

I

CELL BIOLOGY

COMPILED AND EDITED BY

Philip L. Altman and Dorothy Dittmer Katz

2976



(内部交流)

I

CELL BIOLOGY

COMPILED AND EDITED BY

Philip L. Altman and Dorothy Dittmer Katz

Federation of American Societies for Experimental Biology
BETHESDA, MARYLAND

©1976, by Federation of American Societies for Experimental Biology

All rights reserved. This book is protected by copyright. No part of it may be produced in any manner without written permission from the publisher.

PRINTED IN THE UNITED STATES OF AMERICA

Library of Congress Catalog Card Number: 75-42787

International Standard Book Number: 0-913822-10-8

FOREWORD

This volume, which is the first in a new series of Biological Handbooks, is our initial effort to provide the scientific community with a detailed tabulation of data from a limited area of biology. The Editorial Board chose the field of cell biology because it has become a center of interdisciplinary activity, attracting a variety of interested investigators from all branches of science. The Board therefore concluded that a data book devoted exclusively to the cell would serve the widest audience.

Once the topic was chosen, we considered how the data could be organized most effectively. Retrieval, evaluation, and dissemination of facts about the cell were conceived as constituting the principal objectives of the project. Due to the system established by the Handbooks Office for securing and authenticating data, the first two objectives posed no problems. But the third—how to present the data in the most useful manner to the largest audience—became a major concern.

The Editorial Board decided that a classification in anatomical terms would avoid most ambiguities and would best serve the interests of the researcher, the teacher, and the graduate student—those individuals to whom the Biological Handbooks Series is primarily directed. Such classification, of course, would not eliminate inclusion of physiological or biochemical attributes. After all, most investigators of the cell began their studies on organelles with well-defined anatomical features which were soon characterized in biochemical and physiological terms.

The Board recognized that certain cell characteristics, such as the integrated properties which serve to distinguish one cell from another, do not lie within the confines of anatomical classification. Data have nevertheless been included since they are essential, or of interest, to anyone investigating the phenomena of the cell. And since those who work with cells must have ready access to data on suitable cell environments, a separate section on media, solutions, and related information has been included.

It was agreed that certain sacrifices had to be made to achieve a compact but representative volume. Thus the emphasis in this compilation is on vertebrate data. Data on plants and invertebrates appear only where there is generic need for their inclusion. Selectivity and restraint also were exercised in determining the extent of data coverage.

As the anatomical organization of the book developed, topics for tabular treatment were grouped into large categories or sections. Responsibility for the selection of specific tables to be prepared for each section was delegated to a special Advisory Committee formed from experts in the field of cell biology. The Board thought it appropriate that these experts also be asked to provide an introduction to each section which would give a synopsis of the current thought, and which would place in perspective the particular organelle, or organelles, for which data were included. The reader will therefore find prefaced to each section a short essay by one or more of the section advisors.

The actual tables were prepared by individuals recognized as authorities on some phase, or phases, of investigation of the cell. The tables were then reviewed by other experts for accuracy and tabular organization. The final compilation of each section was carried out under the direction of a member, or members, of the Advisory Committee. As a precaution against the introduction of additional errors, the editing, indexing, and composition of camera-ready copy were performed in the Office of Biological Handbooks by a veteran staff under the able executive administration of Philip L. Altman. And no one better exemplifies the high standards maintained by this Office in the preparation of publication copy than his long-time associate and colleague, Dorothy Dittmer Katz.

Acknowledgement is hereby given to the IBM Corporation for a modest monetary contribution toward preparation of this data book. Our sincere gratitude goes to Dr. Lewis M. Branscomb, IBM Vice President and Chief Scientist, for his interest and assistance in obtaining this gift.

Listed on page iv are the names of the Biological Handbooks Editorial Board members who served during preparation of *CELL BIOLOGY*. The names of the members of the Cell Biology Advisory Committee are also given, as well as those of the FASEB Publications Committee and of the staff of the Office of Biological Handbooks. On following pages, the names and institutional affiliations of the contributors and reviewers are listed. The intellectual efforts of the Advisory Committee and of the contributors and reviewers are acknowledged with deepest appreciation.

1 December 1975
Charleston, South Carolina

Harold G. Hempling, *Chairman*
Biological Handbooks Editorial Board

BIOLOGICAL HANDBOOKS EDITORIAL BOARD

THOMAS J. GILL, III
AMERICAN ASSOCIATION OF IMMUNOLOGISTS
University of Pittsburgh School
of Medicine
Pittsburgh, Pennsylvania 15261

KARL F. HEUMANN*
Federation of American Societies
for Experimental Biology
9650 Rockville Pike
Bethesda, Maryland 20014

ORVILLE A. LEVANDER
AMERICAN INSTITUTE OF NUTRITION
U.S. Department of Agriculture
Beltsville, Maryland 20705

HAROLD G. HEMPLING, *Chairman*
AMERICAN PHYSIOLOGICAL SOCIETY
Medical University of South Carolina
Charleston, South Carolina 29401

GERTRUDE D. MAENGWYN-DAVIES
AMERICAN SOCIETY FOR PHARMACOLOGY
AND EXPERIMENTAL THERAPEUTICS
15205 Tottenham Terrace
Silver Spring, Maryland 20906

EUGENE L. HESS*
Federation of American Societies
for Experimental Biology
9650 Rockville Pike
Bethesda, Maryland 20014

SEYMOUR KAUFMAN
AMERICAN SOCIETY OF BIOLOGICAL CHEMISTS
National Institutes of Health
Bethesda, Maryland 20014

WILLIAM B. WARTMAN
AMERICAN SOCIETY FOR EXPERIMENTAL
PATHOLOGY
University of Virginia
Charlottesville, Virginia 22903

CELL BIOLOGY ADVISORY COMMITTEE

VIRGINIA J. EVANS
Biomedical Research Institute
Rockville, Maryland 20852

PHILIP SIEKEVITZ
Rockefeller University
New York, New York 10021

GERALD WEISSMANN
New York University
Medical Center
New York, New York 10016

HAROLD G. HEMPLING, *Chairman*
Medical University of South Carolina
Charleston, South Carolina 29401

GERHARD WERNER
University of Pittsburgh
School of Medicine
Pittsburgh, Pennsylvania 15213

THORU PEDERSON
Worcester Foundation for Experimental
Biology
Shrewsbury, Massachusetts 01545

LEONARD WEISS
Roswell Park Memorial Institute
Buffalo, New York 14203

DAVID F. WILSON
University of Pennsylvania
Medical School
Philadelphia, Pennsylvania 19174

FASEB PUBLICATIONS COMMITTEE

WILLIAM W. FLEMING
AMERICAN SOCIETY FOR PHARMACOLOGY
AND EXPERIMENTAL THERAPEUTICS
West Virginia University
Medical Center
Morgantown, West Virginia 26506

DONALD B. HACKEL
AMERICAN SOCIETY FOR EXPERIMENTAL
PATHOLOGY
Duke University Medical Center
Durham, North Carolina 27710

FRED KARUSH
AMERICAN ASSOCIATION OF IMMUNOLOGISTS
University of Pennsylvania
School of Medicine
Philadelphia, Pennsylvania 19174

CHARLES S. TIDBALL, *Chairman*
AMERICAN PHYSIOLOGICAL SOCIETY
George Washington University
Medical Center
Washington, D.C. 20037

RICHARD W. LUECKE
AMERICAN INSTITUTE OF NUTRITION
Michigan State University
East Lansing, Michigan 48824

ARTHUR C. GUYTON*
University of Mississippi
School of Medicine
Jackson, Mississippi 39216

EUGENE L. HESS*
Federation of American Societies
for Experimental Biology
9650 Rockville Pike
Bethesda, Maryland 20014

FREDERIC M. RICHARDS
AMERICAN SOCIETY OF BIOLOGICAL CHEMISTS
Yale University
New Haven, Connecticut 06520

OFFICE OF BIOLOGICAL HANDBOOKS STAFF

PHILIP L. ALTMAN, *Director*

DOROTHY DITTMER KATZ, *Editor*

ROSIE CHEN
SAKI HIMEL

GERALDINE M. JOHNSON

ELSIE C. COMSTOCK
LAC KHANH TRUONG

**ex officio*

CONTRIBUTORS AND REVIEWERS

- ABELSON, HERBERT T.**
Children's Hospital Medical Center
Boston, Massachusetts 02115
- ADELMAN, M. R.**
Duke University Medical Center
Durham, North Carolina 27710
- ALLFREY, VINCENT G.**
Rockefeller University
New York, New York 10021
- ALLISON, ANTHONY C.**
Clinical Research Centre
Harrow, Middlesex, HA1 3UJ, England
- ALVARES, ALVITO P.**
Rockefeller University
New York, New York 10021
- AULL, FELICE**
New York University Medical Center
New York, New York 10016
- BAHR, GUNTER F.**
Armed Forces Institute of Pathology
Washington, D.C. 20306
- BALIGA, B. S.**
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
- BANERJEE, D.**
New York Blood Center
New York, New York 10021
- BANGHAM, A. D.**
Agricultural Research Council
Cambridge, CB2 4AT, England
- BARER, R.**
University of Sheffield
Sheffield S10 2TN, England
- BARIL, BETTY B.**
Worcester Foundation for Experimental Biology
Shrewsbury, Massachusetts 01545
- BARON, JEFFREY**
University of Iowa
Iowa City, Iowa 52242
- BARRETT, ALAN J.**
Strangeways Research Laboratory
Cambridge, CB1 4RN, England
- BARTLEY, W.**
University of Sheffield
Sheffield, S10 2TN, England
- BASERGA, RENATO**
Temple University Health Sciences Center
Philadelphia, Pennsylvania 19140
- BEAUGE, L. A.**
University of Maryland School of Medicine
Baltimore, Maryland 21201
- BECKER, ELMER L.**
University of Connecticut School of Medicine
Farmington, Connecticut 06032
- BELLI, JAMES A.**
Harvard Medical School
Boston, Massachusetts 02115
- BENJAMINI, E.**
University of California School of Medicine
Davis, California 95616
- BENSON, ANDREW A.**
Scripps Institution of Oceanography
La Jolla, California 92037
- BERGERON, J. J. M.**
McGill University
Montreal, Quebec, H3C 3G1, Canada
- BERTALANFFY, FELIX D.**
University of Manitoba Medical College
Winnipeg, Manitoba, R3E 0W3, Canada
- BHUYAN, B. K.**
Upjohn Company
Kalamazoo, Michigan 49001
- BLOBEL, GÜNTER**
Rockefeller University
New York, New York 10021
- BLOODGOOD, ROBERT A.**
Yale University
New Haven, Connecticut 06520
- BODLEY, JAMES W.**
University of Minnesota Medical School
Minneapolis, Minnesota 55455
- BOGDEN, ARTHUR E.**
Mason Research Institute
Worcester, Massachusetts 01608
- BONNEY, ROBERT J.**
State of New York Department of Health
Albany, New York 12201
- BORISY, GARY G.**
University of Wisconsin
Madison, Wisconsin 53706
- BRADY, ROSCOE O.**
NIH, National Institute of Neurological Diseases and Strokes
Bethesda, Maryland 20014
- BRINLEY, F. J., JR.**
Johns Hopkins Medical School
Baltimore, Maryland 21205
- BURTON, KENNETH**
University of Newcastle Upon Tyne
Newcastle Upon Tyne, NE1 7RU, England
- BUSCH, HARRIS**
Baylor College of Medicine
Houston, Texas 77025
- BUTOW, RONALD A.**
University of Texas Health Science Center
Dallas, Texas 75235
- CAILLEAU, RELDA**
M. D. Anderson Hospital and Tumor Institute
Houston, Texas 77025
- CAMALIER, RICHARD F.**
NIH, National Cancer Institute
Bethesda, Maryland 20014
- CAMERON, IVAN L.**
University of Texas
San Antonio, Texas 78284
- CARRAWAY, KERMIT L.**
Oklahoma State University
Stillwater, Oklahoma 74074
- CASKEY, C. THOMAS**
Baylor College of Medicine
Houston, Texas 77025
- CHASIN, LAWRENCE**
Columbia University
New York, New York 10027
- CHI, EMIL Y.**
University of Washington School of Medicine
Seattle, Washington 98195
- CHIEN, SHU**
College of Physicians and Surgeons of Columbia University
New York, New York 10032
- CHOI, YONG C.**
Baylor College of Medicine
Houston, Texas 77025
- CHOWDHURY, TUSHAR K.**
University of Oklahoma Health Sciences Center
Oklahoma City, Oklahoma 73190
- CIFERRI, ORIO**
University of Pavia
27100 Pavia, Italy
- COHEN, SEYMOUR S.**
University of Colorado Medical Center
Denver, Colorado 80220

COHN, JONATHAN
Rockefeller University
New York, New York 10021

COHN, ZANVIL
Rockefeller University
New York, New York 10021

COLEMAN, R.
University of Birmingham
Birmingham, B15 2TT, England

CONE, CLARENCE D.
Langley Research Center
Hampton, Virginia 23665

CONNEY, ALLAN H.
Hoffmann-La Roche, Inc.
Nutley, New Jersey 07110

COON, M. J.
University of Michigan Medical School
Ann Arbor, Michigan 48104

COOPER, DAVID Y.
University of Pennsylvania Hospital
Philadelphia, Pennsylvania 19104

CORNELL, NEAL W.
St. Elizabeths Hospital
Washington, D.C. 20032

COTTLER-FOX, MICHELE
NIH, National Cancer Institute
Bethesda, Maryland 20014

COX, R. A.
National Institute for Medical Research
London, NW7 1AA, England

CRANE, F. L.
Purdue University
Lafayette, Indiana 47907

CUNNINGHAM, WILLIAM P.
University of Minnesota
St. Paul, Minnesota 55108

DALLNER, GUSTAV
University of Stockholm
S-104 05 Stockholm, Sweden

DALTON, ALBERT J.
NIH, National Cancer Institute
Bethesda, Maryland 20014

DALZIEL, KEITH
University of Oxford
Oxford, OX1 3QU, England

DASHTI, NASSRIN
Oklahoma Medical Research Foundation
Oklahoma City, Oklahoma 73104

DEAN, ROGER T.
University College Hospital Medical School
London, WC1 E6JJ, England

DELL'ORCO, ROBERT T.
Noble Foundation, Inc.
Ardmore, Oklahoma 73401

DESCHNER, ELEANOR E.
Memorial Sloan-Kettering Cancer Center
New York, New York 10021

DETHLEFSEN, LYLE A.
University of Utah Medical Center
Salt Lake City, Utah 84112

DE WEEER, PAUL
Washington University School of Medicine
St. Louis, Missouri 63110

DIAMOND, JARED M.
University of California School of Medicine
Los Angeles, California 90024

DICK, D. A. T.
University of Dundee
Dundee, DD1 4HN, Scotland

DULAK, NORMAN C.
State University of New York
Albany, New York 12222

EAGLE, HARRY
Albert Einstein College of Medicine
Bronx, New York 10461

EISENBERG, EVAN
NIH, National Heart and Lung Institute
Bethesda, Maryland 20014

ELGIN, SARAH C. R.
Harvard University
Cambridge, Massachusetts 02138

ENNIS, HERBERT L.
Roche Institute of Molecular Biology
Nutley, New Jersey 07110

ERECINSKA, MARIA
University of Pennsylvania School of Medicine
Philadelphia, Pennsylvania 19174

ESBER, HENRY J.
Mason Research Foundation
Worcester, Massachusetts 01608

ESTABROOK, RONALD W.
University of Texas Health Science Center
Dallas, Texas 75235

EVANS, EVAN A.
Duke University
Durham, North Carolina 27706

EVANS, VIRGINIA J.
Biomedical Research Institute
Rockville, Maryland 20852

FEIGELSON, PHILIP
College of Physicians and Surgeons of Columbia University
New York, New York 10032

FITZGERALD, LAURENCE R.
University of Tennessee Center for the Health Sciences
Memphis, Tennessee 38163

FLEISCHER, BECCA
Vanderbilt University
Nashville, Tennessee 37235

FLEISCHER, SIDNEY
Vanderbilt University
Nashville, Tennessee 27235

FORSTER, R. E.
University of Pennsylvania School of Medicine
Philadelphia, Pennsylvania 19104

FOUTS, J. R.
NIH, National Institute of Environmental Health Sciences
Research Triangle Park, North Carolina 27709

FOX, CECIL H.
NIH, National Cancer Institute
Bethesda, Maryland 20014

FRANKE, WERNER W.
German Cancer Research Center
69 Heidelberg 1, Germany

FRIEND, DANIEL S.
University of California School of Medicine
San Francisco, California 94143

FRY, R. J. MICHAEL
Argonne National Laboratory
Argonne, Illinois 60439

GANTT, ELISABETH
Radiation Biology Laboratory
Rockville, Maryland 20852

GAYLOR, JAMES L.
Cornell University
Ithaca, New York 14853

GELFANT, SEYMOUR
Medical College of Georgia
Augusta, Georgia 30902

GERALD, PARK S.
Children's Hospital Medical Center
Boston, Massachusetts 02115

GERGELY, J.
Boston Biomedical Research Institute
Boston, Massachusetts 02114

GEYER, ROBERT P.
Harvard University
Boston, Massachusetts 02115

GIBBS, SARAH P.
McGill University
Montreal, Quebec, H3C 3G1, Canada

GILLETTE, JAMES R.
NIH, National Heart and Lung Institute
Bethesda, Maryland 20014

- GILULA, NORTON B.
Rockefeller University
New York, New York 10021
- GLAUMANN, HANS
Karolinska Institutet
113 82 Stockholm 6, Sweden
- GLICK, MARY CATHERINE
University of Pennsylvania School
of Medicine
Philadelphia, Pennsylvania 19104
- GOLBERG, L.
Albany Medical College of Union
University
Albany, New York 12208
- GOLDBERG, NELSON D.
University of Minnesota Medical School
Minneapolis, Minnesota 55455
- GOLDMAN, R.
Weizmann Institute of Science
Rehovot, Israel
- GOLDSMITH, HARRY L.
Montreal General Hospital
Montreal, Quebec, H3G 1A4, Canada
- GOLDSTEIN, IRA M.
New York University Medical Center
New York, New York 10016
- GOOD, NORMAN E.
Michigan State University
East Lansing, Michigan 48824
- GOODMAN, JOEL W.
University of California School
of Medicine
San Francisco, California 94143
- GRAM, THEODORE E.
NIH, National Cancer Institute
Bethesda, Maryland 20014
- GUNN, ROBERT BURNS
Duke University Medical Center
Durham, North Carolina 27710
- GURNEY, THEODORE, JR.
University of Utah
Salt Lake City, Utah 84112
- HACKETT, ADELINE J.
Naval Biomedical Research Laboratory
Oakland, California 94625
- HAHN, GEORGE M.
Stanford University Medical Center
Stanford, California 94305
- HAM, RICHARD G.
University of Colorado
Boulder, Colorado 80302
- HAN, ANTUN
Argonne National Laboratory
Argonne, Illinois 60439
- HANSFORD, RICHARD G.
NIH, National Institute of Child
Health and Human Development
Baltimore, Maryland 21224
- HARLOS, J. P.
Roswell Park Memorial Institute
Buffalo, New York 14203
- HASSELBACH, WILHELM
Max Planck Institut
69 Heidelberg 1, Germany
- HATANO, SADASHI
Nagoya University
Nagoya, Japan 464
- HAWKINS, DAVID
McGill University
Montreal, Quebec, H3G 1A4, Canada
- HAY, ELIZABETH D.
Harvard Medical School
Boston, Massachusetts 02115
- HAYFLICK, LEONARD
Stanford University School of Medicine
Stanford, California 94305
- HELDT, H. W.
University of Munich
8000 Munich 2, Germany
- HEMPLING, HAROLD G.
Medical University of South Carolina
Charleston, South Carolina 29401
- HENSON, PETER M.
Scripps Clinic and Research Foundation
La Jolla, California 92037
- HEYTLER, PETER G.
E. I. du Pont de Nemours and Company
Wilmington, Delaware 19898
- HEYWOOD, STUART M.
University of Connecticut
Storrs, Connecticut 06268
- HILL, WALTER E.
University of Montana
Missoula, Montana 59801
- HOFFMAN, PHILIP G.
NIH, National Institute of Child
Health and Human Development
Bethesda, Maryland 20014
- HOLTZMAN, ERIC
Columbia University
New York, New York 10027
- HOOPER, J. KENNETH
Temple University School of Medicine
Philadelphia, Pennsylvania 19140
- HSU, T. C.
M. D. Anderson Hospital and Tumor
Institute
Houston, Texas 77025
- HUANG, RU CHIH C.
Johns Hopkins University
Baltimore, Maryland 21218
- HUMPHREY, RONALD M.
Texas Medical Center
Houston, Texas 77025
- HURLBERT, ROBERT B.
M. D. Anderson Hospital and Tumor
Institute
Houston, Texas 77025
- IKEMOTO, N.
Boston Biomedical Research Institute
Boston, Massachusetts 02114
- INESI, GIUSEPPE
University of the Pacific
San Francisco, California 94115
- ITO, AKIO
Kyushu University
Fukuoka 812, Japan
- JAMIESON, G. A.
Blood Research Laboratory
Bethesda, Maryland 20014
- JAMIESON, JAMES D.
Yale University School of Medicine
New Haven, Connecticut 06510
- JULIANO, R. L.
Hospital for Sick Children
Toronto, Ontario, M5G 1X8, Canada
- KABAT, ELVIN A.
Columbia University College of
Physicians and Surgeons
New York, New York 10032
- KAESBERG, PAUL
University of Wisconsin
Madison, Wisconsin 53706
- KAIGHN, M. EDWARD
Pasadena Foundation for Medical
Research
Pasadena, California 91101
- KANN, HERBERT E., JR.
Emory University School of Medicine
Atlanta, Georgia 30303
- KAO, FA-TEN
Eleanor Roosevelt Institute for
Cancer Research, Inc.
Denver, Colorado 80220
- KASPER, CHARLES B.
McArdle Laboratory for Cancer
Research
Madison, Wisconsin 53706
- KEENAN, T. W.
Purdue University
Lafayette, Indiana 47907
- KESSEL, DAVID
Milton A. Darling Memorial Center
Detroit, Michigan 48201
- KIMELBERG, H. K.
Albany Medical College of Union
University
Albany, New York 12208
- KIRSHNER, NORMAN
Duke University Medical Center
Durham, North Carolina 27710
- KLEINSMITH, LEWIS J.
University of Michigan
Ann Arbor, Michigan 48104

- KLINGENBERG, E. M.**
University of Munich
8000 Munich 2, Germany
- KNIGHT, ROBERT H.**
University of Nebraska
Lincoln, Nebraska 68503
- KOENIG, HAROLD**
Veterans Administration Research
Hospital
Chicago, Illinois 60611
- KORNFELD, STUART**
Washington University School
of Medicine
St. Louis, Missouri 63110
- KUCHERLAPATI, RAJU S.**
Yale University
New Haven, Connecticut 06520
- KUPFER, DAVID**
Worcester Foundation for
Experimental Biology
Shrewsbury, Massachusetts 01545
- LA CELLE, P. L.**
University of Rochester School of
Medicine and Dentistry
Rochester, New York 14642
- LAGUNOFF, DAVID**
University of Washington School
of Medicine
Seattle, Washington 98195
- LAND, JOHN M.**
University of Pennsylvania School
of Medicine
Philadelphia, Pennsylvania 19174
- LA NOUE, KATHRYN F.**
Milton S. Hershey Medical Center
Hershey, Pennsylvania 17033
- LASFARGUES, E. Y.**
Institute for Medical Research
Camden, New Jersey 08103
- LEE-HUANG, SYLVIA**
New York University Medical Center
New York, New York 10016
- LEHNINGER, ALBERT L.**
Johns Hopkins University School of
Medicine
Baltimore, Maryland 21205
- LEIBOVITZ, ALBERT**
Scott and White Clinic
Temple, Texas 76501
- LEPAGE, G. A.**
University of Alberta
Edmonton, Alberta, T6G 2E1, Canada
- LEVINSON, CHARLES**
University of Texas
San Antonio, Texas 78284
- LIEW, C. C.**
University of Toronto
Toronto, Ontario, M5G 1L5, Canada
- LINGREL, JERRY B.**
University of Cincinnati Medical
Center
Cincinnati, Ohio 45219
- LITTLE, JOHN B.**
Harvard University
Boston, Massachusetts 02115
- LLOYD, JOHN**
University of Keele
Staffordshire, ST5 5BG, England
- LOEWENSTEIN, WERNER R.**
University of Miami School of
Medicine
Miami, Florida 33152
- LOFTFIELD, ROBERT B.**
University of New Mexico School of
Medicine
Albuquerque, New Mexico 87131
- LOVENBERG, WALTER**
NIH, National Heart and Lung
Institute
Bethesda, Maryland 20014
- LOWRY, OLIVER H.**
Washington University School of
Medicine
St. Louis, Missouri 63110
- LU, ANTHONY Y. H.**
Hoffmann-La Roche, Inc.
Nutley, New Jersey 07110
- LUCAS-LENARD, JEAN**
University of Connecticut
Storrs, Connecticut 06268
- LUNG, BEN**
Stanford University School of
Medicine
Stanford, California 94305
- MACY, MARVIN L.**
American Type Culture Collection
Rockville, Maryland 20852
- MARCUS, ABRAHAM**
Institute for Cancer Research
Philadelphia, Pennsylvania 19111
- MARSHALL, JEAN M.**
Brown University
Providence, Rhode Island 02912
- MARTIN, GEORGE M.**
University of Washington School
of Medicine
Seattle, Washington 98195
- MARTONOSI, ANTHONY**
St. Louis University School of
Medicine
St. Louis, Missouri 63104
- MARUSHIGE, KEIJI**
University of North Carolina School
of Medicine
Chapel Hill, North Carolina 27514
- MASON, THOMAS L.**
University of Massachusetts
Amherst, Massachusetts 01002
- MAYHEW, ERIC**
Roswell Park Memorial Institute
Buffalo, New York 14203
- McDONALD, J. KEN**
Medical University of South Carolina
Charleston, South Carolina 29401
- McEWEN, BRUCE S.**
Rockefeller University
New York, New York 10021
- McNUTT, N. SCOTT**
Veterans Administration Hospital
San Francisco, California 94121
- MEHLER, ALAN H.**
Medical College of Wisconsin
Milwaukee, Wisconsin 53233
- MEHRISHI, J. N.**
University of Cambridge
Cambridge, CB2 2QN, England
- MENDELSON, MORTIMER L.**
Lawrence Livermore Laboratory
Livermore, California 94550
- MERCHANT, DONALD J.**
Eastern Virginia Medical School
Norfolk, Virginia 23507
- MISCH, DONALD W.**
University of North Carolina
Chapel Hill, North Carolina 27514
- MOLINOFF, PERRY B.**
University of Colorado Medical Center
Denver, Colorado 80220
- MOORHEAD, PAUL S.**
Children's Hospital of Philadelphia
Philadelphia, Pennsylvania 19104
- MORIARTY, GWEN C.**
University of Nebraska Medical Center
Omaha, Nebraska 68105
- MORRÉ, D. JAMES**
Purdue University
Lafayette, Indiana 47907
- MUDD, J. B.**
University of California
Riverside, California 92502
- MUENCH, KARL H.**
University of Miami School of
Medicine
Miami, Florida 33152
- MUNRO, H. N.**
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
- NEUFELD, ELIZABETH F.**
NIH, National Institute of Arthritis,
Metabolism, and Digestive Diseases
Bethesda, Maryland 20014

- NEURATH, HANS**
University of Washington
Seattle, Washington 98195
- NEVILLE, DAVID M., JR.**
National Institute of Mental Health
Bethesda, Maryland 20014
- NICHOLS, WARREN W.**
Institute for Medical Research
Camden, New Jersey 08103
- NICOLSON, GARTH L.**
Salk Institute for Biological Studies
San Diego, California 92112
- NISHIMURA, SUSUMU**
National Cancer Center Research
Institute
Tokyo, Japan
- NOMURA, MASAYASU**
University of Wisconsin
Madison, Wisconsin 53706
- NOONAN, KENNETH D.**
University of Florida
Gainesville, Florida 32610
- NOVIKOFF, ALEX B.**
Albert Einstein College of Medicine
Bronx, New York 10461
- O'BRIEN, T. W.**
University of Florida
Gainesville, Florida 32610
- OCHOA, SEVERO**
Roche Institute of Molecular Biology
Nutley, New Jersey 07110
- OMURA, TSUNEO**
Kyushu University
Fukuoka 812, Japan
- ONTKO, JOSEPH A.**
Oklahoma Medical Research Founda-
tion
Oklahoma City, Oklahoma 73104
- ORRENIUS, STEN**
Karolinska Institutet
S-104 01 Stockholm 60, Sweden
- PADILLA, GEORGE M.**
Duke University Medical Center
Durham, North Carolina 27710
- PALMIERI, FERDINANDO**
University of Bari
70126 Bari, Italy
- PAPA, SERGIO**
University of Bari
70126 Bari, Italy
- PARDEE, ARTHUR B.**
Princeton University
Princeton, New Jersey 08540
- PARIZA, MICHAEL W.**
McArdle Laboratory for Cancer
Research
Madison, Wisconsin 53706
- PATTERSON, DAVID**
Eleanor Roosevelt Institute for
Cancer Research
Denver, Colorado 80220
- PEDERSEN, PETER L.**
Johns Hopkins University School
of Medicine
Baltimore, Maryland 21205
- PEDERSON, THORU**
Worcester Foundation for Experi-
mental Biology
Shrewsbury, Massachusetts 01545
- PENMAN, SHELDON**
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
- PERACCHIA, CAMILLO**
University of Rochester School of
Medicine and Dentistry
Rochester, New York 14642
- PESTKA, SIDNEY**
Roche Institute of Molecular
Biology
Nutley, New Jersey 07110
- PETERMANN, MARY L.**
Memorial Sloan-Kettering Cancer
Center
New York, New York 10021
- PETERS, THEODORE, JR.**
Mary Imogene Bassett Hospital
Cooperstown, New York 13326
- PHILLIPS, PHILIP G.**
Dartmouth Medical School
Hanover, New Hampshire 03755
- PLUMMER, THOMAS H., JR.**
State of New York Department of
Health
Albany, New York 12201
- POLLARD, HARVEY B.**
NIH, National Institute of Child
Health and Human Development
Bethesda, Maryland 20014
- POOLE, BRIAN**
Rockefeller University
New York, New York 10021
- PORTER, KEITH R.**
University of Colorado
Boulder, Colorado 80302
- POSTE, GEORGE**
Roswell Park Memorial Institute
Buffalo, New York 14263
- PRESCOTT, DAVID M.**
University of Colorado
Boulder, Colorado 80302
- PROSSER, C. LADD**
University of Illinois
Urbana, Illinois 61801
- PUCK, THEODORE T.**
Eleanor Roosevelt Institute for
Cancer Research
Denver, Colorado 80220
- PUMPER, ROBERT W.**
University of Illinois Medical Center
Chicago, Illinois 60680
- RABINOWITZ, MURRAY**
University of Chicago
Chicago, Illinois 60637
- RACKER, EPHRAIM**
Cornell University
Ithaca, New York 14853
- RAJBHANDARY, U. L.**
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
- RAO, POTU N.**
University of Texas System Cancer
Center
Houston, Texas 77025
- RASCH, ELLEN M.**
Marquette University
Milwaukee, Wisconsin 53233
- REDMAN, C. M.**
New York Blood Center
New York, New York 10021
- RENDON, ALVARO**
University of California
Berkeley, California 94720
- RICH, ALEXANDER**
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
- RIFKIN, DANIEL B.**
Rockefeller University
New York, New York 10021
- RIS, HANS**
University of Wisconsin
Madison, Wisconsin 53706
- ROBINSON, D.**
Queen Elizabeth College
London, W8 7AH, England
- ROBINSON, BRIAN H.**
Hospital for Sick Children
Toronto, Ontario, M5G 1X8, Canada
- ROUGHAN, P. G.**
Plant Physiology Division, DSIR
Palmerston North, New Zealand
- RUDDLE, FRANK H.**
Yale University
New Haven, Connecticut 06520
- RUSSELL, JOHN M.**
University of Texas Medical Branch
Galveston, Texas 77550
- RUTTER, WILLIAM J.**
University of California School of
Medicine
San Francisco, California 94143
- SAMBROOK, JOE**
Cold Spring Harbor Laboratory
Cold Spring Harbor, New York 11724

- SANFORD, KATHERINE K.
NIH, National Cancer Institute
Bethesda, Maryland 20014
- SARTORELLI, ALAN C.
Yale University School of Medicine
New Haven, Connecticut 06510
- SASAME, HENRY
NIH, National Heart and Lung Institute
Bethesda, Maryland 20014
- SCHAEFFER, WARREN I.
University of Vermont College of
Medicine
Burlington, Vermont 05401
- SCHATZ, GOTTFRIED
University of Basel
CH-4056 Basel, Switzerland
- SCHEELE, GEORGE A.
Rockefeller University
New York, New York 10021
- SCHIFFER, LEWIS M.
Allegheny General Hospital
Pittsburgh, Pennsylvania 15212
- SCHIMKE, ROBERT T.
Stanford University
Stanford, California 94305
- SCHIMMEL, PAUL R.
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
- SCHMALZ, PHILIP
Mayo Foundation
Rochester, Minnesota 55901
- SCHNEIDER, WALTER C.
NIH, National Cancer Institute
Bethesda, Maryland 20014
- SEAMAN, G. V. F.
University of Oregon Health Sciences
Center
Portland, Oregon 97201
- SELA, MICHAEL
Weizmann Institute of Science
Rehovot, Israel
- SHA'AFI, RAMADAN I.
University of Connecticut School
of Medicine
Farmington, Connecticut 06032
- SHANNON, JOHN E.
American Type Culture Collection
Rockville, Maryland 20852
- SHAPIRO, HERMAN S.
New Jersey Medical School
Newark, New Jersey 07103
- SHAW, DUNCAN J.
Liverpool Polytechnic
Liverpool, L3 3AF, England
- SHIPMAN, CHARLES, JR.
University of Michigan
Ann Arbor, Michigan 48104
- SIEBERT, GÜNTHER
Hohenheim University
D-7 Stuttgart 70, Germany
- SIEKEVITZ, PHILIP
Rockefeller University
New York, New York 10021
- SINCLAIR, W. K.
Argonne National Laboratory
Argonne, Illinois 60439
- SINGER, S. J.
University of California
La Jolla, California 92037
- SISKEN, JESSE E.
University of Kentucky College of
Medicine
Lexington, Kentucky 40506
- SJODIN, RAYMOND A.
University of Maryland School of
Medicine
Baltimore, Maryland 21201
- SLACK, C. R.
Plant Physiology Division, DSIR
Palmerston North, New Zealand
- SLY, WILLIAM S.
Washington University School of
Medicine
St. Louis, Missouri 63110
- SMITH, JAMES R.
W. Alton Jones Cell Science Center
Lake Placid, New York 12946
- SÖLL, DIETER
Yale University
New Haven, Connecticut 06520
- SPICER, S. S.
Medical University of South Carolina
Charleston, South Carolina 29401
- SPITZNAGEL, JOHN K.
University of North Carolina School
of Medicine
Chapel Hill, North Carolina 27514
- STAEHELIN, L. ANDREW
University of Colorado
Boulder, Colorado 80302
- STECK, THEODORE L.
University of Chicago
Chicago, Illinois 60637
- STEIN, GARY S.
University of Florida
Gainesville, Florida 32610
- STEIN, JANET L.
University of Florida
Gainesville, Florida 32610
- STRITTMATTER, PHILIPP
University of Connecticut Health
Center
Farmington, Connecticut 06032
- STUMPF, P. K.
University of California
Davis, California 95616
- STURGESS, JENNIFER M.
Hospital for Sick Children
Toronto, Ontario, M5G 1X8, Canada
- SUNG, S. C.
University of British Columbia
Vancouver, British Columbia, V6T 1W5,
Canada
- SUTERA, S. P.
Washington University
St. Louis, Missouri 63130
- SUYAMA, YOSHITAKA
University of Pennsylvania
Philadelphia, Pennsylvania 19174
- SUZUKI, KUNIIHIKO
Albert Einstein College of Medicine
Bronx, New York 10461
- SZER, WLODZIMIERZ
New York University Medical Center
New York, New York 10016
- SZURSZEWski, JOSEPH H.
Mayo Foundation
Rochester, Minnesota 55901
- TAGER, J. M.
University of Amsterdam
Amsterdam-C, Netherlands
- TAMAOKI, TAIKI
University of Alberta Cancer
Research Unit
Edmonton, Alberta, T6G 2E1, Canada
- TAYLOR, WILLIAM G.
NIH, National Cancer Institute
Bethesda, Maryland 20014
- TEMIN, HOWARD M.
McArdle Laboratory for Cancer
Research
Madison, Wisconsin 53706
- THACH, ROBERT E.
Washington University School of
Medicine
St. Louis, Missouri 63110
- TISCHLER, MARC E.
University of Pennsylvania School
of Medicine
Philadelphia, Pennsylvania 19174
- TOBEY, ROBERT A.
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87544
- TODD, PAUL
Pennsylvania State University
University Park, Pennsylvania 16802
- TOLMACH, L. J.
Washington University School of
Medicine
St. Louis, Missouri 63110
- TRAMS, EBERHARD G.
NIH, National Institute of Neuro-
logical Diseases and Stroke
Bethesda, Maryland 20014
- TROUET, A.
Catholic University of Louvain
B-1200 Brussels, Belgium

- VAN ETEN, JAMES L.**
University of Nebraska
Lincoln, Nebraska 68503
- VAN HOOF, FR.**
Catholic University of Louvain
B-1200 Brussels, Belgium
- VAN'T HOF, JACK**
Brookhaven National Laboratory
Upton, Long Island, New York 11973
- VEECH, R. L.**
St. Elizabeths Hospital
Washington, D.C. 20032
- VIDALI, GIORGIO**
Rockefeller University
New York, New York 10021
- VIGNAIS, PAULETTE**
Centre d'Études Nucléaires
38041 Grenoble Cedex, France
- VIGNAIS, PIERRE**
Centre d'Études Nucléaires
38041 Grenoble Cedex, France
- VIVEROS, O. HUMBERTO**
National Institute of Mental Health
Bethesda, Maryland 20014
- WANG, TUNG YUE**
State University of New York
Buffalo, New York 14214
- WATLINGTON, C. O.**
Medical College of Virginia
Richmond, Virginia 23298
- WAYMOUTH, CHARITY**
Jackson Laboratory
Bar Harbor, Maine 04609
- WEBSTER, PETER L.**
University of Massachusetts
Amherst, Massachusetts 01002
- WEIHING, ROBERT R.**
Worcester Foundation for Experimental Biology
Shrewsbury, Massachusetts 01545
- WEINTRAUB, HAROLD**
Princeton University
Princeton, New Jersey 08540
- WEISBLUM, BERNARD**
University of Wisconsin Medical Center
Madison, Wisconsin 53706
- WEISENBERG, RICHARD**
Temple University
Philadelphia, Pennsylvania 19122
- WEISS, LEONARD**
Roswell Park Memorial Institute
Buffalo, New York 14203
- WEISSMANN, GERALD**
New York University Medical Center
New York, New York 10016
- WERNER, GERHARD**
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania 15213
- WHITE, DAVID**
University of Nottingham Medical School
Nottingham, NG7 2UH, England
- WHITMORE, G. F.**
Ontario Cancer Institute
Toronto, Ontario, M4X 1K9, Canada
- WILLIAMS, G. R.**
University of Toronto
Toronto, Ontario, M5S 1A8, Canada
- WILLIAMSON, JOHN R.**
University of Pennsylvania School of Medicine
Philadelphia, Pennsylvania 19174
- WILSON, DAVID F.**
University of Pennsylvania School of Medicine
Philadelphia, Pennsylvania 19174
- WOLSTENHOLME, DAVID R.**
University of Utah
Salt Lake City, Utah 84112
- WOOL, IRA G.**
University of Chicago
Chicago, Illinois 60637
- WRIGHT, ERNEST M.**
University of California School of Medicine
Los Angeles, California 90024
- ZIMMERMAN, ARTHUR M.**
University of Toronto
Toronto, Ontario, M5S 1A1, Canada
- ZIMMERMAN, STUART**
University of Texas System Cancer Center
Houston, Texas 77025
- ZINDER, OREN**
NIH, National Institute of Child Health and Human Development
Bethesda, Maryland 20014
- ZURIER, ROBERT B.**
University of Connecticut School of Medicine
Farmington, Connecticut 06032

INTRODUCTION

CELL BIOLOGY is volume I in a new series of Biological Handbooks. Each volume will be devoted to the presentation of reference data on a discrete subject of vital importance to investigators, teachers, and students. Present plans are for the production of one such volume per year.

Contents and Review

CELL BIOLOGY is arranged in seven sections with the material organized in the form of 102 tables of quantitative and descriptive data. In addition, two appendixes of animal and plant names are included. Contents of this volume were authenticated by 340 outstanding experts in the fields of biology and medicine. The review process to which the data were subjected was designed to eliminate, insofar as possible, material of questionable validity and errors of transcription.

Headnote

An explanatory headnote, serving as an introduction to the subject matter, may precede a table. More frequently, tables are prefaced by a short headnote containing such important information as units of measurement, abbreviations, definitions, and estimate of the range of variation. To interpret the data, it is essential to read the related headnote.

Exceptions

Occasionally, differences in values for the same specifications, certain inconsistencies in nomenclature, and some overlapping of coverage may occur among tables. These result, not from oversight or failure to choose between alternatives, but from a deliberate intent to respect the judgment and preferences of the individual contributors.

Conventions and Terminology

The main conventions used throughout this volume were adapted from the third edition of the *CBE Style Manual*, published in 1972 for the Council of Biology Editors by the American Institute of Biological Sciences. Terminology was checked against *Webster's Third New International Dictionary*, published in 1961 by G. & C. Merriam Company.

Contributors and References

Appended to the tables are the names of the contributors,

and a list of the literature citations arranged in alphabetical sequence. The reference abbreviations conform to those in the *Bibliographic Guide for Editors and Authors*, published by The American Chemical Society in 1974.

Cell Lines and Enzyme Nomenclature

Animal cell lines having CCL (Certified Cell Line) numbers are registered in the American Type Culture Collection (ATCC), and have been confirmed in the second edition of the *Registry of Animal Cell Lines* published in 1972 by the ATCC.

Enzyme names and Enzyme Commission numbers were verified in *Enzyme Nomenclature*, the 1972 recommendations of the Commission on Biochemical Nomenclature, published by Elsevier Scientific Publishing Company for the International Union of Pure and Applied Chemistry and the International Union of Biochemistry.

Scientific Names

In the tables, a synonym following the scientific name of an organism indicates that the synonym, although cited in the reference, is no longer the preferred name. No other attempt was made to provide taxonomic synonymy. All scientific names were either verified in standard taxonomic checklists and classification lists, or submitted for authentication to the appropriate authorities at the Smithsonian Institution's National Museum of Natural History, the U.S. Department of Agriculture, or the American Type Culture Collection.

To aid the user in identifying an organism, the index includes the taxonomic orders for animals, and the families for plants. Two appendixes provide cross-reference to scientific and equivalent common names occurring in this volume.

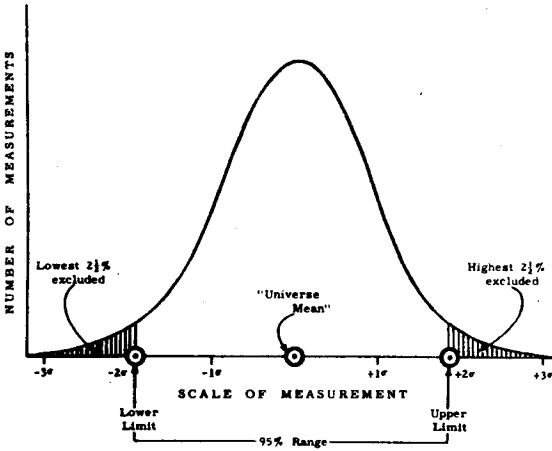
Range of Variation

Values are generally presented as either the mean plus and minus the standard deviation, or the mean and the lower and upper limit of the range of individual values about the mean (either observed or statistical). Usually, it is of greater importance that the range be given rather than the mean. The several methods used to estimate the range—depending on the information available—are designated by the

continued

letters "a, b, c, or d" to identify the type of range in descending order of accuracy.

"a"—When the group of values is relatively large, a 95% range is derived by curve fitting. A recognized type of nor-



mal frequency curve is fitted to a group of measured values, and the extreme 2.5% of the area under the curve at each end is excluded (see illustration).

"b"—When the group of values is too small for curve fitting, as is usually the case, a 95% range is estimated by a simple statistical calculation. Assuming a normal symmetrical distribution, the standard deviation is multiplied by a factor of 2, then subtracted from and added to the mean to give the lower and upper range limits.

"c"—A less dependable, but commonly applied, procedure takes as range limits the lowest value and the highest value of the reported sample group of measurements. It underestimates the 95% range for small samples and overestimates for larger sample sizes, but where there is marked asymmetry in the position of the mean within the sample range, this method may be used in preference to the preceding one.

"d"—Another estimate of the lower and upper limits of the range of variation is based on the judgment of an individual experienced in measuring the quantity in question.

CELL BIOLOGY

CONTENTS

INTRODUCTION	xvii
------------------------	------

ABBREVIATIONS AND SYMBOLS	xix
-------------------------------------	-----

I. GENERAL CELL CHARACTERISTICS

Introduction	1
1. Diploid Chromosome Numbers of Mammals	2
2. Human Karyotype	9
3. Computer-analyzed Transit Times for Vertebrate Cell Cycle and Phases	11
4. Generation Times and Cell Cycle Parameters for Mammalian Cells in Culture	13
5. Doubling Times of Frequently Used Mammalian Cell Lines and Strains	15
6. Mitotic Indices for Mammalian Tissues	16
7. Dimensions of Vertebrate Cells	23
8. Effects of Drugs and Research Biochemicals on Cycling Animal and Plant Cells In Vivo	25
9. Inactivation of Feeder Layers of Mammalian Cells with Ionizing Radiation	27
10. Nutritional Mutants of Mammalian Cell Lines In Vitro	28

II. CELL ENVIRONMENT

Introduction	31
11. Low-Passage Human Skin Fibroblast Lines in the ATCC Repository	32
12. ATCC Characterized Reference Animal Cell Lines	32
Part I. Man	33
Part II. Mouse	38
Part III. Other Mammals	40
Part IV. Other Vertebrates and Insects	43
13. Routine Characterizations and Quality Control Tests Performed on Reference Animal Cell Lines	45
14. Freezing Procedures for the Preservation of Animal Cell Cultures in Liquid Nitrogen	46
15. Enzymes Used for Disaggregation of Tissue to Obtain Viable Cells	46
16. Procedures for Isolation, Identification, and Enzyme Activities of Liver Cells	48
17. Various Proposed Functions of Serum on Cells	50
18. Hormonal Content of Various Serums Used in Cell Cultivation In Vitro	51
19. Media Useful in Cloning Cells	52
20. Synthetic Hydrogen Ion Buffers for Tissue Culture	55
21. Theoretical Titration Curves at 37°C for HEPES and NaHCO ₃	57
22. Effects of Temperature on Cell Division	58
Part I. Various Phases of the Cell Cycle: Mammalian Cells	58
Part II. Various Stages of Mitosis: Rat Yoshida Sarcoma	58
Part III. Longevity in Culture: Human Diploid Fibroblasts (MRC-5)	58
23. Effects of Carbon Dioxide Concentrations on Vertebrate Cell Tissue Culture	59
24. Balanced Salt Solutions for Animal Tissues	61
25. Constituents of Synthetic Culture Media for Animal Tissues	63
Part I. General Purpose Media	64
Part II. Special Purpose Media	68
26. Oxygen Consumption of Mammalian Tissues	72

III. CELL PERIPHERY

Introduction	91
27. Preparative Procedures for Mammalian Surface Membranes	92
28. Enzyme Activity in Plasma Membranes of Mammalian Tissues and Cultured Cells	95
29. Chemistry of Antigenic Groups	98