

HUMAN BIOLOGY

BY

GEORGE ALFRED BAITSELL

*Colgate Professor of Biology
Fellow of Calhoun College
Yale University*

SECOND EDITION

13.6 + 1/2
B191

McGRAW-HILL BOOK COMPANY, INC.

NEW YORK TORONTO LONDON

1950

HUMAN BIOLOGY

Copyright, 1940, 1950, by the McGraw-Hill Book Company, Inc. Printed in the United States of America. All rights reserved. This book, or parts thereof, may not be reproduced in any form without permission of the publishers.

McGRAW-HILL PUBLICATIONS IN THE
ZOOLOGICAL SCIENCES
E. J. Boell, CONSULTING EDITOR

HUMAN BIOLOGY

McGraw-Hill Publications in the Zoological Sciences

E. J. Boell, CONSULTING EDITOR

- Baitsell* · HUMAN BIOLOGY
Breland · MANUAL OF COMPARATIVE ANATOMY
Chapman · ANIMAL ECOLOGY
Haupt · FUNDAMENTALS OF BIOLOGY
Hyman · THE INVERTEBRATES: PROTOZOA THROUGH CTENOPHORA (Vol. I)
THE INVERTEBRATES: PLATYHELMINTHES AND RHYNCHOCOELA (Vol. II)
THE INVERTEBRATES: ACANTHOCEPHALA, ASCHELMINTHES, AND ENTOPROCTA
(Vol. III)
THE INVERTEBRATES: ECHINODERMATA (Vol. IV)
Leach · FUNCTIONAL ANATOMY OF THE MAMMAL
Mayr, Linsley, and Usinger · METHODS AND PRINCIPLES OF SYSTEMATIC ZOOLOGY
Metcalf and Flint · FUNDAMENTALS OF INSECT LIFE
Mitchell · GENERAL PHYSIOLOGY
Mitchell and Taylor · LABORATORY MANUAL OF GENERAL PHYSIOLOGY
Pearse · ANIMAL ECOLOGY
Quiring · FUNCTIONAL ANATOMY OF THE VERTEBRATES
Rogers · TEXTBOOK OF COMPARATIVE PHYSIOLOGY
Shull · EVOLUTION
Shull · HEREDITY
Shull, LaRue, and Ruthven · PRINCIPLES OF ANIMAL BIOLOGY
Shull, LaRue, and Ruthven · LABORATORY DIRECTIONS IN PRINCIPLES OF ANIMAL
BIOLOGY
Snodgrass · PRINCIPLES OF INSECT MORPHOLOGY
Storer · GENERAL ZOOLOGY
Storer · LABORATORY MANUAL FOR GENERAL ZOOLOGY
Storer and Usinger · ELEMENTS OF ZOOLOGY
Weichert · ANATOMY OF THE CHORDATES
Weichert · ELEMENTS OF CHORDATE ANATOMY
Weichert · REPRESENTATIVE CHORDATES
Welch · LIMNOLOGY
Wieman · AN INTRODUCTION TO VERTEBRATE EMBRYOLOGY
Wolcott · ANIMAL BIOLOGY
Wolcott and Powell · LABORATORY GUIDE IN ANIMAL BIOLOGY
-

There are also the related series of McGraw-Hill Publications in the Botanical Sciences, of which Edmund W. Sinnott is Consulting Editor, and in the Agricultural Sciences, of which R. A. Brink is Consulting Editor.

PREFACE TO THE SECOND EDITION

The favorable reception given to "Human Biology" has made possible the publication of the second edition, and thereby given opportunity for a thorough rewriting and the introduction of new material in the main text and in the Appendix. The primary concerns of the author have been to bring the material up to date and to broaden the field under consideration by additional textual and illustrative material in general biology. The title of the volume might well be "Biology—Human and General." Considerable thought has been given to the selection and preparation of the new material, particularly in the new introductory chapter, which, it is hoped, will help to orient beginners in this field.

The inclusion of additional general material does not indicate any change in the main aim of the text as stated in the first edition, namely, the presentation of "the pertinent facts of biology from the vantage point of man, the most interesting and important organism in the world of life." Several new college texts have recently appeared with the same viewpoint—a fact indicating increasing interest in the human biology approach, following the publication of the first edition in 1940.

Particular mention should be made of the many new illustrations added to this edition, most of them through the generous cooperation of Professor J. W. Buchanan of the University of Southern California, to whom the author is greatly indebted. These drawings originally appeared in Professor Buchanan's "Elements of Biology," published by Harper and Brothers.

The editorial assistance of Yvette Gittleson, assistant editor of the *American Scientist*, has been of the highest value in the preparation of this manuscript, particularly in the extended consideration of the vertebrate nervous system. Jean Day Zallinger has redrawn many figures with special skill and understanding. Editorial and secretarial assistance has been efficiently given by Charlotte B. Emmer, Harriet C. Marsh, Helen K. Sandback, and Elinor R. Smith; and Mrs. Sandback has, as in the first edition, largely carried the heavy burden of the preparation of the Index. To all these and many others the author is glad to extend his sincere thanks.

GEORGE A. BAITSSELL

NEW HAVEN, CONN.
September, 1950

PREFACE TO THE FIRST EDITION

"Human Biology" endeavors to present the pertinent facts of biology from the vantage ground of the most interesting and important organism in the world of life, namely, man. Accordingly, the study of human biology involves a great deal more than human anatomy and physiology; it is essentially a humanizing of general biology in that attention is centered primarily on human structure and function rather than on the characteristics of types selected from the lower organisms.

At least two major factors have influenced the author to devote the time and energy and to submit to the trials and tribulations necessarily associated with writing and publishing a college textbook in biology. First in importance has been the increasing realization, year by year, that the great majority of students beginning work in college biology were, inherently, far more interested in acquiring knowledge about the human organism than they were concerning any other living species. Student interest in any subject is naturally expected to lead to increased endeavor. Nevertheless, the author has frequently been surprised at the efforts voluntarily assumed by interested students in collecting the available information relevant to some structural or functional feature of man. Of first-rate importance in this connection is the fact that scientific data dealing with mammalian physiology and anatomy are available in abundance, possibly to a greater degree than elsewhere in the biological field. Furthermore, this body of scientific knowledge, particularly when associated with the functional aspects of man, is being augmented continuously from the results obtained by many investigators in the best laboratories of this and other countries.

Second, the author has been impressed with the necessity of supplying new and vital material at an advanced level for the basic courses in college biology. Biological knowledge possessed by the students now entering college is undoubtedly greatly superior both in quantity and quality to that of their predecessors. By this is meant that a larger percentage of students take a laboratory course in biology before entering college and that the material presented in these courses is much more extensive than in earlier years. Any college instructor

who takes the trouble to examine the contents of various excellent and widely used biology texts for secondary schools and representative student notebooks covering the year's work in these courses will certainly be convinced that careful consideration must be given to the content of college courses in biology so that the students' interest may not be dulled and their time wasted by the repetitious study of laboratory types which have been carefully considered in an earlier course. Particularly is this condition important to the great majority of college students electing biology, for their major scholastic interests lie elsewhere and they will, therefore, take only one year in the biological field.

The central problem is evident: Shall the incoming students be reintroduced at college levels to a series of more or less standardized biological types, most of which they feel—rightly or wrongly—are well known to them from previous study, or shall the college course be built, for the most part, around materials previously untouched? It seems evident that a biology course in which primary consideration is focused upon the organization and activities of human protoplasm offers new and superior possibilities for the presentation of highly important material and for increasing student interest in the biological field. If the human biology material is presented from a comparative standpoint, the student will learn not only the biology of man but also biology in its broader aspects, for man is a part of, not apart from, the world of life.

One example may be noted. The study of human nutrition cannot be completed until the photosynthetic processes of the green plants and the decay processes of the colorless plants are brought into the picture. The fact that the nutrition of every type of organism depends upon enzyme action gives opportunity for extended consideration of these organic catalysts which are involved in every vital process. And the same condition obtains with the other basic phenomena associated with the living state for, as is generally recognized, organisms perform the same vital functions in essentially the same way. They eat, grow, respire, secrete, excrete, react, and reproduce as a result of the activities of the associated cellular units of which they are composed. Accordingly, it seems evident that to "Know thyself" is not only an important and interesting discipline, but it may also be excellent biology.

In an endeavor to widen the scope of the book, so that the interested student may have abundant material to pursue important fields of interest at advanced levels, an Appendix has been supplied containing

direct quotations from the publications of various authorities. It is hoped that this material will prove to be highly stimulating to instructor and student and, at the same time, provide reference to a noteworthy list of books for additional collateral reading. Original material by the author has also been included in the Appendix when it was felt that its content tended to mar the continuity and appropriate level of the main text.

GEORGE A. BAITSELL

OSBORN ZOOLOGICAL LABORATORY
YALE UNIVERSITY
NEW HAVEN, CONN.
May, 1940

ACKNOWLEDGMENTS

It is a real pleasure to acknowledge the cooperation of the following authors and publishers who have generously granted permission for reproducing copyrighted illustrations and textual material; in all instances the source of material is given in the text or in the legend of the figure:

George Allen & Unwin, Ltd.: "Human Heredity," by Baur, Fischer, and Lenz.

American Book Company: "Biology," by Hunter, Walter, and Hunter.

Appleton-Century-Crofts, Inc.: "Outlines of Evolutionary Biology," by Dendy.

The Blakiston Company: "Animal Biology," by Lane; "Human Anatomy," by Morris; "Comparative Anatomy," by Neal and Rand.

The Chemical Foundation: "Chemistry and Medicine," edited by Dr. J. Stieglitz.

Ginn & Company: "The Human Mechanism," by Hough, Sedgwick, and Waddell, 2d edition revised.

Harcourt, Brace & Company, Inc.: "Exploring Biology," by Smith.

Harper & Brothers: "Elements of Biology," by Buchanan; "Animal Biology," by Guyer; "Science in Health and Disease," by Haggard; "Story of Living Things," by Singer.

Harvard University Press: "Genetics and Eugenics," by Castle.

Henry Holt and Company, Inc.: "Principles of Modern Biology," by Marsland-Plunkett; "The Human Body," by Martin; "General Biology," by Sedgwick and Wilson; "History of the Human Body," by Wilder.

Lea & Febiger: "Principles of Hematology," by Haden.

W. W. Norton & Company: "Tides of Life," by Hoskins; "Genetics," by Jennings; "Scientific Basis of Evolution," by Morgan; "Physiological Basis of Personality," by Stockard.

Prentice-Hall, Inc.: "Ascaris," by Goldschmidt.

W. B. Saunders Company: "Developmental Anatomy," by Arey; "Introduction to Human Physiology," by Crandall; "Fundamentals of Bacteriology," by Frobisher; "Elementary Bacteriology," by Greaves; "Textbook of Physiology," by Howell; "College Zoology,"

by Hunter and Hunter; "Textbook of Pathology," by MacCallum; "Textbook of Histology," by Maximow-Bloom.

Charles C Thomas, Publisher: "Selected Readings in the History of Physiology," by Fulton.

University of Chicago Press: "The Machinery of the Body," by Carlson and Johnson; "Unresting Cells," by Gerard.

John Wiley & Sons, Inc.: "Animal Parasites and Human Disease," by Chandler; "Outlines of Biochemistry," by Gortner.

The Williams & Wilkins Company: "To Remind," by Hardy; "The Harvey Lectures," Series 32, 1937, Harvey Society of New York; "The Kahn Test," by Kahn; "Blood Groups," by Snyder.

Yale University Press: "Evolution of Earth and Man," edited by G. A. Baitsell; "The Development of the Sciences," edited by Dr. L. L. Woodruff; "Science in Progress," edited by G. A. Baitsell; "On Understanding Science" by Conant.

Special mention should be made of the courtesies shown by The Macmillan Company in permitting the use of considerable material from their publications, including that from the author's "Manual of Biology." Also for permission to publish a number of figures from their publications which are designated in the legend by the author's name only. These figures have been secured from the following Macmillan publications: "College Zoology," by Hegner; "Lessons in Elementary Physiology," by Huxley-Barcroft; "Textbook of Anatomy and Physiology," by Kimber, Gray, and Stackpole; "Organic Evolution," by Lull; "General Biology," by Mavor; "Food Products," by Sherman; "Biology of Vertebrates," by Walter; "Genetics," by Walter; "The Human Skeleton," by Walter; "Vitamin B, and Its Use in Medicine," by Williams and Spies, "The Cell in Development and Heredity," by Wilson; "Foundations of Biology," by Woodruff.

Special mention should also be made of textual and illustrative material obtained from various publications of the McGraw-Hill Book Company, Inc. These illustrations are designated in the legend by the author's name only, and comprise all those not otherwise credited. This material has been taken from the following McGraw-Hill publications: "Fundamentals of Biology," by Haupt; "An Introduction to Botany," by Haupt; "The Invertebrates, Protozoa through Ctenophora," by Hyman; "Microbiology," by Lutman; "General Physiology," by Mitchell; "Laboratory Studies in Zoology," by Reed and Young; "Textbook of Comparative Physiology," by Rogers; "Protoplasm," by Seifriz; "Introduction to Cytology," by Sharp; "Evolution," by Shull; "Heredity," by Shull; "Principles of Animal Biology," by Shull; "Botany: Principles and Problems," by Sinnott; "Principles of

Genetics," by Sinnott and Dunn; "General Zoology," by Storer; "An Orientation in Science," by Watkeys and Associates; "General Zoölogy," by Wieman; "An Introduction to Vertebrate Embryology," by Wieman; "Animal Biology," by Wolcott.

Cell types, drawn by Dr. J. Mansion Valentine for the Weber Charts, is reproduced by permission of the New York Scientific Supply Company and of Bruce M. Mills, administrator of the Weber estate.

The author is greatly indebted to Professor G. E. Hutchinson for an original article on the "Biological Elements" and to Dr. Grace E. Pickford for a noteworthy treatment of the "Enzymes."

The original illustrations are largely the work of Armin Hemberger, artist in the Department of Pathology, Yale School of Medicine. An examination of his drawings in this book will quickly reveal the author's indebtedness to him. In the development of the drawings of the various organ systems, Mr. Hemberger has had the advantage of helpful criticism and suggestions from the following members of the Medical School faculty: Doctors Harold S. Burr and Leon S. Stone of the Department of Anatomy, and Doctors Clyde Deming and Harlan Perrins of the Department of Clinical Medicine, and from his student, Jean B. Herrman.

The author finds it difficult to express in any adequate manner his indebtedness to his colleagues in the Department of Zoology and to many others for their help in the preparation of this manuscript. In particular, mention should be made of the assistance of the following staff members for reading various portions of the manuscript and for contributing many valuable constructive suggestions during the past three years while the material has been used in temporary form: Doctors S. C. Ball, T. C. Barnes, G. E. Hutchinson, D. Merriman, J. S. Nicholas, D. F. Poulson, T. K. Ruebush, and L. L. Woodruff. Great credit is due to Professor L. L. Woodruff, who has been interested enough to read the proof of the entire manuscript and has offered valuable aid in many ways, including the generous permission to use important material, both figures and text, from the "Foundations of Biology" (Macmillan) and "The Development of the Sciences" (Yale University Press).

Sincere thanks are due to the members of the technical staff of the Osborn Zoological Laboratory, particularly Lisbeth Krause, who has redrawn a considerable number of figures, Elinor Smith, Elizabeth Gelback, Helen K. Sandback, and F. W. Countryman, on whom has fallen the burden of a great deal of secretarial work in connection with the preparation of the manuscript, the reading of proof, and the development of the index.

CONTENTS

PREFACE TO THE SECOND EDITION	v
PREFACE TO THE FIRST EDITION	vii
ACKNOWLEDGMENTS	xi
I. THE WORLD OF LIFE	1
Living and Lifeless	2
The Chemistry of Life	4
Cellular Organization	7
Colloidal Nature of Protoplasm	11
II. PROTOPLASMIC ACTIVITIES	15
Metabolism	15
Growth and Reproduction	21
Irritability and Adaptation	23
Movement	25
Enzymes	27
III. ORGANIZATION OF THE HUMAN BODY	31
Cells and Tissues	34
Organs and Organ Systems	42
The Body Plan	44
IV. BIOLOGY OF NUTRITION (I)	49
Structural Aspects of Nutrition	49
Digestive System in Man	50
V. BIOLOGY OF NUTRITION (II)	65
Functional Aspects of Nutrition	65
Digestion and Absorption	72
Photosynthesis	78
VI. BIOLOGY OF RESPIRATION	86
Structural Features Associated with Respiration	87
Functional Features Associated with Respiration	100
VII. BIOLOGY OF SECRETION (I)	109
Glandular Structure and Function	109
The Liver	113
The Endocrine Glands	117
VIII. BIOLOGY OF SECRETION (II)	121
The Endocrine Glands (Continued)	121
The Regulation of Body Functions	126

IX. BIOLOGY OF EXCRETION	136
Excretion and the Skin	137
Excretion and the Lungs	139
Excretion and the Liver	139
Excretion and the Kidneys	140
X. BIOLOGY OF THE VASCULAR SYSTEM (I)	152
Structural Features Associated with the Vertebrate Vascular System	154
XI. BIOLOGY OF THE VASCULAR SYSTEM (II)	173
Functional Features Associated with the Vascular System	173
XII. BIOLOGY OF THE SKELETAL SYSTEM (I)	190
Structural Features Associated with the Skeletal System	190
XIII. BIOLOGY OF THE SKELETAL SYSTEM (II)	209
Functional Features Associated with the Skeletal System	218
XIV. BIOLOGY OF THE MUSCULAR SYSTEM	224
Structural Features Associated with the Muscular System	224
Functional Features Associated with the Muscular System	235
XV. BIOLOGY OF THE NERVOUS SYSTEM (I)	245
The Peripheral Division	247
The Autonomic Nervous System	254
Conduction	258
XVI. BIOLOGY OF THE NERVOUS SYSTEM (II)	263
Sense Organs	263
Sense of Hearing and Position	266
XVII. BIOLOGY OF THE NERVOUS SYSTEM (III)	275
Sense of Sight	275
Sensory Function in the Nervous System	285
XVIII. BIOLOGY OF THE NERVOUS SYSTEM (IV)	289
The Central System	289
Structural Features of the Central Nervous System	291
Integration	311
XIX. BIOLOGY OF GROWTH AND REPRODUCTION (I)	317
Types of Reproduction	318
Development of the Frog	330
XX. BIOLOGY OF GROWTH AND REPRODUCTION (II)	341
Development of the Chick	341
Development of the Mammal	348

XXI. BIOLOGY OF GROWTH AND REPRODUCTION (III)	365
Mitosis	367
Chromosome Structure	372
XXII. BIOLOGY OF GROWTH AND REPRODUCTION (IV)	381
Germ Cell Formation	381
XXIII. BIOLOGY OF INHERITANCE (I)	394
The Particulate Nature of Inheritance.	395
Mendelian Inheritance.	397
XXIV. BIOLOGY OF INHERITANCE (II)	420
Linkage of Genes	420
Crossing Over	429
Mutations	434
XXV. HUMAN HEREDITY (I)	442
Inherited Characteristics.	443
Galton and the Principles of Biometry.	449
Blood Groups.	452
XXVI. HUMAN HEREDITY (II)	458
Human Hybridization.	458
Inbreeding.	464
Eugenics: Negative and Positive	472
XXVII. THE WEB OF LIFE (I)	475
Autotrophic Organisms	476
Heterotrophic Organisms.	478
Basic Requirements for Life	485
XXVIII. THE WEB OF LIFE (II)	489
The Biotic Environment.	489
XXIX. BIOLOGY OF DISEASE.	509
Noninfectious Diseases.	510
Immunity	511
Immunology: Uses and Techniques	515
Epidemiology.	526
Types of Cellular Response.	528
APPENDIX	537
INDEX	691

CHAPTER I

THE WORLD OF LIFE

Biology is concerned with life phenomena of every kind and nature. We recognize life in the innumerable plant and animal organisms that are abundantly present in practically every niche of the earth, on land, in the sea, and in the air; and each of us, as a conscious human being, is aware of an inherent life principle that is associated with the many varieties of life in our environment. Life is known to us only in the form of completely organized units, or *individuals*. You are one of these individuals and so am I. Each individual in this world of life, whether large or small, simple or complex, plant or animal, is characterized by certain structural and functional features that distinguish the organism from nonliving material and also identify it as a distinct variety of life. The basic unity of design and behavior characterizing all types of life is due to the fact that the building material of man and of all other organisms consists of a life substance called *protoplasm*. In addition this unique material is the medium for housing all life phenomena, including nutrition, respiration, movement, reproduction, and the other vital activities.

Increasingly, as methods and equipment became available, scientists have attempted to solve the underlying problems associated with the nature of the materials, both living and lifeless, present in, on, and above the earth. They have developed broad and fertile fields of scientific knowledge, including the physical sciences (chemistry, physics, geology, and mathematics) and the life sciences, collectively known as *biology* and subdivided into numerous branches associated with the structural and functional aspects of animal science (*zoology*) and of plant science (*botany*).

The body of scientific knowledge now available through man's intellectual endeavors is very comprehensive and important and is continually being increased by further successful search for nature's secrets. Sometimes the new knowledge thus secured is spectacular in results and incalculable in its power and effect on man. A profoundly important example is now shown in the destructive release of atomic power by development of the atomic bomb.

Great discoveries in science rarely result immediately from research by a single scientist. Rather they are the cumulative result of long-continued investigations by many scientists. For example, there is a record of more than a half-century of research in nuclear physics, beginning in 1895 with the work of Becquerel, who first observed radiation phenomena, and culminating in the atomic fission of uranium in 1942. Then followed the application of these results to the war

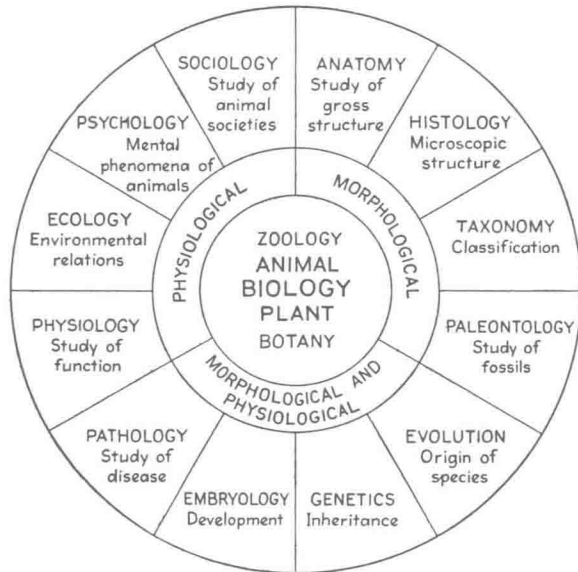


FIG. 1. The biological sciences. (Woodruff.)

emergency. In the years ahead atomic power, directed in the paths of peace, may well become the most important secret ever brought into the realm of the known by scientific research.

LIVING AND LIFELESS

Until comparatively recently it was not generally realized that there was much common ground between the materials of the inanimate world and those concerned with life phenomena. At present, however, the basic unity between living and lifeless materials is very apparent; it is, in fact, difficult to find the exact boundary separating them, even though at first glance the distinctions appear to be clear and to give every evidence of a definite separation. Everyone knows that sticks and stones, automobiles and houses are not living organisms, whereas beetles, birds, frogs, and men partake of a common life heritage. But