response of the respiratory quotient after their ingestion by man differed widely, led to an intensive study of the factors that might cause these variations. The finding by other workers that the response of the respiratory quotient in rats seems to differ widely from that in man led to a series of studies by means of the open-circuit apparatus and gas analysis on the variations in the changes in the respiratory quotient after the ingestion of these three sugars by various species of animals, including the mouse, rat, canary, monkey, goat, and cat. The results show that there are wide variations in the metabolism of carbohydrates with these three sugars, both qualitatively and quantitatively. Although animals in general burn carbohydrates, fats, and proteins as does man, the manner in which these processes are carried out, both qualitatively and quantitatively, differs widely in the different species, so that it is not safe to transfer the results from one species to another without some qualifications.

The results of the various investigations of the Laboratory are presented in 35 monographs published by the Institution and in 414 articles that have appeared in scientific journals.

Since the beginning of 1941 the purely scientific activities of the Laboratory have gradually lessened because of the participation of the members of the staff in war researches.

STAFF NOTES

Mr. Robert C. Lee, a member of the staff since January 1929, resigned August 31, 1944. Miss Elsie A. Wilson, since September 1913 a member of the staff, resigned November 30, 1944. Mr. George Lee, a member of the staff since September 1929, resigned January 31, 1945. Mr. George Lee was an expert gas analyst and photographer. Mr. Robert C. Lee conducted a large amount of experimental work and in recent years contributed substantially to the published output of the Laboratory. Miss Wilson has been of inestimable value as secretary and editor and has aided very materially in the preparation of many manuscripts for publication. Miss Evelyn Barenberg was employed as secretary from November 20, 1944 to June 1, 1945.

The entire time of Mr. Robert C. Lee and Mr. George Lee until they resigned was employed in the war activities. Mr. V. C. Coropatchinsky has been engaged exclusively the entire year in the construction of newly developed apparatus for the war researches. About a month of Miss Wilson's time was spent on the preparation of reports on the war activities. On March 23, 1945, Dr. Carpenter gave his annual lecture on basal metabolism before students of the Harvard Medical School.

LITERARY WORK

The following articles have been completed for publication in scientific journals:

"The basal metabolic rates of South American Indians," by Elsie A. Wilson. (Accepted for publication in the *Handbook on the Indians of South America.)*

"The respiratory quotient and blood pyruvate and lactate responses after oral ingestion of glucose and fructose in diabetes mellitus with and without insulin," by Howard F. Root, Elmer Stotz, and Thorne M. Carpenter. (Accepted for publication in the *American Journal of Medical Sciences.)*

"The effects of the dietary supply of carbohydrate upon the response of the human respiratory quotient after glucose administration," by Howard F. Root and Thorne M. Carpenter. (Accepted for publication in the *Journal of Nutrition.)*

"The respiratory quotients (R.Q.) of diabetic subjects after meals," by Howard F. Root and Thorne M. Carpenter.

PUBLICATIONS

(i) *A new method for studying breathing with observations upon normal and abnormal subjects.* Leslie Silverman, Robert C. Lee, and Cecil K. Drinker with the cooperation of Francis M. Rackemann. Jour. Clin. Investig., vol. 23, pp. 907-913 (1944).

A new pneumotachographic device is described for making a graphic record of the velocity of air movement during inspiration and expiration. The inspiratory and expiratory air currents cause the deflections of fine wires, deflections that are recorded photographically by a moving paper camera. Typical illustrations of the resulting curves are presented, showing the results on one normal individual and on five patients with respiratory difficulties. The total minute volume and the instantaneous air flow can be obtained from the records made by the instrument.

(2) *The effects of glucose, fructose, and galactose on the respiratory exchange of the goat.* Ernest G. Ritzman and Thorne M. Carpenter. Jour. Nutrition, vol. 28, pp. 71-79 0944)•

The respiratory exchanges of four male and five female adult goats were determined 40 hours after withdrawal from food (1) under basal conditions and (2) in eight successive •J-hour periods after the administration by stomach tube of 250 ml. of water at *$7°~-$$°* C, or of 25 gm. of glucose, fructose, or galactose dissolved in 125 ml. of water and an additional 125 ml. of water for rinsing. Water produced a slight but somewhat delayed increase in the R.Q. Fructose caused the greatest increase in the R.Q. and the greatest increase in the metabolism of carbohydrates. Glucose was next in these effects, and galactose had the least effects. Qualitatively these results much resemble those found with man with these sugars. There was evidence of a slight amount of fermentation after the ingestion of galactose and of fructose by the goats.

(3) *The effects of sugars on the respiratory exchange of cats.* Thorne M. Carpenter. Jour. Nutrition, vol. 28, pp. 315-323 (1944).

The respiratory exchange was measured in successive £-hour periods for 4 hours with *Bve* cats in the basal state, after ingestion of 75 ml. of water, after ingestion of 10 gm. of glucose, fructose, galactose, sucrose, maltose, or lactose, and after ingestion of a combination of 5 gm. each of glucose and fructose or of glucose and galactose. The values of the basal R.Q. were uniform, for the most part, and did not show a marked tendency to change during the eight J-hour periods of measurement. The ingestion of water resulted in a rise in R.Q. with one cat for the entire 4 hours, but with the other cats only in the first i'-hour period. Glucose caused the great-

est rise in R.Q., and the peak occurred in the sixth and seventh J-hour periods. All the other sugars, disaccharides as well as monosaccharides, caused definite rises in the R.Q. On the assumption that in the control experiments with water only fat and protein were metabolized and that in the experiments with the sugars the protein metabolism of a given cat was the same as its average protein metabolism in the experiments with water, it was calculated that the metabolism of carbohydrates was highest after glucose and lower after galactose and fructose in the order named. The cats were able to metabolize the disaccharides nearly as well as would be expected, in view of their constituent monosaccharides formed by hydrolysis. When combinations of hexoses equivalent to 10 gm. of sucrose or lactose were ingested, the resultant metabolism of carbohydrates was greater than would be expected from the sum of the amounts metabolized after ingestion of the respective hexoses given separately. Cats resemble men in the metabolism of the rnonosaccharides in that they show increases in R.Q. and in carbohydrate metabolism after ingestion of these sugars, but they differ from men in that the peak does not occur so promptly and, qualitatively, the order of magnitude of the effect is not the same.

(4) *Basal metabolism from the standpoint of racial anthropology.* Elsie A. Wilson. Amer. Jour. Phys, Anthropol., n. s., vol. 3, pp. 1-19 (1945).

From many hundreds of metabolism measurements on normal men, women, and children of the white population of the United States, average values or normal standards of basal metabolism have been derived showing the energy needs of normal people. These normal standards vary, depending on age, weight, height, and sex. When other racial groups besides North American whites were studied, for example Chinese students in the United States, Maya Indians of Yucatan, and various races in South America, India, Australia, and other parts of the world, it was discovered that their basal energy needs were often higher or lower than the normal standards for the white population in the United States. Many investigators believe that these differences are ascribable to race and that this factor must be considered in addition to age, weight, height, and sex. Other investigators claim that race plays no role, but that the deviations from the normal standards for North American whites can be explained by differences in nutritive condition, climate, and other factors.

This review of the literature on the basal metabolism of different human races discusses these conflicting opinions and points out the many different conditions entering into the measurements that make it difficult to decide whether race itself is or is not a factor in basal metabolism. Among these are differences in physical activity and degree of muscular relaxation, differences in body size and body configuration, differences in diet, differences in climate and seasons of the year, and differences in anthropological and constitutional types. Another complication is that the normal standards of basal metabolism are commonly related to body size, particularly the surface area of the body, and the formula for calculating this area worked out for whites may not necessarily apply to all races. Moreover, different methods have been used in measuring the basal metabolism of the various races studied, instead of one and the same method.

A tabular summary is given of the results of those racial investigations in which basal metabolic rates above the normal American standards have been found. Another summary is given of the results of those investigations in which minus values of more than 10 per cent have been found, and still a third summary of the results of racial studies made between 1940 and 1942.

One of the striking findings is that most of the groups having basal energy needs distinctly higher than the standards for normal whites belong to the Mongolian race. These groups include Eskimos and American Indians.

From this survey it is evident that so many different factors may play concurrent roles in

affecting the basal metabolism that it is impossible at the present time to say whether the different basal metabolic levels noted for the various races thus far studied are reflections of a racial characteristic or are the results of a combination of some or all of the factors mentioned. The desirability of further studies on different races with the use of the same technique of measurement in all cases is urged, to rule out the factor of difference in technique. The suggestion is made that sufficient measurements be made to establish a normal standard for each individual race, based on measurements of normal individuals of the race in their native country. When such standards have been established for many different races, a comparison of these with the present-day American and European standards should throw more light on the role played by race in basal metabolism.

(5) *The respiratory quotient and blood pyruvate and lactate after ingestion of glucose or fructose by diabetic patients.* Thorne M. Carpenter, Howard F. Root, and Elmer Stotz. Federation Proa, vol. 4, pp. 152-153 (i945)-

A preliminary communication of results to be published in full subsequently.

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SPECIAL PROJECTS: BIOLOGICAL SCIENCES

T. H. MORGAN, ALFRED H. STURTEVANT, and LILIAN V. MORGAN, California Institute of Technology, Pasadena, California. *Maintenance of a Drosopkila stoc\ center, in connection with investigations on the constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15 to 43.)

The results of the work of A. H. Sturtevant on chromosome types of *Drosophila melanogaster* are reported as follows:

The fourth chromosome of *Drosophila melanogaster* is usually given as 0.2 units long. This value is evidently too high; there is probably less than 0.05 per cent crossing over between any of the known loci. When linkage experiments are carried out, it often happens that the design is such that nondisjunction will simulate crossing over, and this confusion has probably led to the value usually given.

TABLE 1

CROSSING OVER IN DIPLO-IV TRIPLOID FEMALES OF DROSOPHILA MELANOGASTER

Loci	Total no. flies	No. crossovers	Percentage
gvl ey.	1513	40	2.6
gvl sv.	680	22	3.2
ci ey.	965	15	1.6
ci sv.	158	7	4.4

Recent experiments have, however, shown that crossing over in this chromosome is greatly increased in triploid females, as shown in table 1. Most triploid strains carry only two fourth chromosomes, and the data were derived from such females. Crossing over in triplo-IV triploids Is more difficult to analyze, and, therefore, few counts have been made from them; a few crossovers were, however, present in the small numbers obtained.

These experiments have resulted in the production of three new multiple stocks, that are of value in studies on this chromosome: *gvl* sv^n, *ci* sv^n, and *gvl* sv^n ey^B. It should be added that the two latter are inconvenient to work with, owing to an unexplained high incidence of male sterility.

The construction of a crossing-over map has encountered an unexpected difficulty, namely, that the data indicate that some of the crossovers obtained have resulted from double crossing over. This is so unexpected, for a section showing so little total crossing over, that the result must be thoroughly checked before any confidence can be placed in it. All that can be said at present is that most of the observed crossing over occurs in an interval lying between the loci of *gvl* and *ci* on the one hand, and those of *sv* and *ey* on the other, but that occasional crossovers also occur between the members of each of these two pairs of loci.

These studies are being continued and the preference properties of the crossover chromosomes are also being determined.

Dr. K. W. Cooper, of Princeton University, has carried out studies, partly in this laboratory, on the effects of inversions on crossing over and chromosome disjunction. Some of the data are in press, and other experiments are still in progress. These studies, like those on preference properties of fourth chromosomes, are aimed at throwing light on the mechanics of chromosome behavior—a field that has recently been somewhat neglected by geneticists, but in which the material available in *Drosophila melanogaster* makes it

possible to carry out critical tests with a precision and efficiency nowhere else attainable.

The fourth-chromosome recessive character sparkling *(spa),* described in the report of i942-1943, has been further studied by L. V. Morgan in experiments designed to test the correlation between the manifestation of *spa* and relative amounts of heterochromatin and euchromatin.

Spa is manifested primarily by roughness and brightness of the eye and by other conditions such as shape and convexity. Roughness seems to be in part due to irregularity in the rows of ommatidia, which sometimes vary in size.

In order to facilitate comparison of different degrees of *spa,* an arbitrary scale of 7 grades was chosen. An eye of grade 6 is exceedingly rough, has no fleck, and is often bulging, round, and small. In grade 1 roughness is very slight, sometimes not involving all of the eye, sometimes discernible only in certain positions in relation to the source of light; it scarcely differs from grade 0 or "smooth." Grade 2 is evidently *spa.* When feasible, one parent in the mating was heterozygous for *spa* and for its wild-type allelomorph in a chromosome marked by the dominant wing mutant cubitus interruptus dominant *(ci^D).* Thus homozygous *spa* eyes could be compared in the same conditions directly with wild-type eyes, which sometimes are of a granular texture rather than entirely smooth. As there is no actual division between grades, the classification of borderline cases varies. For this reason and because *spa* is probably sensitive to genetic modifiers, the controls were present whenever possible in the same culture in which *spa* was rated, or sibs were used as Piflies.

Temperature affects the grade of *spa,* which is enhanced when the flies are raised at 17-19^0 C, the range chosen for the experiments. When first found, *spa* was raised at room temperature. In extracted homozygous flies *spa* was easily seen in females, but did not show in males. Raised at 19°, females were of higher grades and males showed low grades of *spa.*

Females have been found to be of higher grades than their brothers in every experiment in which the females were XX and the males were XY (possibly excepting flies carrying a deficiency for chromosome 2). But females carrying normal X's and also a Y chromosome do not show *spa* as observed in the regular class of attached-X females which are XXY. Their exceptional XXO sisters are *spa* and of higher grades than are the regular XY males. Sons of XXO females which are XO males show the highest grades of *spa* (6 and 5), exceeding even the grades of the few XXO females found in the same stocks of flies. These observations show a lowering of the grade of *spa* in the presence of a Y chromosome.

A correlation has also been found between the presence of differing amounts of heterochromatin in the X and the expression of *spa.* The X deficient for X heterochromatin and for the locus of bobbed found by Gershenson (Df G) was used (symbol X"). The grades of offspring of females heterozygous for X and X" mated to XY males are recorded in table 2 under A. Both females and males deficient in X heterochromatin are of higher grades than are the corresponding flies carrying the normal X's.

In another class of females (X"X"Y) which carried two deficient X's and a Y chromosome, there were smooth-eyed flies and flies of grade 1 (table 2 under B). This indicates that two X deficiencies have an effect on *spa* which is opposite to and nearly balances the effect of Y. An extra

Y in a deficient male (X⁻YY) suppresses *spa* as seen in the males of the class that had received a Y from each parent. The result is similar to the suppression of *spa* by Y in XXY and XY as compared with XXO and XO.

There are other examples of effects on *spa* of different amounts of heterochromatin in the X and the Y chromosomes. An X chromosome known as bobbed lethal *(bb[1])* is probably deficient for the locus

TABLE 2

NUMBER OF FLIES OF DIFFERENT GRADES OF SPA
(X~ stands for deficient X of Gershenson)

	0	1	2	3	4	5	6
A. GRADES OF SPA IN OFFSPRING OF X-X BY XY WITH AND WITHOUT X"							
X"X	..	..	..	..	16	38	?Q
X~Y	..	49	55	..	..	..	..
XX	..	..	13	33	S?	14	3
XY	70	8	..	..	..	..	..
B. GRADES OF SPA IN OFFSPRING OF X⁻X~Y BY X"Y							
X"X"Y	42	48	j	..	..	..	..
X~Y	..	2		43	13	3	..
X"YY	64	..		..	..	..	..

of *bb,* and an X chromosome found by Dobzhansky (Df D) is deficient for the locus of *bb* and for a heterochromatlc region. Each of these showed an effect on *spa* in XX"' females and in X~Y males. The females showed *spa* to a high degree and the males were only slightly *spa.* The grades were not rated by the scale, but in comparisons made at long intervals of stocks of the three deficiencies, Df G appeared to be the most effective in enhancing *spa,* and *bb[1]* the least effective. The stocks were unrelated, so there were no checks on modifiers except *ci[l]*\ which was present in some instances.

In X"X-Y females that carried Df D, *spa* was less evident even than in corresponding Df G females, which are of low grade. When a normal X is present in place of one deficient *X,* the females (X"XY) carrying either deficiency do not sHow *spa,* though X~X females are of high grades.

When a deficient Y, known as Y sterile (Y^{st}), which is probably the long arm of Y, is combined with *bb[1]* deficiency in X~X~Y^{st} females, *spa* is of a high order. Another Y, "Y bobbed deficiency" (Y^{66}~), is deficient for *bb* and for about one-third of the short arm of Y, but males carrying it are fertile. It has less effect on the suppression of *spa* than has a normal Y. In attached-X females that are XX$^{Y\&6}$~> $^{s}P^{a}$ is evident, and XY$^{B\&}$" males are even more *spa* than the females, but less *spa* than are XO males.

It was found further that duplication of X heterochromatin has an effect opposite to that of a deficiency and in the direction of the effect of Y. Flies carrying a largely heterochromatic fragment of X, Dp (1 ;f) 101, in addition to the normal complement of X, produced smooth duplication males ($XX^{Dp}Y$) and XY males which were slightly *spa;* and 84 per cent of XX females were of grades 4 and 3, while 82 per cent of the females carrying the duplication (XXX^{Dp}) were of the lower grades 2 and 1, although a common effect of duplication is slight roughening of the eyes.

Another deficiency for heterochromatin, Df(2)M-Sio, was tested. It is a deficiency for a heterochromatic region of the right arm of chromosome 2, which produces a dominant mutant effect (A/) and is lethal when homozygous. The Minute offspring (A/) of flies heterozygous for the deficiency are conspicuously more *spa* than are their normal sibs. This is true especially of the

males, which run into the highest grades as do the females. Of the not-M offspring, lower in grade, the males are less *spa* than the females.

The effect on the fourth-chromosome character *spa* of the presence of different amounts of heterochromatin is in agreement with the effect of heterochromatin on variegations in other chromosomes which has been described by Schultz. The experiments with *spa* give consistent results in the sense that when heterochromatin of X or of Y is increased, the manifestation of *spa* is diminished, and when heterochromatin of X, Y, or 2R is decreased, *spa* is enhanced.

H. C. SHERMAN, Columbia University, New York, New York. *Research on influence of nutrition upon the chemical composition of the normal body.* (For previous reports on this and directly preceding researches, see Year Books Nos. 32 to 41 and 43.)

The fact that a normal bodily chemistry may yet be improved by a more scientific adjustment of the nutritional intake has opened a far-reaching field of research into the effects of food upon life processes and life histories. The present research deals, as has been briefly explained in previous reports, with the effects of such nutritional improvements. These are induced in some cases by adjustments of the quantitative proportions of natural foods in the diet, and in other cases by enrichment of the diet with chemically individual nutrients.

By the former method we found that a diet already adequate in the sense that it supports normal growth, health, and life histories through successive generations can yet be so improved as to better the average status in each part of the life cycle.

Our subsequent experiments with individual nutrients indicate that calcium, vitamin A, riboflavin, and protein each plays a part in the enhancement of an already normal status of nutritional well-being, with resultant improvement in the plane of positive health, and the average length of life. Rats are the experimental animals used in this work because, in all aspects of the nutritional chemistry with which we are here concerned, their processes run strikingly parallel with those of human beings, and enough faster so that they complete their normal life cycles in about one-thirtieth of the time. Rat families in our laboratory colony are now thriving in the sixtieth generation on our basal diet A, which in the sense here described is already adequate, yet capable of improvement at more than one point, as doubtless are the dietaries on which a large proportion of people are living.

Hence such study of the influence of food—upon the bodily chemistry and resultant nutritional well-being and life history—holds much of significance for the correlation of chemical composition and biological function, and for important human implications.

Our experiments with calcium as the sole variable factor were summarized briefly in our report of 1940-1941 and more fully in the journal articles there recorded (Year Book No. 40, pp. 287-288).

At that time and in the following year (Year Book No. 41, pp. 245-246) progress reports were made upon our analogous experiments with vitamin A, the data of some of which are now being prepared for journal publication. These experiments are showing that a moderate surplus of vitamin A in the daily diet is even more potent than previously supposed in the support of bodily reserves of this nutrient

at all ages up to at least middle life. Moreover, in families thus fed through successive generations, growth is stabilized and the period of full adult vigor appears, in the experiments thus far completed, to have been extended. We hope to carry these experiments into larger numbers at the higher levels of nutritional intake and the more advanced ages.

Our experimental studies of the influence upon body composition of different liberal levels of nutritional intake of riboflavin, both as sole variable and in conjunction with different levels of food protein, are being continued. As was noted in last year's report, our work with riboflavin as sole variable yields a general picture of a riboflavin content of body tissue which varies with the nutritional intake at relatively low levels, whereas at higher levels of intake the concentration of riboflavin in the tissue reaches a "plateau" and thereafter remains essentially constant with further increase of riboflavin intake. This plateau level of riboflavin content of body appears, however, to be influenced by the protein content of the diet, consistently with the theory that riboflavin in body tissues exists largely in combination with protein. Thus in a series of five comparisons of the body concentrations of riboflavin and total nitrogenous compounds (quantitatively an essential measure of protein content) in rats that had been fed diets of the same liberal riboflavin content but with 12 per cent and 32 per cent, respectively, of protein, it was found that in every case the animal receiving food of higher protein content showed a higher body content of both protein and riboflavin. The average results were: in animals from diet with 12 per cent protein, 5.70 micrograms of riboflavin per gram, and 16.95 per cent of protein in the body; and in animals from diet with 32 per cent protein, 6.63 micrograms of riboflavin, and 18.42 per cent of body protein. Such differences, of the order of one-tenth, in the amounts of these active factors of the life process in the body tissues clearly suggest that science is here developing a previously unappreciated potentiality for the modification of life processes and thus of life histories through nutritionally guided use of food. The quantitative investigation of these relationships is complicated by the fact that the difference of nutritional intake influences the amount of fatty and fatlike substances formed and retained in the body. This is consistent with the oxidation-enzyme nature of the riboflavin-protein compound. Thus the situation deserves fuller experimental study, both as to its scope from the standpoint of systematically varied levels of the active factors fed and as to the extension of such feeding experiments to cover longer segments of the life histories. For such experiments the animals of our laboratory-bred colony, having known nutritional backgrounds for many generations, offer special advantages for collusiveness of interpretation in the direct comparison of diets and also for the solution of the problem of how far so-called adaptation to suboptimal food supply is a factor in responsiveness to better feeding.

The generous and efficient service of those who have collaborated in the work here reported, whether as research assistants or as volunteers, is gratefully acknowledged.

DIVISION OF HISTORICAL RESEARCH

Cambridge, Massachusetts

A. V. KIDDER, *Chairman*

Now that the war is over, several members of the staff who have been serving in the armed services or in other forms of war work are expected soon to return, and it is hoped that in the near future some at least of the interrupted activities of the Division may be resumed. Indeed, during the past year it has been possible to undertake a limited amount of archaeological and ethnological field work. Most staff members not in service, however, have devoted themselves to the writing of reports. As a result, the Division's investigations have been brought nearer to the stage of definitive publication than at any previous time.

Dr. Leo F. Stock retired July 31, 1945, after thirty-five years of service with the Department and Division of Historical Research. A member of the group of distinguished scholars brought to the Department by Dr. J. Franklin Jameson, Dr. Stock has centered his research on the debates in the British Parliament regarding North America. His five volumes on this subject not only throw much factual light on events of the period treated, but also make clear the slow development of democratic processes in dealing with colonial possessions. They form a necessary introduction to the legislative history of the United States after its independence. A former president of the American Catholic Historical Association, Dr. Stock has been a valued agent of liaison between the Institution and the very effective Catholic historical organizations and institutions.

With great regret we record the passing of two persons formerly connected with the Division, Ann Axtell Morris and George Clapp Vaillant.

Mrs. Morris, who possessed great abilities as a writer and an artist, was entrusted by her husband, Earl H. Morris, with the copying of the extremely important frescoes discovered by him during the excavation of the Temple of the Warriors at Chichen Itza, and was co-author of the monograph on that building. In later years she assisted Dr. Morris on his many expeditions in Arizona and New Mexico, making a specialty of the recording and study of pictographs. Her two books, *Digging in the Southwest* and *Digging in Yucatan,* which have had a large sale that still continues, have done much to acquaint the public with the methods and aims of archaeology.

Dr. Vaillant, formerly with the American Museum of Natural History and at the time of his death Director of the Museum of the University of Pennsylvania, was a member of Dr. Morley's staff at Chichen Itza in 1926. During that season he excavated the Temple of the Initial Series and, at the Temple of the Phalli and elsewhere, made stratigraphic studies which laid the foundation for subsequent ceramic research in Yucatan by H. B. Roberts and G. W. Braincrd. Dr. Vaillant's work for the American Museum on the early cultures of Mexico was a brilliant scientific achievement, and, like Mrs. Morris' books, his *Aztecs of Mexico* has done much to promote an intelligent interest in archaeology. Throughout his career he kept closely in touch with the Division's work, giving freely of his time to visit our excavations and advise with us as to problems of mutual interest.

ACTIVITIES, 1944-1945

Major H. E. D. Pollock, after three years with the photographic division of the Air Corps in North Africa and Italy, returned late in 1944 for duty in Washington, and has recently been accorded inactive status. He will resume his studies of Maya architecture in the autumn of 1945. Mr. Gustav Strömsvik enlisted in 1943 in the Royal Norwegian Navy. He served on the North Atlantic convoys, took part in the invasion of Normandy, and, since the landings there, has held an administrative position at Norwegian headquarters in Edinburgh. He has recently been discharged. Mr. Karl Ruppert, volunteer in the American Field Service, was with the British Army during the Burma campaign and later in Italy. In the spring of 1945 his unit was transferred to northern Europe, where it was engaged until the end of hostilities in the evacuation of wounded and in helping to clear captured concentration camps. He has now resumed his position with the Division. Dr. G. W. Brainerd, who holds the rank of lieutenant in the Naval Reserve, is attached to the Special Devices Division of the Office of Research and Invention. His duties have taken him to India, Ceylon, and China. Miss Eleanor W. Ritchie, secretary of the Division, is a lieutenant (j.g.) in the Naval Reserve, on duty in Washington.

In civilian capacities, several members have taken part in the war effort. Mr. E. M. Shook is in charge of the large quinine plantation of El Porvenir in Guatemala. In the course of this work he has been able, as *in* past years, to make valuable observations on sites in a region hitherto very little known archaeologically and to obtain photographs of monuments and of objects in private collections. Dr. A. M. Halpern has continued as director of the language program in the Civil Affairs Training School at the University of Chicago. Dr. R. S. Chamberlain, senior cultural assistant in the United States Embassy in Guatemala, has had opportunity, during his four years at that post, to foster the close international intellectual relations which, we believe, have been a not unimportant by-product of the Division's more than three decades of activity in Mexico and Central America. He expects to resume his historical studies in the near future. Mr. F. B. Richardson, in 1944 legal attaché at the Embassy in Ecuador, attended the conference at San Francisco as adviser on Latin American affairs.

Dr. S. G. Morley spent the winter in Yucatan, continuing his research on the Maya hieroglyphs. He has been in constant touch with Sr. Alfredo Barrera Vasquez, whose translation and correlation of variant historical and ceremonial Maya texts—the so-called Books of Chilam Balam—were carried on in 1943-1944 under a grant from the Rockefeller Foundation administered, at the Foundation's request, by Carnegie Institution. Mr. R. E. Smith continues in charge of the Division's office in Guatemala City. During the past winter he was informed that road work at Coban in Alta Verapaz had exposed a prehistoric midden. This he excavated, recovering a large collection of clay figurines and pottery fragments, many of the latter of a very beautiful incised ware of which only a few pieces had previously been known. Mr. Smith has also devoted much time to the installation of the archaeological collections in the Guatemala National Museum, which, under the directorship of Sr. Flavio Rodas, is being transferred to new and larger quarters. As chairman of the advisory committee on the museum, he has been assisted by

Sr. Antonio Tejeda, artist of the Division, and Sr. Antonio Goubaud.

Sr. Tejeda continues to produce meticulously accurate and beautiful paintings of Maya pottery. Although only a relatively small proportion of these ran at present be used as illustrations in the Division's publications, it has been our policy to have such reproductions made of all important pieces from our own excavations and of those in museums and in private hands. The archive thus being built up will be of very great value to students who cannot see the material itself. It also serves as insurance against loss of the originals through dispersal of private collections or, in the case of museums, through destruction by earthquake, an ever present danger in the Central American republics. This year Sr. Tejeda has been working on Mr. Smith's Alta Verapaz pottery; on pieces in the Dieseldorff collection, now the property of the National Museum; and on vessels recovered by Mr. S. H. Boggs in El Salvador.

Sr. Tejeda's younger brother, Cesar, first employed in 1942 as assistant to Mr. Shook at Kaminaljuyu, developed great ability in mending and restoring pottery. During his work as preparator and in the field with Mr. Shook and Mr. A. L. Smith, he showed outstanding promise as an archaeologist. When this was brought to the attention of the authorities, he was granted a government fellowship for attendance at the Escuela Nacional de Antropologia in Mexico City, where he has now matriculated. A fellowship was also given to Sr. Juan de Dios Rosales, for several years assistant to the late Dr. Manuel Andrade and to Drs. Redfield and Tax in their respective linguistic and ethnological investigations and, more recently, to Sr. Goubaud in the food survey. Such field experience as the Division has been able to give Srs. Tejeda and Rosales and such aid in acquiring academic training as it has been able to procure for them and for Srs. Alfonso Villa and Antonio Goubaud—largely through the generous and ready cooperation of the Rockefeller Foundation—is believed to be a most valuable contribution to the development of anthropology in Latin America, for although North American students can accomplish a certain amount of useful research, the major work must eventually be done by natives of the countries themselves, as it now is in Mexico by the able group headed by Dr. Alfonso Caso.

During the past winter Mr. A. L. Smith and Sr. Cesar Tejeda made a survey of sites in the northwestern Guatemala highlands that are thought to date from late prehistoric times. Srs. Goubaud and Rosales, in the early months of 1945, completed the collection of data regarding food habits and food consumption of the Guatemala Indians and Ladinos. Dr. Kirk Bryan, professor of geology at Harvard University, spent two weeks in Guatemala studying physiographic conditions bearing upon the antiquity of human occupancy of that country. Reports on these investigations and on the ethnological work are appended.. The Chairman was in Guatemala during January and February for consultation with government authorities as to future undertakings. He also had opportunity to work in the Division office on archaeological collections made in former years. Temporarily unsettled political conditions prevented his visiting Mr. S. H. Boggs* excavations at Tazumal in eastern El Salvador, which are being carried on by the Salvadorean government, and for which Carnegie Institution has provided modest financial aid for the prosecution of certain stratigraphic studies. The Chairman later went to Boulder,

Colorado, to confer with Drs. E. H. Morris and Anna O. Shepard regarding their work on Southwestern archaeology and ceramic technology; and to Albuquerque, New Mexico, to confer with Dr. F. V. Scholes. In California, he studied collections at Los Angeles and Berkeley.

At Cambridge, Mr. J. E. S. Thompson has begun the preparation of a comprehensive monograph on the Maya hieroglyphic writing. A report on certain aspects of this study appears below. Mr. Thompson has been awarded the Rivers Memorial Medal by Cambridge University for his contributions to Maya research. Miss Tatiana Proskouriakoff has begun a detailed analysis of dated Maya sculptures. This will not only lay a foundation for studies of other aspects of Maya art, but provide more reliable stylistic criteria than have hitherto been available for the dating of the many monuments which bear either no dates or illegible ones. Mrs. W. H. Harrison, in addition to her manifold duties as editor of the Division, has been compiling a dictionary of terms applicable to Middle American archaeology. This should serve to standardize usage and clarify nomenclature. Her report on publications also appears below, as do those of Dr. L. F. Stock on his work in United States history and of Dr. George Sarton on the history of science. The report on Kaminaljuyu by the Chairman, Dr. J. D. Jennings, and Mr. Shook has been finished and is now in press. In the field of Maya history, Dr. Scholes and Mr. R. L. Roys have continued the writing of their report on the Acalan-Tixchel area. Dr. Scholes and Miss Eleanor B. Adams, who now make their headquarters at Albuquerque, have been provided with quarters and given every facility for the prosecution of their work by the University of New Mexico.

GUATEMALA HIGHLANDS PROJECT

A. L. SMITH

During the winter of 1944-1945, Mr. A. L. Smith, assisted by Sr. Cesar Tejeda, spent four months in archaeological reconnaissance in the departments of Huehuetenango and El Quiche. The purpose of the work was to obtain as much information as possible, without intensive excavation, as to both hilltop and valley sites with a view to selecting representative examples of each type for future excavation. All sites were mapped, architectural details were recorded by drawings and photographs, and samples of pottery were recovered from inside or below constructions as well as from the surface. Special effort was made to locate refuse dumps.

The trip was made in the Institution's station wagon, and local labor was employed. The hiring of workmen was greatly facilitated by the cooperation of the Minister of Public Education, the governors of departments, and the mayors of the towns and villages visited. Seventeen sites were examined, some large and some small, all within fairly easy access of a main highway.

Huehuetenango, capital of the Department of Huehuetenango, was the first base used. In this region seven sites were investigated: Zaculeu, Cambote, Chicol, Piol, Xetenan, Cucal, and Pucal. Of these, Zaculeu, a fortified site surrounded by barrancas on three sides, proved to be by far the largest and most interesting. It lies about 4 km. northeast of Huehuetenango. Considerable excavation has been carried on here in the past, the Guatemalan government in 1927 having excavated and partially restored the principal mound, a large pyramid surmounted by a temple. About ten days were spent at Zaculeu in recording materials for restored drawings of several buildings and a ball court. A

large collection of potsherds was also made. Cambote, directly south of Zaculeu and in plain view therefrom, rests on a tongue of land but is not so well protected as Zaculeu. Very little masonry was showing here, and there was no ball court. Chicol, Piol, and Xetenan are all small hilltop sites practically surrounded by barrancas. All three have ball courts. Cucal is a small valley site without a ball court. At Pucal, a small hilltop site near Cucal, only one mound remains, but there is evidence that there were several others which had been leveled for agricultural purposes, the stones being used in the building of modern fences.

The next base of operations was the village of Aguacatan, about 26 km. east of Huehuetenango in the Department of Huehuetenango, where a month was spent investigating Huitchun, Chalchitan, Xolchun, and Chichoche. Huitchun, sometimes called Chichun, rests on a low hill just west of the village. It is a small group surrounding a court and has a ball court. Chalchitan, one of the largest sites visited, and the one to which most of the month's work was devoted, lies in the valley just east of the village. Unfortunately a great many of the mounds had been dug into by treasure hunters, causing much damage to inner constructions. There is still much left, however. One of the two ball courts was excavated and found to cover an earlier ball court, within which there was evidence of still earlier construction. Two nicely carved stone heads, one of a serpent and the other of a jaguar, were recovered from high up in the center of the playing walls of the earlier ball court. A tomb with a corbeled vault was discovered in one of the largest mounds. This had been looted years ago. Probably the most interesting find was a building showing six distinct architectural phases, the most instructive of which were a platform with four round columns, one off each corner, and a later construction of four walls with stepped tops. There is much pottery of all periods at Chalchitan. Xolchun, east of Chalchitan, is a good-sized hilltop site. Its main features are a well preserved ball court, terracing, block masonry, and a type of late pottery with white geometric design on a red slip. Chichoche is a small group of mounds in sight of Xolchun across the barranca to the southeast.

Sacapulas, a village in the Department of El Quiche about 37 km. east of Aguacatan, was the last place used as a base. From here the ruins of Chutix Tiox, Chutinamit, Pacot, Xolchun, Rio Blanco, and Xecataloj were studied. The best preserved of these is Chutix Tiox, a hilltop site extremely well protected against attack, its only entrance being blocked by a wall. The main group is on a high terrace with stairways on all sides. An interesting feature is a stucco jaguar in a crouching position at the base of one of the several platforms. It was possible to take measurements of almost all the buildings. Chutix Tiox is similar to Xolchun in that it has the same kind of ball court, a great deal of terracing, and the same white-on-red pottery. Chutinamit, just outside Sacapulas, is another well protected hilltop site, almost completely surrounded by barrancas. Its only entrance, on a narrow neck of land to the north, was protected by three parallel walls stretching from barranca to barranca. Pacot, also almost inaccessible, is small, but the buildings are well preserved. Xolchun, not to be confused with the Xolchun in the Department of Huehuetenango, lies on the tongue of land formed by the junction of the Rio Blanco and the Rio Negro. A stela, used as the capstone of a tomb, was found in a small temple. Its upper part bore a well carved geometric design. A most unusual structure was an oval, almost circular, platform with seven

terraces. Rio Blanco, a small valley site, shows several periods of construction, and the types of pottery found there indicate a long occupancy. Among the wares noted were plumbate and Utatlan. Xecataloj is a small valley group on the north bank of the Rio Negro about 1.5 km. east of Sacapulas.

It would appear that the well protected hilltop sites are later than the more vulnerable valley sites. Before definite conclusions are reached, however, the collections of potsherds, now in the Institution's office in Guatemala City, must be studied. Probably of significance is the fact that the white-on-red ware occurs only at hilltop sites. Another point is the fact that those in the valleys all have several architectural periods, whereas in most cases the hilltop sites do not. The latter are characterized by much terracing, ball courts with well marked end zones, and split stairways with balustrades. The mounds are usually grouped about a plaza with one or more small platforms in the center. Ball courts in the valley sites lack end zones. At present the two groups that appear most desirable to excavate are Chalchitan and Chutix Tiox: Chalchitan because of its long occupation, its architectural and ceramic sequence, its accessibility, and the availability of good labor at Aguacatan; Chutix Tiox because of the excellent preservation of buildings of various types and because it could conveniently be worked from a base at Sacapulas. Final choice, however, should be postponed until further reconnaissance of the highland region has been carried out.

SOILS AND CLIMATIC CHRONOLOGY IN GUATEMALA

KIRK BRYAN

Dr. Kirk Bryan, professor of geology at Harvard University, spent two weeks in Guatemala studying recent deposits in the neighborhood of Guatemala City and in the Motagua Valley. He also made a short trip to Lake Atitlan and Chichicastenango in order to acquaint himself with the more westerly highlands and ash basins.

The city of Guatemala is built in a wide valley dissected by broad, deep gulches (barrancas) and bounded by hills and mountains. It lies in the divide between drainage to the Pacific and drainage to the Motagua River and thence to the Atlantic. The valley floor is composed of tuff that was deposited as successive showers of volcanic ash. The tuff filled the valley near the city to depths of 1000 feet or more. It was also deposited on the hills but was almost immediately washed off into the valleys. Eastward toward the Motagua each valley had a filling of ash successively finer in grain and shallower in depth. As the height of the fill decreases eastward, it appears that concurrently with the filling of the valleys, runoff took place across the body of ash, so that there was a stream grade on the top of the ash of about 4000 feet in 30 miles, or 13 feet to the mile. In the Motagua Valley there is a terrace of waterworn pumice fragments that rises about 200 feet above the present river grade. It seems to be the river-laid equivalent of the tuff fillings of the tributary valleys. One must suppose that enormous quantities of ash were carried by rainwash off the slopes of the hills into the valleys and thence to the Motagua. Here the river transported most of the load into the sea, but was itself overloaded to such an extent that it built up its grade and formed the tuff terrace.

The origin of the ash showers is presumed to be in one or more of the great volcanoes which fringe the southwestern border of the Guatemala highlands. The tuff has not, however, been traced to any

definite source. Toward the end of eruption the rate of fall decreased and became spasmodic. The upper measures of the tuff sequence near Guatemala City are distinctive. A typical section consists of the following members:

	Feet	Inches
Soil, dark brown to black. .	o	*6—S*
Subsoil, dark brown columnar or blocky; in low places, columnar black clay	*from* 1	6
	to 2	0
Disconformity, erosion of shallow valley		
Pumice tuff (upper sand or *arena)*.	3	0
Massive decomposed buff-colored tuff *(talpetate)* . .		60
Pumice tuff (lower sand or *arena)*.	4	0
Decomposed buff-colored tuff grading down into massive undecomposed tuff *{talpetate fino)*.	*from* 0	6
	to 2.	***0***
White to gray tuff.	many feet	

The *talpetate fino* is an old land surface in which the previously deposited tuff was decomposed and converted into a massive yellow clayey layer of variable thickness. Over this surface pumice tuff was deposited by fall from the air. The fragments of pumice range up to half an inch in diameter. The material is used as building sand, hence its local name *arena.* The next layer is a decomposed tuff, very massive and compact. It is obviously a subsoil representing a long period of decomposition under a climate wetter than that of the present time. This compact massive material is used in local building as quarried blocks and as a constituent of sun-dried brick. It is therefore well known and is called ***talpetate',*** a word presumably related to the Mexican ***tepetate.*** The overlying pumice tuff is similar in all respects to the lower pumice tuff.

These formations slope gently upward and, in places, extend to the slopes leading to the adjacent mountains. In particular, the upper pumice tuff mantles steep mountain slopes of older rocks along the Guatemala-Lake Atitlan highway as far as Mixco. Near Guatemala City these three formations are eroded in broad shallow valleys, which drain into the deep barrancas. One of these valleys extends from northwest to southwest through the site of Kaminaljuyu. At its lowest points it reaches the *talpetate fino.* The surface soil is dark brown to black, blocky silty clay, or clay. Intensive cultivation by prehistoric and modern people has disturbed the soil nearly everywhere. Also there are numerous borrow pits from which the prehistoric people obtained material for pyramids and other structures. Many of these pits were back-filled with debris, and the area has since been cultivated. It is thus difficult to find truly natural conditions. Obviously, however, the soil was developed only in part by weathering of underlying material. It is usually an unconformable blanket over the underlying formations and has been largely built up by the gradual fall of ash from near-by volcanoes. The soil processes operating on this continually increasing layer have produced the deep humus-bearing subsoil. In the lower areas, where water has stood in the rainy season, the subsoil is a columnar black clay. On better-drained sites it is a blocky silty clay and in places shows fragments of the underlying pumice tuff or *talpetate.*

It appears that the existing climate, with its strong dry season, produces a soil that accumulates calcium carbonate in the subsoil. It is therefore a climate on the arid side. There is a break in the sedimentation between the soil and subsoil and the upper pumice tuff represented by the ero-

sion of the broad valley already referred to. One must suppose that the *talpetate*, which is an old subsoil of the ferric oxide-aluminous type, was formed in a climate wetter than that of the present. This epoch, however, was far anterior to the earliest known culture of the area. As shown by the excavations of the Carnegie Institution, the oldest pottery of the site, when found in undisturbed areas, occurs at the base of the soil just above the jointed clay. In many localities the soil, subsoil, and part of the underlying material—*arena* or *talpetate*—has been excavated. The back-fill may be 3 feet or more thick and may contain pottery of any age. The soil and subsoil appear to represent a continuous period of growth by accretion of wind-borne volcanic dust and of soil formation under a pine-grass cover. The soil phenomena of the remote past, as represented by the *talpetate* and *talpetate fino*, record wetter conditions. Within the period of known prehistoric occupation no detectable change in climate is indicated by the soils.

HIEROGLYPHIC AND HISTORICAL RESEARCH

S. G. MORLEY

Dr. Morley left New Orleans for Merida, Yucatan, Mexico, on November 7, 1944, returning therefrom on May 3, 1945. He spent the summer at Santa Fe, New Mexico, his usual summer headquarters, where Dr. E. L. Hewett, Director of the School of American Research and the Museum of New Mexico, very kindly placed at his disposal office quarters in the Palace of the Governors at Santa Fe, now the Museum of New Mexico. He will return to Yucatan at the beginning of November.

Dr. Morley has devoted the year to two principal research activities: preparation of the Maya hieroglyphic dictionary, and work on the Maya chronicles in the Books of Chilam Balam.

For work on the hieroglyphic dictionary, a full-time draftsman, Mr. Isaac Esquiliano, of Merida, has been continuously employed for the past three years, drawing the individual glyphs of the Maya stone, stucco, and wood inscriptions under Dr. Morley's direction and supervision. During this period Mr. Esquiliano, a Mexican of mixed Spanish and Maya descent, has developed a very high degree of skill in drawing the Maya glyphs.

At the beginning of this enormous task it was decided to draw first all the glyphs of known meaning, and later those of unknown meaning. Further, in order to facilitate accurate representations, it was decided to concentrate on one glyph at a time, drawing all known occurrences of this particular glyph before proceeding to another. In this way, in the case of partially effaced and badly eroded glyphs, the draftsman would have the benefit of previous experience and familiarity with better-preserved examples of the same glyph.

The first section of the dictionary is thus devoted to the Initial Series introducing glyph, a highly important character in the Maya inscriptions, which not only stands at the head of most inscriptions where it occurs, but whose principal element indicates the name of the patron deity of the Maya month in which the accompanying date falls. This first section is about finished, barring a few odd examples of this sign, chiefly in inscriptions from Campeche.

The next eight sections of the dictionary are being devoted to the different examples of glyphs G and F of the Initial Scries and to the six different signs of the Supplementary Series—glyphs E, D, C, X, B, and A—all of which deal with the moon.

Of these, the examples of glyphs E, D, C, and X are also nearly completed.

The drawings of the different occurrences of glyph D have brought to light important new variants and have made possible a number of corrections in decipherment of the corresponding moon ages expressed by that character.

With the cumulative experience gained in repeatedly drawing the same glyph, we have been able to get more out of partially effaced inscriptions than was formerly possible, and although only a beginning has been made, the project may be said to be off to a good start.

The Maya chronicles project deserves a brief word of introduction. There have been preserved in certain native Maya manuscripts known as the Books of Chilam Balam, which are written in the letters of Spanish script but in the Maya language, five chronicles or rescripts of Maya preconquest history. These chronicles are of varying degrees of merit, and there is strong internal evidence that three of them have been copied from a single source, probably an ancient Maya historical manuscript in the hieroglyphic writing, the original of which is now either lost or destroyed.

These five chronicles contain practically all that has survived on the documentary side (i.e., as opposed to the stone, stucco, and wood inscriptions) of ancient Maya history. Laconic as the chronicles are, they nevertheless present a fairly accurate picture with a solid chronological background of the main events of Yucatan history from the early fifth to the late seventeenth century; and, as primary historical source material of the very highest importance, they have long merited the exhaustive and critical study now being given them by Dr. Morley and Dr. Alfredo **Barrera** Vasquez.

Dr. Barrera Vasquez, now working under a grant from the Colegio de Mexico but having formerly held both Guggenheim and Rockefeller fellowships, has been collaborating with Dr. Morley on a definitive translation of these Maya chronicles into both Spanish and English, and on an interpretive study of their contents.

For the past decade, under the auspices of the above agencies and others, Dr. Barrera Vasquez has been devoting a major portion of his time, first, to making a reconstructed text, filling the lacunae in one chronicle from another and including all variant versions; and, second, to translating the original Maya into Spanish. For the past two years he has spent a month in Yucatan each spring working with Dr. Morley on this investigation. The Barrera Vasquez reconstructed Maya text of the chronicles has been translated directly into English, which language, it has been found, renders the original Maya more exactly than does Spanish. Dr. Morley has written a commentary on the chronicles, incorporating therein the results of his own epigraphic studies during the past thirty years in so far as the latter concern the course of ancient Maya history in the northern half of the Yucatan Peninsula.

The history of Yucatan, as set forth in the Maya chronicles, begins with the discovery of the province of Ziyancaan Bakhalal (the region around the modern Lake Bacalar in southeastern Yucatan) by a group of ancient Maya called the Itza, probably proceeding from some Old Empire site in what is now northeastern Peten, Guatemala, in 9.0.0.0.0 8 Ahau 13 Ceh of the Maya era, or A.D. 435, and closes with the fall of **Tayasal,** the last Itza capital, in central Peten, in A.D. 1697, more than twelve and a half centuries of documented Maya history.

HIEROGLYPHIC RESEARCH

J. E. S. THOMPSON

In the previous report a brief description was given of a new approach to the problem of the decipherment of the Maya hieroglyphs. This method, which involves comparison of glyphic texts with the content of the Books of Chilam Balam, continues to yield interesting results.

In the various Books of Chilam Balam occurs the expression *u xocol haab ii la\in,* "the count of the year to the east," and one may safely assume that similar phrases involving the other world directions were current in Yucatan in the sixteenth and seventeenth centuries. In the hieroglyphic texts of the monuments, the four world direction glyphs are frequently followed by a glyph which consists of an element previously identified as a symbol for counting, and the sign for year. The whole is surmounted by a well known superfix of unknown meaning. There can be no doubt that these pairs of glyphs mean "To the east [north, west, or south] the count of the year." The whole supplies a close parallel to the Books of Chilam Balam save that the world direction is given first, not last.

A problem which has vexed Maya archaeologists for some fifty years is that of the meaning of the "spectacle glyph" which is attached to month signs on occasions which can be proved arithmetically to fall the day before the first day of a month. This sign has been generally read as zero. There are two serious objections to this reading. First, signs with a meaning approximating that of zero are known, but are never substituted for the spectacle glyph. Secondly, the spectacle glyph is combined with the winged Cauac (the haab or year sign), which, if the interpretation as zero were correct, could only mean zero approximate years. There are cases, however, where this glyph occurs with dates which end 13 approximate years. The interpretation is thus obviously at fault.

In the Books of Chilam Balam one frequently finds the phrases *u cutal Pop, U cutal Uo,* etc., "the seating of Pop," "the seating of Uo," etc., set opposite the first day of each month. On page 7 of the Chilam Balam of Tizimin is the expression *// cutal ti tun,* "at the seating of the approximate year." Interpretation of the spectacle glyph as "the seating of" fulfills all the demands of the various contexts, and agrees with Maya phraseology. This interpretation led to the identification of two new glyphs, variants of the spectacle glyph, which record whether the addition of a distance number leads to the end of a tun or merely to an odd day. The glyphs must mean respectively "[leading] to the seating of the tun" and "[leading] to the seating of the day." More and more evidence accumulates that the hieroglyphic texts closely parallel the spoken word.

Little success has hitherto attended efforts to interpret affixes, and variations in those attached to glyphs of known meaning have for the most part been ignored, or dismissed as artistic variations. As an example of slight variations in meaning which they reflect, one might cite the three common suffixes of period glyphs. The geometric forms of the katun and tun usually stand on three small circles when these glyphs occur in Initial Series or as period endings. When these glyphs (and other period glyphs) are used as distance numbers, the suffix takes the form of two or three circles between two inverted crescents. Thus, if one finds a period glyph with this form of suffix, one knows that it is part of a distance number. Rarely, the simple suffix of three circles is retained, and the suffix indicative of a distance number is placed beneath it.

A rare suffix, the "bundle" element, is used with the katun and tun only to record anniversaries; that is to say, the completion of a number of tuns or katuns from some important date that is not a tun ending. An example of this is on Lintel 3, Piedras Negras. The Initial Series 9.15.18.3.13 is followed by the katun glyph with a "count" prefix and the bundle suffix. This date is precisely one katun later than a date prominent at Piedras Negras.

The suffix with three circles may be ornamental, or its meaning must be generalized; the other two suffixes are indicative of the way the periods are being used. There are somewhat similar distinctions in the Books of Chilam Balam.

The Maya language has a great number of numerical classifiers, each object or group of objects having its classifier. In English there are a few such numerical classifiers, e.g. head of cattle, loaves of bread, sheets of paper, but the system is with us vestigial. The Maya of Yucatan used *te* as a numerical classifier *inter alia* with years and months. In the hieroglyphic texts there is a small prefix which is sometimes placed between the numeral and the period or month glyph, but which never occurs with day signs. The fact that it sometimes appears as a suffix of head variants of numerals shows that it is connected with the number, not the period or month sign. It almost surely corresponds to *te.* This surmise is further strengthened by the absence of the prefix from day signs, since in spoken Maya the numbers with day names do not take this classifier. Its absence or presence seems to depend on the space available. It is most frequent with low coefficients, where its presence serves to prevent undue distortion of the accompanying glyph; it is almost unknown with high numbers.

The normal work of identification of glyphs has made some progress. ^Among new glyphs recognized is a rare head variant of the introductory sign to the distance number, there being a very fine example on Temple 11, Copan. A section of the Dresden Codex has been found to treat of the burner period, prominent in the Books of Chilam Balam. Several new readings of dates have been made in addition to those published in various papers during the period covered by this report.

Mr. Thompson is now engaged in a comprehensive survey of Maya epigraphy. The first volume of this study should be completed during 1946.

SOCIAL ANTHROPOLOGICAL RESEARCH

ROBERT REDFIELD AND ASSOCIATES

No notable single accomplishment marked the advance made in social anthropological research of the Division during the past year; no outstanding discovery in the field is to be reported; and no new unit of investigation was begun. The members of the group were engaged in terminal or transitional activities. Dr. Redfield made a short visit to Yucatan and to Guatemala; in Yucatan he reviewed the circumstances that would attend a proposed restudy of Chan Kom, one of the Yucatecan communities studied a decade ago; and in Guatemala he carried forward, in consultation with members of the staff and with representatives of the new government of the Republic, various pieces of business incidental to the Division's research program in that country. Dr. Tax's time was borrowed in large part by the University of Chicago; nevertheless, for Carnegie Institution he brought nearer completion a nontechnical book on the Indian culture of Panajachel. Sr. Antonio Goubaud concluded a period of special employment, and completed a monograph containing the results of the study of diet in

rural Guatemalan communities which he carried on in the field in 1944 with the assistance of Sr. Juan Rosales and Sr. Agustin Pop. Sr. Alfonso Villa Rojas prepared for microfilm reproduction his extensive notes on Tzeltal communities of Chiapas, and in June came to Chicago to write comparative monographs. The publication, during the year, of Sr. Villa's book *The Maya of east central Quintana Roo* provides the student with the last expected monograph resulting from the Yucatan project, the first of the two research programs carried on by this group of workers, and so brings this first project to a close, while the Guatemalan project is still in progress.

The brevity of this annual report provides opportunity here to review what has been done during the past fifteen years.

By 1930 the Institution had already for many years been carrying on researches in Maya archaeology. In that year, there was initiated a new program in which problems of the Maya area were to be attacked by specialists representing many kinds of scientific interest. Ethnology was included, and Dr. Redfield formed a plan to study the living people of Yucatan. Because the Maya of Yucatan are all much the same in language and in native custom, a project was proposed, and carried out, to investigate four communities chosen to represent different degrees of exposure to modern urban influence. The project was so conceived as to serve two interests: that in the ethnography of the Maya, and that in the effects of contact with modern civilization of simpler and more isolated societies. The program was realized in every particular except that a promised publication on the city of Merida was not produced. There were published: a monograph on a peasant village *(Chan Kom, a Maya pillage,* Publication 448, **1934);** another on a tribal community *(The Maya of east central Quintana Roo,* Publication 559, 1945); publications on a town of mixed population and marginal in character to village and city *(The fol\ literature of a Yucatecan town,* Publication 456, Contribution 13, 1935, and *Disease and its treatment in Dzitas, Yucatan,* Publication 523, Contribution 32, 1940); and, in 1941, a summary and concluding volume expressing the more general conclusions of the study *(The fol\ culture of Yucatan,* University of Chicago Press).

This project had the following principal results. Sources of information on the present-day Yucatec Maya were provided that exceed in both quantity and quality everything else on the subject that had previously appeared or has since been published. The ethnography of the region was assembled in a single synthesis, in *The fol\ culture of Yucatan.* The student of Maya history was provided with a full account of the present-day pagan cult, including texts of prayers. It was fairly well established that the culture of Quintana Roo is a reintegration of elements of custom both pagan and Christian, and it was shown that processes of culture growth which move toward consistency operate indifferently on European and on Indian elements. From ethnographic facts almost exclusively, a historical hypothesis was offered as to the course of development of conventional attitudes between racial groups and status groups in the peninsula. For what was probably the first time, a study of a regional American Indian field was (virtually) opened with a project directed by concepts and questions of general interest to students of society and of social change and was carried through to completion. Conceptions and hypotheses as to • the natural association of certain characteristics of human living in isolated folk societies, formed by earlier writers, were restated and clarified, and

the power of these ideas to guide the acquisition of new knowledge was demonstrated in terms of a large body of well reported fact. A number of general propositions as to society and its changes were enunciated and given some support from this body of fact. Interdependence between heterogeneity of population and the secularization of life was demonstrated for this case, and it was shown that in Yucatan religion has tended to pass over into magic. The role of sorcery in expressing the insecurity of a member of a disintegrated society was strongly suggested. These are some of the many conclusions of general interest which were reached.

While the Yucatan project was still in progress, the work of this group was extended into the western highlands of Guatemala, then into the adjoining highlands of Chiapas, and finally into the eastern highlands of Guatemala, so that all parts of America occupied by Maya-speaking peoples, save the Huaxtec area of northeastern Mexico, were included in the field of study. In the development of the Guatemalan investigation, the principal part has been played by Dr. Tax. Beginning in 1934 with Santo Tomas Chichicastenango, Dr. Tax, with or without associates, studied Cakchiquel or Zutugil communities on Lake Atitlan, and made briefer studies of Chorti, Pokomam, and Mam communities in Guatemala, and of Tzotzil communities in Chiapas. To Alfonso Villa fell the task of making studies, of long duration and intensity, of the difficult Tzeltal Indians of Chiapas. In 1942 Dr. John Gillin, of Duke University, became associated with the ethnological program of the Institution, making observations on Pokomam communities in eastern Guatemala. His work there was supplemented by that of Dr. Melvin M. Tumin. Dr. Gillin extended his research to a non-Maya people, the Xinca of Guazacapan, Guatemala.

The extraordinarily diverse local variations of culture in Guatemala made impossible any such single theme of investigation as had been possible in the relatively uniform Indian country of Yucatan. Dr. Tax accordingly devised and put into effect methods for representative sampling of the area included, and for making verifiable and comparable the reports of the several investigators. In 1934 the *municipio* was identified as the basic unit of study, and principal types of municipios were recognized. In succeeding years outlines were prepared to guide the junior investigators; a survey of eastern Guatemala was made by Drs. Redfield and Tax in which a schedule was worked out for the quick reporting of certain information according to municipios; the preparation of community maps was systematized; a method for comparing local cultures quickly according to sample elements of belief and custom was tested; and a project for the preparation of field notes in more or less uniform manner for microfilm reproduction and general distribution among all research students of the area was put into effect.

The problems guiding the later stages of investigation were developed in the course of the ethnographic exploration. These problems are in part ethnological, in part historical. Dr. Tax is determining the distribution of the principal ethnographic types among the Maya peoples, and is bringing this descriptive classification into comparison with linguistic classifications offered by students of Maya languages. Identification is being made of regions In which certain elements of culture (calendar, pagan fertility rituals, sorcery, and nahualism) are strongly emphasized, as compared with other areas in which these elements are absent or unImportant. Prob-

lems o£ more general or sociological significance are receiving great attention. The conclusions reached in Yucatan as to the interdependence of individualization and secularization with loss of isolation and homogeneity have been tested and revised in the light of facts from Guatemala. The west highland communities of Guatemala have been recognized as providing an exceptional and important societal type: highly commercial and individualized societies with local cultures and with people maintaining a primitive world view. The lack of dependence of secularization upon technological revolution has been brought to the attention of those who have studied secularization from the history of western Europe alone. Dr. Tax has completed a monograph in which for the first time the economy of a nonliterate farming and trading people has been reported with the facts and figures of cost accounting. He has also written monographs on other aspects of the Indian culture of Panajachel, and monographs by other investigators on Zutugil, Pokomam, Tzotzil, and Tzeltal communities are in preparation.

The studies described above have contributed significantly to the development of social anthropology in Mexico and in Guatemala. It may be claimed that fifteen years ago this sort of research was entirely unrepresented in these two countries, that it is now being effectively carried on in both by their own citizens, and that the work of the Carnegie Institution group has been the chief instrument of this change. Soon after its publication in English, *The fol\ culture of Yucatan* was issued in Spanish translation; a Portuguese edition is now under discussion. In 1942 Dr. Tax taught for a semester in the National School of Anthropology of Mexico, and then took to Chiapas a group of Mexican students whom he trained in field methods. Certain of these students then continued field research without direct guidance. In 1943 Alfonso Villa taught in the School, and he too supervised the work of Mexican students in, the field. Villa himself had been brought to the United States in 1933 to study anthropology at the University of Chicago. He was followed by Antonio Goubaud of Guatemala. Later Juan Rosales, whose gifts as a field investigator had been discovered by Dr. Manuel Andrade, was also brought to the United States for training; after returning to Guatemala he was sent by the government of that country to the School in Mexico for thorough preparation as an anthropologist.

The Division's work in social anthropology has included many activities marginal to the main lines of investigation, and has drawn within its program many enterprises carried on under auspices other than those of Carnegie Institution. In 1939 Villa participated in a study of the Tarascan Indian carried on for the Mexican government. The work of Sr. Julio de la Fuente in Oaxaca was done partly under the influence of the Carnegie group, and in 1943-1944 he came to Chicago to write under its guidance. In 1944 and 1945 the Institution carried out a study of diet of rural Guatemalans; the results will be published by the government of Guatemala. The students of Drs. Redfield and Tax at the University of Chicago have written monographs on subjects of Middle American ethnology and social anthropology; these papers are in substance contributions to the program of the Institution; they include works on the following topics: the *mayordomia,* the concept of the evil eye, collective and cooperative labor, godparenthood and related institutions, the relations between Indians and Ladinos. Two fellows of the Social Science Research Council have carried on field research in the Maya area under direction

of Drs. Redfield, Tax, and Tumin. There have been edited and prepared for publication half a dozen manuscripts on Middle American ethnology written by persons outside the staff of the Institution. Two of these may especially be mentioned: Charles Wisdom's *The Chorti Indians of Guatemala* (University of Chicago Press, 1940), and Oliver La Farge's *Santa Eulalia* (forthcoming). Finally, it may be mentioned that the very considerable expansion of the program of research on the living Maya has been accomplished without corresponding increase in the budget provided by the Institution. The work has been aided by contributions from other sources, including the Viking Fund, the Rockefeller Foundation, the University of Chicago, Duke University, the Social Science Research Council, the National Institute of Anthropology and History of Mexico, and the government of the Mexican state of Chiapas.

HISTORY OF THE MAYA AREA

F. V. SCHOLES, R. L. ROYS, E. B. ADAMS

During the past year additional manuscript sources have been examined and extracted in preparation for studies on the colonial history of Yucatan. A brief review of certain data of interest to workers in other branches of Maya research will be made at this time.

The survival of native religion in post-conquest times, concerning which other materials have been summarized in previous reports, is further illustrated by documents relating to the *visita* of Yucatan made in 1583 by Dr. Diego García de Palacio of the Audiencia of Mexico. In a letter to the Crown dated at the Villa de Valladolid December 26, 1583 (AGI, México, leg. 70), Palacio stated that the practice of idolatry was widespread throughout the entire Valladolid district. At Tzama and Pole on the east coast and also in the towns of San Miguel and Santa Maria on Cozumel Island, all the Indians "without exception" were said to be idolaters. At Tzama there had been a "temple of idols" where the Indians gathered to celebrate "festivals, dances, and other ceremonies as in ancient times." We surmise that this place was simply the *popolna,* defined in the Motul dictionary as the "casa de comunidad," where certain dances were taught. In such case, the Indians no doubt had regular temples in the bush, as was true on Cozumel Island (see Roys, Scholes, and Adams, Carnegie Inst. Wash. Pub. 523, Contr. 30, p. 27). This "temple" at Tzama had now been burned, presumably by order of Palacio, and all the more than five hundred idols had been smashed and cast into the sea.

Palacio goes on to state that the common people guilty of idolatry had been given mild punishments, but the caciques, native priests, "and the *tnaestros* who made the statues *{estatuas)* and figures" had been arrested and would receive more severe punishment; "because in view of the boldness and excess with which they have lived in this sin, it is necessary, in order that henceforth mercy should not give them reason for greater obstinacy, as apparently has been the case up to the present time." The reference to *maestros* (masters, teachers, artisans) who made the idols is of some interest. The word *estatuas* usually seems to mean wooden idols, and Landa gives an account of the making of such figures. Palacio's letter and a supplementary report refer, however, only to clay idols, so in this case the *estatuas* were apparently of this kind.

The prevalence of idolatry on the cast coast and Cozumel is not surprising, since the towns of this region were located at some distance from the nearest mission

centers- Palacio's letter states, however, that in towns situated only one, two, or three leagues from the Villa de Valladolid similar conditions prevailed. On one journey outside the villa he had collected 1160 idols, in addition to many others that were destroyed, and he had punished more than 600 idolaters. He had also banished from this area certain "dogmatizers, priests, and *maestro/'* of these idolaters.

A supplementary report (Valladolid, 12 diciembre, 1583; in AGI, México, leg. 70) describes some of these 1160 "quifines," or idols, that had been gathered up. Some were said to be as large as children three, four, and five years old. Others were "figures of men with emblems *(divisas)* of animals on their heads, and others with miters and tiaras and other headdresses of men and women according to ancient custom, which the said Indians were accustomed to wear . . . in their sacrifices, festivals, and rites when they performed their idolatry."

Figures of men with "emblems of animals" on their heads are familiar in the Maya codices and on the monuments. Some of the animal headdresses have been thought to be carved wooden helmets. Clay figures of this kind were probably gods, including deified men. The "miters" suggest Mexican tradition, and figures with such characteristics may have represented deified lineage ancestors, old invaders (?). The significance of "tiaras" in the case of gods is not clear. Gem-studded bands seem to be found on both gods and warlike men at Chichen Itza: on caryatids, "chac-mools," and relief figures. The first Spaniards found gold headbands in chests in the temples of northern Yucatan and obtained others in Tabasco. We are inclined to associate them principally with deified heroes or lineage ancestors, but they may have a wider scope.

The report describing these idols also mentions figures of "leones," "tigres," and dogs, and "temples *(cues)* of different plans and forms." The pumas and jaguars of architectural sculptures evidently represent the military orders, but here we presumably have actual gods. The "leones" may have represented the war god, Citchac-coh ("father-red-puma"). The Book of Chilam Balam of Chumayel mentions a Chac-bolay-balam (chac-bolay means "tigre bermejo y bravo") and a Chac-bolay also figures in the Tizimin manuscript. We find no mention of dog gods in the colonial literature, Maya or Spanish. Figures of dogs are familiar, however, in the codices, and in the Dresden 7a a dog appears in a long row of deities. Dogs were also a favorite sacrifice, and Landa tells of offerings of clay dogs with bread on their backs. The figures mentioned in this 1583 report may have been something like votive offerings, if they were not idols of a dog god.

Despite the punitive measures imposed by Dr. Palacio, idolatry continued to exist in the Valladolid area and other parts of the province (see data recorded in previous reports). A letter of Bishop Vázquez de Mercado dated May 2, 1606 (AGI, México, leg. 72) records that "Indian idolaters were daily being discovered in various towns of this diocese." During a visitation made by the bishop in the Valladolid district "there were discovered and punished more than 80 Indians who, in gangs *(cuadrillas)*, assembled in different pueblos to perform the said idolatries." Moreover, a beneficed priest in that area had recently sent a report of 56 other idolaters whom he had found in the towns of his benefice. They had clay idols "de malisimas figuras . . . que a unos llamaban Dios Padre, a otros Dios Hijo y a otros Dios Espíritu Santo y Santa María y a otros rnuchos nombres de santos y santas como a ellos les parece, teniendo los dichos sus

sacerdotes que hacían las ceremonias y sahumerios cuando todos se juntaban a idolatrar."

This reference to clay idols called God the Father, God the Son, God the Holy Spirit, Holy Mary, and other names of saints is reminiscent of a report by Francisco Hernández in 1545 (see Las Casas, Apologética historia, ch. 123; Saville, Mus. Amer. Indian, Indian Notes and Monographs, vol. 9, no. 3). Hernández reported that God the Father was Igona (Itzamna); the Son was Bacab, son of a virgin named Chibirias (Ix-chebel-yax, according to Seler); the Holy Spirit was Ekchuuah. Cf. Tozzer, *Landa's Relatión* (Cambridge, 1941), Syllabus, page 310. Tozzer also discusses a report of 1913 by Bartolomé del Granado Baeza which records saint names for three of the Pauahtuns. The bishop's letter of 1606 indicates that the naming of certain gods by the names of saints started early, and it continues to the present day (see Gann, Bur, Amer. EthnoL Pub. 64, pp. 46-47). Deities with saint names appear, however, to have retained their pagan functions and characteristics. The bishop, of course, was well advised in condemning the practice.

The bishop's letter of 1606 was written in response to an inquiry from the Audiencia of Mexico, which in turn was prompted by a royal cedula of April 24, 1605, asking for information concerning the practice of idolatry in Yucatan "and why it is more prevalent in that province than in others." The bishop stated that it was not because of lack of instruction in the elements of Christian faith and doctrine, for he had personally examined some of the idolaters and they had given adequate answers to all questions of faith. It was his opinion that there were two major causes for the continued practice of the native religion. The first was the mild punishment that had been imposed, even in the case of the caciques and native priests. It is well known, of course, that Landa used stern measures during the investigation of 1562. Although the latter investigation put an end to the practice of human sacrifice, the severe punishments and torture employed by Landa not only caused serious unrest in Yucatan, but also aroused unfavorable criticism in high Spanish quarters. Consequently, in later years the clergy tried another tactic, employing public or private admonitions or some form of mild punishment in dealing with the idolaters. As already noted, Dr. Palacio proposed to deal more harshly with the caciques and native priests than with ordinary offenders, but in general the local authorities apparently tried to cope with the situation without resort to stern measures. But this method had failed, for, as the bishop said, Indians who had been punished on other occasions had continued their idolatrous practices, "the cause of which, I understand, is the mild punishment they have received for this great offense against God." "It appears to me therefore that it would be suitable for your Majesty to order . . . that the leaders and priests, especially those guilty of second offenses, should be given the most severe penalty."

The second cause noted by the bishop was the lack of compact Indian settlements, "because in all this diocese there is no well formed town; on the contrary, each household lives by itself scattered among the bush in such a way that a town of roo citizens may occupy a district of half a league because of the scattering of the houses."[1] This statement probably exaggerated the situation, but it indicates, nevertheless, that the policy of congregating the Indians into compact towns instituted by Tomás López in 1552 had not been effectively carried out, or that during the later decades of the sixteenth century

there had been considerable laxity in regard to town organization and control. To remedy the situation the bishop recommended that effective measures should be taken to reassemble the Indians "in streets and squares surrounding the church, so that in this way there would not be such freedom for their debaucheries and other sins, and so that they will be better indoctrinated."

The *definitorio* (governing council) of the Franciscans also made a statement on the subject which supported the bishop's views. The Franciscans, however, added another point of vital importance: the fact that the Indians of settled towns in northern Yucatan maintained contacts with the "gentiles" of the interior, with whom they carried on trade, selling them such articles as salt, knives, axes, machetes, and similar goods. "As a result of this trade and commerce they learn the idolatry and ancient rites which they may have forgotten as a result of evangelical teaching." The Franciscans might also have added that the bush country of the interior was also a convenient place of refuge for groups of Indians who, for one reason or another, wished to escape Spanish control, civil or religious. Throughout the entire colonial period the Spanish authorities sought to bring the interior under effective control, but in the main they never achieved more than temporary success. The bush and forests of central and southern Yucatan were always a haven for Indians who wished to escape oppression, or to live according to the old native customs.

During the past year Mr. Roys has continued and nearly completed the transcription of a Maya manuscript known as the Ritual of the Bacabs. This document of 237 pages consists mostly of medical incantations, although some directions for treatment are also included. The last page is written on the back of a printed Indulgence dated in 1779. Although much of the manuscript is not difficult to read, on many pages there are water stains or the writing has faded, so it has been necessary to make a preliminary study of the more legible parts in order to complete the transcription.

In spite of the late date of the manuscript, these incantations are practically free from European influence. With the exception of an occasional "Amen" and very rare mention of the Spanish Dios, no reference to the Christian religion has yet been found. "The four gods, the four Bacabs," who were prominent deities, are often invoked, and it is from these that the manuscript was given its title by its discoverer, William Gates. The Pauahtuns, believed to be wind gods, are barely mentioned. As might be dxpected, the Maya goddess of medicine also plays a prominent part; but she is usually cited in a twofold phase, as Chacal ("the red") Ix Chel, and Sacal ("the white") Ix Chel. Only once have we noted an Ekel ("black") or a Kanal ("yellow") Ix Chel. The distinction may indicate a reference to the four world quarters, to which these colors were ascribed.

A number of other deities are invoked or cited. We find the thirteen sky gods known as Oxlahun-ti-ku, and the nine deities of the underworld, Bolon-ti-ku, which are occasionally mentioned in the Books of Chilam Balam, but the others appear only rarely in colonial Maya literature.

Several times there is an invocation to the little-known Colop-u-uich-ku. The name strongly suggests a sun god, and in the Vienna dictionary he *is* described as "the principal god . . . from whom they said all things proceeded and who was incorporeal, hence they made no image of him." We also find a mention

of Kin-ich-kak-mo ("sun-eyed fire parrot"), a more familiar deity associated with the sun.

The sky god Itzamna, usually considered the head of the Maya pantheon, also appears in these incantations. We read of "the home of the father (or lord?) of the sun, Chac Ahau Itzamna." This name could be translated as "great (or red?) lord Itzamna." There is an obscure reference to "the thigh of Hun Itzamna," and a Kanal ("yellow") Itzamna is also cited. Associated with Itzamna are the iguana *{huh)* and another lizard *(itzam).*

Frequent accessories, apparently in the ceremonies which accompanied these incantations, were a green human figure of wood *(yax uinicil te,* or *che)* and a similar one of stone *(yax uinicil tun).* In the treatment of a sore foot, we infer that changing the dressing is symbolized by what is called changing the bed covers of these figures. These coverings are alleged to be the tails of the quetzal *(yaxum)* and the macaw. In this manner, states the healer, "I remove the great causer of pain."

The disease is often personified and is informed that 4 Ahau, or sometimes 1 Ahau, was the day of its birth. The healer addresses it with authority and threatens it. To one disease he says: "Thus I throw you down. I am your mother, I am your father; I cast you into the midst of the sea." To another he claims a similar relationship and condemns it "to the evils of the underworld."

Many of these incantations have a genuine poetic quality and abound in graceful figures of speech. In treating various feverish skin eruptions the healer states that he is cooling the throbbing pain with his red, white, and black fountains and with cenotes, forest ponds, and hailstones of these colors.

Some o£ the incantations are ordinary magic, such as charming a scorpion or cooling water while it is on the fire. The most interesting and poetical is that of the birth of the spider, which has been published by J. E. S. Thompson (Carnegie Inst. Wash. Pub. 509, Contr. 29). Here a green wooden spider and one of stone appear to take the place of the human figures in the other incantations.

The language of this manuscript is often obscure, and a complete translation will be very difficult.

In view of J. E. S. Thompson's approach to the problems of hieroglyphic writing by seeking parallels between such texts and certain passages in the colonial Maya literature written in European script (Year Book No. 43, pp. 172-173), we have searched the latter for chronological expressions or figures of speech which might easily lend themselves to pictorial representation. Their precise significance is not always clear, since they have come down to us mostly in manuscripts of the eighteenth century. By this time the copyists, who occasionally interpolated their own comments, had forgotten or become confused over some of the details of the old calendar system. We even find the katun explained as being a period of twenty-four years. The following excerpts have been selected from a series of yearly prophecies covering twenty years, which are recorded in the Books of Chilam Balam of Tizimin and Mani. They are given here as examples of phrases which we might expect to find expressed in hieroglyphic writing, but it does not, of course, necessarily follow that such will prove to be the case.

These prophecies begin with a statement of "the taking of *lac* of Katun 5 Ahau." The *lac* today is a shallow bowl, and the term has also been defined as a clay idol, but we infer it was an effigy bowl, possibly an incense burner. There

are occasional references to the "burden" or "charge" *(cucJi)* of the katun. In one of these the number 5, the coefficient of the day for which the katun is named, is said to be its burden; and we are reminded of a full-figure Initial Series inscription at Copan, although here it is not the coefficient which is represented as being the burden.

One of the year bearers is "the day of setting in order the bird *(ch'ich')* of the katun." Since we find elsewhere the "bird" of the day closely associated with its augury, the term probably has the same meaning for the katun.

For the tenth year there is a reference to the fan and bouquet of the ruler, presumably the god presiding over the katun, who "points his finger at the day he takes over his government." He is set up at his cup *(Inch)*, on his throne or dais *(dzam)*, his mat *(pop)*, and his seat *(\anche)*; and this establishment of the lord of the katun was very probably a chronological ceremonial.

For the year in which the last hotun begins we find a reference to the "binding of the burden of the katun." Here, instead of the coefficient, the burden appears to symbolize the destiny of the katun, which consists mostly of various misfortunes. This meaning is confirmed by the Motul dictionary. In the following year the burden is bound again, and the "rulers of the land" are said to be blindfolded. Whether earthly rulers or gods are meant is a little uncertain. Elsewhere in these Maya manuscripts the blindfolding of a deity appears to symbolize the loss of his power. Here it seems to indicate the approaching end of the katun, an event which concerned both gods and men.

At the end of these prophecies we are told that on a day 13 Oc "the katun is paced off" *(u che\ oc \aturi)*. This is evidently a play on the day name Oc, which can also mean "foot." In the Codex Pérez, however, the "pacing off" of the katun appears to begin on the day Oc, which falls just ten days before the end of the katun.

Mr. Thompson has noted a danger in this approach because of the uncertainty as to the language of the people who carved the inscriptions. A large proportion, though by no means all, are found in areas where either Yucatecan Maya or one of the Choloid languages was spoken at the time of the conquest. The latter comprise Chontal, Choi, and Chorti, and it has been shown that these three are hardly more than dialects of the same language, which, indeed, the sixteenth-century Spaniards considered them to be (Thompson, Amer. Anthropologist, n. s., vol. 9, pp. 584-603; Scholes and Roys, Acalan-Tixchel, in preparation).

Philologists have established a close relationship between Yucatecan Maya and Choloid, and it has long been known that for a person who knew one, the other was not very difficult to learn. Nevertheless, how close the resemblance was for practical purposes is a matter of some consequence. It is certainly closer than would appear from the comparative word lists that have been published, and to form some idea of this a comparison has been made between Becerra's large vocabulary of Palenque Choi (Anales del Museo Nacional de Arqueología, Historia y Etnografia, quinta época, vol. 2, pp. 249-278) and the Yucatecan Maya. Many words are almost identical and have the same meaning in both languages. In other cases the words are the same, but they have a slightly different meaning. Becerra's *bush* is defined as an ordinary gourd *(calabaza)*, whereas the Maya *hux* (pronounced the same) in northern Yucatan was a small

wild variety. There are also numerous instances where a Maya would understand a Choi term in spite of its difference from the word used in northern Yucatan. In Maya a skull is *tze*, and although the Choi equivalent is *bu\el jol*, it resembles the Maya *baac* ("bone") and *hoi* ("head"). Similarly, the Choi word for heel, *yit\o*, would be understood by a Maya as meaning the bottom of the leg or foot. There are certain sound shifts, but it seems unlikely that they would cause much difficulty. For consonants the two most frequent shifts are those in which Maya *can* ("serpent") and *che* ("tree") correspond to the Choloid *chan* and *ie* or *tie.*

A comparison of the first 400 words of Becerra's Choi vocabulary with their various Maya equivalents or near equivalents suggests strongly that a Yucatecan would either understand or have an approximately correct idea of the meaning of 50 to 60 per cent of them. Available Choloid texts are few and brief except for the long Acalan Chontal narrative, which contains a very considerable variety of subject matter. Here the sentence structure is very similar to that of Yucatecan Maya. The tentative conclusion of this inquiry is that whatever its origin, Maya hieroglyphic writing was probably adequate for the use of both these linguistic groups.

UNITED STATES HISTORY

LEO F. STOCK AND JUHX }. **MENG**

It was expected that this report would announce the completion of the manuscript oi" volume VI of the *Proceedings and debates of the British Parliaments respecting North America.* The amount of material bearing upon the Seven Years' War, however, is so voluminous and the necessary annotations are proportionately sci time-consuming that there still remain three or four months of work before the volume will be ready for printing. The questions at issue during this significant period, which preceded and which in large measure created the immediate conditions leading to the American Revolution, will make this volume an important one.

This may be the final volume of the series to be sponsored by the Institution. After thirty-five years of service, Dr. Stock's formal connection with the Division of Historical Research terminated July 31, 1945. In view of the extensive use so far made of the series in graduate schools and by writers in the field of colonial history, and because of the amount of unprinted sources that have been collected for the period ahead, the editor will continue to give as much time to this work as the pursuit of postretirement interests will permit.

Dr. Stock also intends to complete the orderly arrangement of the files of the former Department of Historical Research. Their value was illustrated in the correspondence between Viscount Bryce and Dr. J. Franklin Jameson which was printed in the January 1945 issue of the *American Historical Review.*

As in previous years, Dr. Stock has replied, for the Division, to many inquiries of historical nature, and has rendered other aid to students who came to Washington-

Volumes III and IV of the *Guide to materials for American history in the libraries and archives of Paris* are now complete in manuscript for anticipated publication when present printing and binding difficulties have been eased. Volume V, the final one of the series, deals with the colonial archives and is now in preparation. The work is being done by John J. Meng under the general direction of Waldo G. Leland.

Comforting information relating in part to the future usefulness of the *Guide* was

received during April 1945 from M. Abel Doysié in Paris. M. Doysié, one of the collaborators in the preparation of the publication, wrote concerning the Foreign Office archives: "The building was burnt, but the archives are safe though not available yet." Doysié himself is once more engaged in historical research, after several months in a German concentration camp and the destruction of his home by bombing.

HISTORY OF SCIENCE

GEORGE SARTON

Introduction to the history of science. Most of Dr. Sarton's time was devoted to the final revision of the manuscript of volume III and to proofreading. Thus far 421 galleys have been read, more than a third of the total but less than half. So large and complex is this work that at least another year will be needed to complete the proofreading and indexing.

Editing of Isis. The publication of *Isis* has been considerably slowed up, because the Harvard University Printing Office is short of labor and is obliged to do the University work first. Two numbers only have appeared (nos. 100 and 101), and volume 35 (1944) is not yet completed, the last part (no. 102) being now in page proof. Numbers 100 and 101 include 12 main articles, 17 shorter notes, 23 reviews, 830 bibliographic items, and are illustrated with 4 plates and 29 figures in text. Since Its foundation in 1913 *Isis* has never been smaller. Editorial work has been continued, however, by Dr. Sarton and Dr. Pogo$_7$ and a large amount of manuscript is ready for publication as soon as circumstances permit.

From 1913 to 1940 *Isis* had been printed in Belgium. Word has been received from the St. Catherine Press in Bruges that the stock of *Isis* and *Osiris* has been preserved in spite of the fact that other presses in the neighborhood have been destroyed. Volume 32 of *Isis* and volumes 8 and 9 of *Osiris,* which were being printed in Bruges at the time of the German invasion, will be published as soon as possible. /This will not be before 1946 or perhaps 1947.

Ancient science down to Epicuros. Four chapters are completed, dealing respectively with the dawn of science, Egypt, Mesopotamia, and the Aegean area.

PUBLICATIONS

MARGARET W. HARRISON

Of the three major publications reported in press at the time of last year's review, wartime difficulties in the printing industry have permitted the publication of only one, Alfonso Villa's *The Maya of east central Quintana Roo* (Publication 559), released in May 1945. Beginning with a brief survey of the history of Quintana Roo and ending with a critical bibliography of the War of the Castes and a discussion of historical sources by Howard F. Cline, the book describes the Indian mode of life in the most isolated of the four Yucatecan Maya communities studied by ethnologists and sociologists of the Institution from 1930 to 1936. A second community was reported on by Robert Redfield and Sr. Villa in *Chan Kom, a Maya village* (Publication 448), issued in 1934; and a third by Dr. and Mrs. Redfield in *Disease and its treatment in Dzitas, Yucatan* (Contribution 32 in Publication 523), issued in 1940. The final results of the study became available in Dr. Redfield's *The fol\ culture of Yucatan,* published by the University of Chicago Press in 1941. The report on the remaining community, Merida, is not yet completed.

Miss Proskouriakoff's *Album of Maya architecture* (Publication 558) has progressed as far as page proof of the text.

The gravure illustrations, the main feature of the publication, have been printed for several months.

Textiles of highland Guatemala (Publication 567), by Lila M. O'Neale, professor of decorative art at the University of California, Berkeley, is ready for binding. The text and gravure illustrations are printed; the line cuts are undergoing final revision.

Under the joint authorship of France V. Scholes and Ralph L. Roys, the manuscript of *Acalan-Tixchel: a contribution to the history and ethnography of southwestern Campeche* (Publication 560) has nearly reached completion. It is expected that the text will be ready for the printer by early fall of 1945.

Excavations at Kaminaljuyu, Guatemala (Publication 561), by A. V. Kidder, J. D. Jennings, and E. M. Shook, with technological notes by Anna O. Shepard, is now in galley proof. This book is a detailed account of the excavation of two mounds, in each of which were found several superimposed structures and richly stocked tombs. The grave furniture, fully described and illustrated, contained a large number of important objects which served to establish chronological relations between the local Guatemala highland culture and several other major cultural developments in the Maya area and in central Mexico.

J. Eric S. Thompson has finished the manuscript of *An archaeological reconnaissance in the Cotzumalhuapa region, Escuintla, Guatemala,* which will form Contribution 44, the first paper in volume 9 of Contributions to American Anthropology and History. This paper contains an analysis of the historical accounts of the Indian tribes on the Pacific littoral of Guatemala and a comparative study of the sculpture found in that area.

To the second volume of Notes on Middle American Archaeology and Ethnology have been added eighteen numbers during the year. Half of these, listed in the bibliography at the end of this report, have come from members of the staff, the Misses Proskouriakofi and Shepard and Messrs. Kidder, Morley, Roys, Smith, and Thompson. Specialists outside the Institution contributed the remainder: *Archaeological finds near Douglas, British Honduras* (no. 40), by A. Hamilton Anderson and Herbert J. Cook; *Ixtle weaving at Chiquilistlan, Jalisco* (no. 42) and *Worked gourds from Jalisco* (no. 43), by Isabel T. Kelly; *The graphic style of the Tlalhuica* (no. 44), by R. H. Barlow; *The Venus calendar of the Aztec* (no. 46), by R. C. E. Long; *Costumes and wedding customs at Mixco, Guatemala* (no. 48), by Lilly de Jongh Osborne; *Moon age tables* (no. 50), by Lawrence Roys; *A second Tlaloc gold plaque from Guatemala* (no. 51), by Karl-Heinz Nottebohm; and *Roc\ paintings at Texcalpintado, Morelos, Mexico* (no. 52), by M. A. Espejo.

Mrs. Harrison has in preparation the compilation of a dictionary of terms applicable to Middle American archaeology, covering architecture, ceramics, artifacts, and sculpture. The terms are confined to English words and foreign words taken over into ordinary archaeological usage. A preliminary list of tentative definitions will be distributed in mimeographed form to specialists in this field for corrections and additions before final publication.

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