Biological
Handbooks

Blood and Other Body Fluids

ANALYSIS AND COMPILATION BY Philip L. Altman

EDITED BY Dorothy S. Dittmer

PREPARED UNDER THE AUSPICES OF THE Committee on Biological Handbooks

Federation of American Societies for Experimental Biology

WASHINGTON, D. C.

MADE IN THE UNITED STATES OF AMERICA

Library of Congress Catalog Card Number: 61-12371

Foreword

Blood and Other Body Fluids is the first of the biological handbooks to appear under the general direction of the Committee on Biological Handbooks, Federation of American Societies for Experimental Biology. This volume, however, does not inaugurate a new series, but is in fact a continuation of the handbooks prepared under the auspices of the National Academy of Sciences - National Research Council.*

The contents and contributors for this compilation were determined with the approval of the Advisory Committee on Blood and Other Body Fluids. After the data were analyzed, compiled, and edited by the Handbook Office staff, they were submitted for review to the contributors and other authorities in the areas covered in this volume.

On behalf of the Committee on Biological Handbooks, acknowledgement is made to the numerous scientists who have been so liberal with their time and advice, and to the National Institutes of Health, the National Science Foundation, and Wright Air Development Division of the United States Air Force for the generous support and co-operation which have made possible the production of this book. Participation in this undertaking was fulfilled under National Institutes of Health Grant No. RG-6553, National Science Foundation Grant No. NSF-G11180, and Air Force Contract No. AF 33(616)-6773.

---

* Previous publications in the Biological Handbooks Series

Standard Values in Blood	1952	Handbook of Toxicology:	
Standard Values in Nutrition and Metabolism	1954	Volume I, Acute Toxicities	1955
Handbook of Biological Data	1956	Volume II, Antibodies	1957
Handbook of Respiration	1958	Volume III, Insecticides	1959
Handbook of Circulation	1959	Volume IV, Tranquilizers	1959
		Volume V, Fungicides	1959

Contributors and Reviewers

Aballi, Arturo J.
Abood, L. G.
Adler, Harry F.
Adolph, E. F.
Alexander, James K.
Allen, Fred H., Jr.
Allison, James B.
Alt, Howard L.
Altland, Paul D.
Altschule, Mark D.
Asdell, S. A.
Assali, N. S.

Babers, Frank H.
Bacchus, Habeeb
Baez, Silvio
Ballintine, Elmer J.
Barker, J. N.
Barnett, Henry L.
Barron, Donald H.
Bartels, Heinz
Bass, David E.
Battaglia, Frederick C.
Bauer, Walter
Beatty, Clarissa H.
Beerstecher, Ernest, Jr.
Behnke, Albert R.
Bergeim, Olaf
Berliner, Robert W.
Berman, Lawrence
Best, Charles H.
*Bethell, Frank H.
Bing, Richard J.
Bischoff, Fritz E.
Bishop, David W.
Bitman, Joel
Block, Matthew
Block, Richard J.
Bonnycastle, Desmond D.
Booker, Walter M.
Boolootian, Richard A.
Bowman, Russel O.
Brecher, George
Brinkhous, K. M.
Britton, C. J. C.
Brodsky, William A.
Broun, Goronwy O.
Brown, Ellen
Brown, Royal L.
Brun, Robert
Buck, John B.

Calcagno, Philip L.
Carlsen, Elizabeth
Cartwright, G. E.
Catchpole, H. R.
Caton, William L.
Chaikoff, I. L.
Chance, Britton
Chanutin, Alfred
Chaplin, Hugh, Jr.
Chesley, Leon C.
Cohagen, D. L.
Cole, Warren H.
Collier, H. B.

Conklin, Ruth E.
Coon, William W.
Cotlove, Ernest
Cournand, Andre
Courtice, F. C.
*Craige, A. H., Jr.
Cronkite, Eugene P.
Cumings, J. N.
Cummins, Alvin J.

Darling, Robert C.
Das, Jogananda
Davidsohn, Israel
Davis, Hallowell
*De Beer, Edwin J.
DeLalla, Oliver F.
DeMarsh, Q. B.
Denstedt, Orville F.
Dessauer, Herbert C.
Deutsch, Harold F.
Diggs, L. W.
Dill, D. B.
Dische, Zacharias
Doan, Charles A.
Dole, Vincent P.
Doran, David J.
Dugdale, Marion
Duke-Elder, W. Stewart
Duncan, C. W.
Dunlap, J. S.

Eastham, M. D.
Ebaugh, Franklin G., Jr.
Ebert, Richard V.
Edsall, John T.
Eichelberger, Lillian
Elliott, K. A. C.
Endicott, Kenneth M.
Engel, Frank L.
Erdoes, Ervin
Escoffier-Lambiotte, C.
Everett, Newton B.
Eversole, W. J.

Feldman, Joseph D.
Ferguson, John H.
Finch, Clement A.
Fine, Jacob
Fingerman, Milton
Fisk, Albert A.
Fitts, William T., Jr.
Flock, Eunice V.
Foord, Alvin G.
Forbes, Thomas R.
Forbes, William H.
Forrest, Andrew P. M.
Frank, Howard A.
Frazer, A. C.
Freeman, Smith
Fregly, Melvin J.
Friedman, J. J.

Gabrio, Beverly W.
Gamble, Clarence J.
Gaudino, Mario
Giere, Frederic A.
Glaser, Kurt
Gofman, John W.
Goldstein, Leon
Goodyer, Allan V. N.
Grad, Bernard
Gram, H. C.
Granick, S.
Guest, George M.
Guest, M. Mason
Gutman, Alexander B.

Hallpike, C. S.
Hamilton, Paul B.
Hamre, Christopher J.
Handler, Philip
Handley, Charles O., Jr.
Hansard, Sam L.
Hansel, William
Hardenbergh, Esther
Harrell, George T.
Harris, John E.
Hart, J. Sanford
Hastings, A. Baird
Heath, Clark Wright
Hegnauer, A. H.
Hellman, Louis M.
Hendry, E. B.
Henschel, Austin
Hernandez, Thomas
Hetzer, Herbert O.
Hiatt, Edwin P.
Hickam, John B.
Hier, Stanley W.
Hill, Robert M.
Hilpert, Peter
Himwich, Williamina A.
Hinman, Frank, Jr.
Hirschboeck, John S.
Hoch, Hans
Holaday, Duncan A.
Hollander, Franklin
Holman, H. H.
Hubbard, Ruth
Huckabee, William E.
Huffman, C. F.
Hunt, J. N.
Hunter, F. R.
Hunter, George
Hunter, John
Hurtado, Alberto
Hutton, Kenneth E.

Ingram, Marylou
Irvin, J. Logan
Israëls, M. C. G.

Jaques, L. B.
Jones, Jack Colvard
Jones, Oliver P.

Kabat, Elvin A.
Kaiser, Irwin H.
Kanter, Gerald S.
Kelly, Harriet J.

*Deceased

Kerr, Stanley E.
Keys, Ancel
Kirk, John E.
Kisch, Bruno
Klein, J. Raymond
Klingman, Walter O.
Koelle, George B.
Koenig, Virgil L.
Korman, Henry
Krause, Arlington C.
Krupp, Marcus A.
Kvorning, Sven Ancher

Langham, Maurice E.
Largent, Edward J.
Larson, Daniel L.
Lasker, Reuben
Lauber, Frances U.
Lauson, Henry D.
LeBrie, Stephen J.
Lehninger, Albert L.
Leopold, Irving H.
Levenstein, Irving
Levey, Stanley
Levine, Philip
Levine, Victor E.
Lewis, Howard B.
Lewis, Jessica H.
Liebowitz, Daniel
Limarzi, Louis R.
Livermore, George R., Jr.
Logan, J. E.
Looney, Joseph M.
Lorincz, Allan L.
Lotspeich, W. D.
Love, R. Malcolm
Lucas, Miriam Scott
Lucia, Salvatore P.
Luckey, T. D.
Ludwig, Daniel
Luft, Ulrich C.
Lundquist, Frank

Macy, Icie G.
Manery, J. F.
Mann, George V.
Mann, T.
Manwell, Clyde
Marbarger, John P.
Martin, Arthur W.
Mayerson, H. S.
McCartney, M. G.
McCutcheon, F. Harold
McKenzie, Fred F.
Meister, Alton
Mendlowitz, Milton
Miller, John H.
Mirsky, I. Arthur
Monkhouse, Frank C.
Moore, Dan H.
Morales, Daniel R.
Mulligan, Richard M.
Musacchia, X. J.
Muus, Jytte

Naumann, Hans N.
Neiland, Kenneth A.
Nesbitt, Robert E. L., Jr.
Niedermeier, William

Notkin, Louis J.

Oberholzer, R.
Okunzua, G.
*Opitz, E.
Osgood, Edwin E.
Overman, R. R.
Owen, Charles A.
Owren, Paul A.

Page, Irvine H.
Paschkis, Karl E.
Patton, Robert L.
Pearson, William N.
Penrod, Kenneth E.
Perlman, H. B.
Peschel, Ernst
Petermann, Mary L.
Platner, W. S.
Platt, David
Ponder, Eric
Prosser, C. Ladd
Prystowsky, Harry

Quick, Armand J.

Radford, Edward P., Jr.
Randall, Walter C.
Rebuck, John W.
Redmond, James R.
Reinhardt, William O.
Rekers, Paul E.
Reynolds, Monica
Ridley, Frederick
Riegel, Klaus
Rigdon, R. H.
Riser, William H., Jr.
Roberts, Sidney
Robertson, James D.
Rodbard, Simon
Rogers, W. P.
Root, Raymond W.
Rooth, Gösta
Ropes, Marian W.
Rossiter, Roger J.
Roth, James L. A.
Rothman, Stephen
Rubin, Mitchell I.

Sabine, Jean C.
Sammons, H. G.
Samuels, Leo T.
Savel, Jean
Sayers, George
Schaefer, Karl E.
Schafer, David E.
Schechtman, A. M.
Scheer, Bradley T.
Scheinberg, Peritz
Schmid, Karl
Schmidt-Nielsen, Knut
Schwartz, Irving L.
Schweigert, B. S.
Seegers, Walter H.
Selkurt, Ewald E.
Senior, John
Severinghaus, John W.
Shaffner, C. S.
Share, Leonard

Singer, Richard B.
Sizer, Irwin W
Skaug, Odvar
Skoryna, Stanley C.
Smith, Catherine A.
Smith, Clement A.
Smith, Ralph I.
Smyth, J. D.
Sokoloff, Leon
Spangler, S.
Spicer, Samuel S.
Stasney, Joseph
Stearner, S. Phyllis
Stearns, Genevieve
Steele, Betty F.
Stefanini, Mario
Stickney, J. Clifford
Stone, Alan
Stowe, Clarence M., Jr.
Sundberg, R. Dorothy
Surgenor, Douglas M.

Tcherdakoff, Philippe
Thomas, J. Earl
Thorson, Thomas B.
Tietz, Norbert W.
Tocantins, Leandro M.
Tompkins, Edna H.
Travis, Dorothy F.
Tromba, Francis G.
Truter, E. V.

Van Drimmelen, G. C.
Van Pilsum, John F.
Van Slyke, Donald D.
Vaughan, Stuart L.
Venning, Eleanor H.
Visscher, Maurice B.
Von Euler, U. S.

Ware, Arnold G.
Warner, E. D.
Wasserman, Karl
Webster, Donald R.
Wedgwood, Ralph J.
Weil, William B., Jr.
Wesson, Laurence G., Jr.
West, Clark D.
Wheatley, Victor R.
White, I. G.
Whitehorn, W. V.
Wiener, Alexander S.
Wiggers, Carl J.
Wilber, Charles G.
Wilson, D. Wright
Windle, William F.
Wintrobe, M. M.
Winzler, Richard J.
Wirtschafter, Z. T.
Wise, John P.
Wroblewski, Felix
Wu, S. H.
Wyatt, Gerard R.

Yoffey, J. M.
Young, I. Maureen

Zarrow, M. X.
Zwemer, Raymund L.

*Deceased

Introduction

This handbook, which includes a revision of Standard Values in Blood published in 1952, presents comprehensive data on blood and other body fluids specifically compiled for reference purposes. The material is conveniently organized in the form of tables, graphs, diagrams, nomograms, and line charts. Most of the tables have been prepared especially for the Biological Handbooks Series from various authoritative collections of data and from the current literature. Contents of the volume have been authenticated by 380 leading investigators in the fields of biology and medicine. The review process to which the tables have been subjected was designed to eliminate, insofar as possible, errors of transcription and material of questionable validity.

For the convenience of the user, the tables have been arranged in 25 sections. An explanatory headnote, designed to serve as an introduction to the subject matter, occasionally precedes the tables in a section. Individual tables may be 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, reading of the related headnote is essential.

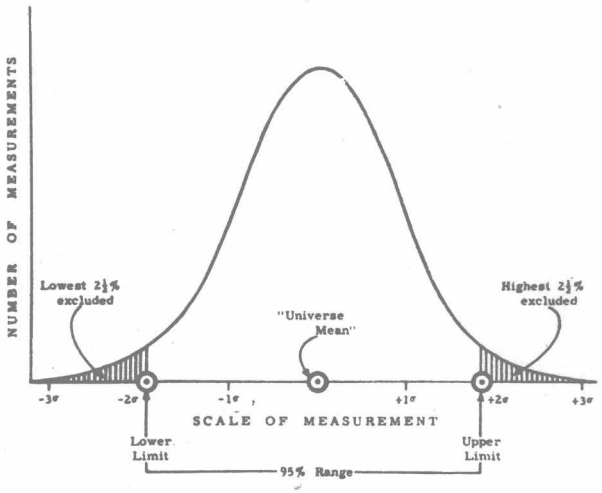
On occasion, differences in values for the same specifications, certain inconsistencies in nomenclature, and some overlapping of coverage may occur among tables. These result not from oversights or failure to choose between alternatives, but from the deliberate intention of the handbook staff to respect the judgment and preferences of the contributor. Although units of measurement may vary within a table, values can be converted by using the information given in APPENDIX I: CONVERSION FACTORS AND FORMULAS.

Appended to the tables are the names of the contributors, and a list of the literature citations arranged in alphabetical order. The reference abbreviations conform to the LIST OF ABBREVIATIONS FOR SERIAL PUBLICATIONS, Fourth Series, Volume X, Army Medical Library, Washington, D. C. (U. S. Government Printing Office, 1948), and the 1955 SUPPLEMENT thereto. Abbreviations for new or unlisted publications were constructed from the "Dictionary of Abbreviated and Contracted Words" in the SYNOPSIS OF STYLE, Fourth Series, Volume II, Army Medical Library, Washington, D. C. (U. S. Government Printing Office, 1937).

It is suggested that the table of contents be used in conjunction with the index: the table of contents to determine the scope of the data for a particular fluid, and the index to locate a specific constituent, property, or animal. Because of the animal nomenclature used in the tables, the index lists vertebrates by common name and invertebrates according to genus.

Values are generally presented as a mean and the lower and upper limit of the range of individual values about the mean. This range may be estimated in several ways, the method depending on the information available. Letter designations (a, b, c, d) identify types of ranges 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 normal 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 may be used in preference to the preceding method where there is marked asymmetry in the position of the mean within the sample range.

(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. The trustworthiness of such limits should not be underestimated.

Abbreviations and Symbols

MEASUREMENT

yr = year
mo = month
wk = week
da = day
hr = hour
min = minute
sec = second

wt = weight
lb = pound
g = gram
kg = kilogram
mg = milligram
μg = microgram
μμg = micromicrogram
mEq = milliequivalent
μEq = microequivalent
M = mole
gM = gram-mole
mM = millimole
μM = micromole
mOsm = milliosmole

ht = height
mi = mile
ft = foot
in. = inch
m = meter
cm = centimeter
mm = millimeter
μ = micron
mμ = millimicron

sq in. = square inch
sq m = square meter
sq cm = square centimeter
sq mm = square millimeter
sq μ = square micron

L = liter
ml = milliliter
μL = microliter
cu cm = cubic centimeter
cu mm = cubic millimeter
cu μ = cubic micror

v = volt
kv = kilovolt
mv = millivolt
mho = conductance unit (reciprocal of resistance in ohms)

IU = international unit
ppm = parts per million
rpm = revolutions per minute
av = average

sat % = saturation per cent
vol % = volumes per cent
g % = grams per cent
mg % = milligrams per cent

g-cal = gram-calorie
kg-cal = kilogram-calorie

^{o}C = degree Centigrade
^{o}F = degree Fahrenheit
> = greater than
< = less than
σ = standard deviation

BIOLOGICAL SPECIFICATION

Hb = hemoglobin
RBC = red blood cell (erythrocyte)
WBC = white blood cell (leukocyte)
CSF = cerebrospinal fluid

STP = standard temperature and pressure
sp = species
♂ = male
♀ = female

Contents

IV. BLOOD LIPIDS, CARBOHYDRATES, MISCELLANEOUS ORGANIC ACIDS

V. BLOOD VITAMINS, HORMONES, ENZYMES

VI. BLOOD CELLS

VII. BLOOD OXYGEN DISSOCIATION

VIII. BLOOD ARTERIOVENOUS DIFFERENCES

IX. BLOOD ACID-BASE BALANCE

X. BLOOD CHANGES

XI. BLOOD COAGULATION

XII. BLOOD GROUPS

XIII. HEMOLYMPH

VIII. BLOOD ARTERIOVENOUS DIFFERENCES

IX. BLOOD ACID-BASE BALANCE

X. BLOOD CHANGES

XIV. LYMPH

XV. CEREBROSPINAL FLUID

XVI. NERVE ELECTROLYTES AND WATER CONTENT

XVII. FLUIDS OF BODY CAVITIES

XVIII. BODY WATER

XIX. URINE

XX. DIGESTIVE SECRETIONS

XXI. REPRODUCTIVE SECRETIONS

XXII. FLUIDS DURING PREGNANCY

XXIII. MILK

XXIV. DERMAL SECRETIONS

XXV. FLUIDS OF EAR AND EYE

APPENDIXES

I. Blood Physical Properties and General Chemical Components

1. BLOOD VOLUMES

For a summary of blood methods and interpretations, consult reference 10, Part I.

Part I: MAN

Subjects were unanesthetized, predominantly white adults (normal individuals or hospital controls), under average environmental temperature (22-28°C) and sea-level barometric pressure conditions. Number of determinations is the same as the number of subjects, unless otherwise indicated. Plasma and erythrocyte volumes were obtained by various dilution methods, the diluent or tagging substance being given in the pertinent method column. A tagging substance listed under erythrocyte volume (column E) indicates that cell volume was determined after in vivo dilution of the tagged cells, either by counting radioactivity of washed or dried cells, or by multiplying radioactivity of whole blood by venous or arterial hematocrit uncorrected for trapped plasma. Venous hematocrit values were obtained by centrifuging the blood sample (3000 rpm, 30 minutes, 18 cm radius) and were not corrected for trapped plasma, unless otherwise specified. In most instances, whole blood volume was calculated from other values in the same study; where a tagging substance is given in column H, blood volume was determined directly by dilution of the tagged erythrocytes in whole blood, on the assumption that the erythrocyte concentration in the sampled blood represented the total body erythrocyte concentration. Method (columns C and H): PV = plasma volume, EV = erythrocyte volume, VH = venous hematocrit, BV = whole blood volume. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Subjects		Plasma Volume		Erythrocyte Volume		Venous Hematocrit % cells	Whole Blood Volume		Reference
	Sex	No.	Method	ml/kg body wt	Method	ml/kg body wt		Method	ml/kg body wt	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Male	30	T-1824	41.1	P^{32}	28.0[1]		PV + EV	69.1	23
2		40	T-1824	47.9 (39.2-62.5)	Fe^{55} or Fe^{59}	29.8 (21.5-36.3)		PV + EV	77.7 (63.8-97.0)	7
3		20	T-1824	45.7 (35.8-56.5)			44.1 (39.3-49.4)	$\frac{PV}{100 - VH} \times 100$	81.6 (65.4-95.2)	29
4		49	T-1824	43.1 (32.0-58.2)			44.7 (36.0-51.8)[2]	$\frac{PV}{100 - VH} \times 100$	77.7 (62.7-97.7)	6
5		11	T-1824	40.5 (28.5-48.2)			47.2 (42.0-53.0)[3]	$\frac{PV}{100 - VH} \times 100$	76.7 (60.5-92.6)	4
6		31	I^{131}, human serum albumin	41.4 (33.6-61.8)			44.1 (34.9-49.0)[4]	$\frac{PV}{100 - VH} \times 100$	74.2 (60.0-96.0)	28
7		53	T-1824	45.6 (31.7-56.5)			44.7[1]	$\frac{PV}{100 - VH} \times 100$	82.3 (59.8-101.7)	9
8		51	T-1824	44.7 (34-58)			45.0[1]	$\frac{PV}{100 - VH} \times 100$	85.1	20
9		32	T-1824	47.4 (36.5-59.7)			42.6 (37.9-49.2)[1]	$\frac{PV}{100 - VH} \times 100$	82.6 (62.2-102.2)	24
10		11	T-1824	47.4 (43.7-61.4)				$\frac{PV}{100 - VH}$[5] $\times 100$	82.8 (72.7-99.4)	12
11		34	T-1824	45.3 (32.4-56.9)			43.5 (39-51)	$\frac{PV}{100 - VH} \times 100$	80.1 (57.5-106.0)	19
12		42			Cr^{51} as sodium chromate	28.2 (20.0-39.8)	45.8 (39.0-54.6)	Cr^{51} as sodium chromate	61.5 (45.9-81.0)	16
13		32[6]	T-1824	45.2 (35.3-55.9)			46.5			14
14		21	Cr^{51} as chromic chloride	39.3 (28.7-48.5)						5
15		59	T-1824	36.7			48.2			11
16		25			Cr^{51} as sodium chromate	31.8 (25.4-38.7)				26

/1/ Hematocrit corrected for trapped plasma by factor of 0.96. /2/ Venous hematocrit calculated from formula: $\frac{\text{reading of packed cells}}{\text{reading of fluid level - 2.0}}$. /3/ Centrifuged until cells completely packed. /4/ Measured by specific gravity (dropping blood into copper sulfate solutions of known density). /5/ Centrifuged at 8000 rpm. and 7.2 cm radius, for 1 hour. /6/ 62 determinations.