TEXTBOOK OF
GENERAL BIOLOGY

BY

WALDO SHUMWAY

Professor of Zoölogy, University of Illinois

1931

TEXTBOOK OF GENERAL BIOLOGY

THIS BOOK IS DEDICATED

TO MY FRIENDS

DONALD AND STELLA KEYES

PREFACE

This book has been written because of a feeling that there is a place for a fresh survey of modern Biology especially designed for those who do not plan to specialize in Botany or Zoölogy. Biology, as the term is used in this book, refers to those phenomena of life which are common to both plants and animals. No attempt is made to cover the fields of Botany and Zoölogy even in outline form, but rather to select from the wealth of illustrative material offered by each, such facts and theories as have a general significance. Such a selective process must necessarily be a subjective one, and the author recognizes his sins of omission and commission. But in a textbook designed for a course of one semester, or two terms, he can hope to present only an outline of biological principles arranged in what he considers a logical series.

Teachers are familiar with the difficulties encountered by students who attempt to wrestle with biological theories before they have some acquaintance with biological facts. Accordingly, since the average college freshman has had little science and less Biology, he is introduced to the subject by an account of the structure and activities of a vertebrate, the frog. Among the many desirable characteristics of this well-known martyr of the laboratory is the ease with which it may be compared with the human body, a real advantage to the beginning student. Following this an account of a flowering plant is provided. For this purpose the familiar wheat is chosen as an example of a highly organized and common plant. After describing the form, functions, and life history of this plant and comparing them with those of the frog, the student is ready to embark upon the study of general biological principles.

These principles seem to center about two concepts, that of the organism, and that of the species. The organism is distinguished by its ability to transform chemical substances, to respond to external stimuli, and to reproduce itself, and these properties are discussed in the light of modern biological research, from a physico-chemical standpoint. The species is considered as an aggregate of organisms distinguished by their hereditary resemblances, their geographical distribution, and their descent from a common ancestor in evolution.

After a discussion of these principles a brief survey of the major plant and animal groups is intended to give some idea of the evolution of these kingdoms. Finally, a short account of some of the ways in which the study of Biology is applied to the improvement of human life concludes this introduction.

A frequent complaint arises that the beginning textbook in any science contains at least as large a vocabulary of unfamiliar words as the beginning text in a foreign language. While this may well be true, it is equally clear that these strange polysyllables are by no means a barbarous jargon designed to warn off all trespassers. On the contrary, they form a kind of scientific shorthand which is a real convenience to the professional scientist. The author has attempted to transcribe much of this biological stenography into plain English. Some of the symbols and abbreviations seem indispensable, but they have been reduced to a minimum and carefully defined. A pronouncing glossary is appended to the text.

It has been the author's aim to write for those to whom laboratory facilities are not available. Accordingly, illustrations have been used freely to take the place of demonstration material. These are carefully labeled, and the use of abbreviations has been avoided.

Biological principles are becoming increasingly important to the students of education, of psychology, and of the social sciences in general. These students, however, are so occupied with the immediate problems in their particular fields that they have little time for the technical vocabulary or the laboratory methods of another discipline. The author hopes that this book will prove serviceable to them and to the ever-widening circle of those who are trying to orient themselves in the world of modern science.

WALDO SHUMWAY

URBANA, ILLINOIS
March 21, 1931

ACKNOWLEDGMENTS

An elementary textbook in a science such as Biology, whose literature is so extensive and is increasing so rapidly, cannot hope to be original in more than arrangement and style. Nor can any writer of such a text pretend to have more than a speaking acquaintance with many of the subjects to be presented. His indebtedness to the original sources must be traced through one or more compilers who have preceded him. The present writer acknowledges his debt to his teachers, past and present, direct and indirect, and hopes that his present effort will not be unworthy of their teaching.

He is particularly grateful to his colleagues Professors H. B. Ward, Charles Zeleny, V. E. Shelford, and L. A. Adams of the Department of Zoölogy, to Professors C. F. Hottes and J. T. Buchholz of the Department of Botany, to Dr. W. A. McAllister of the Department of Psychology, and to Dr. D. H. Thompson of the Illinois State Natural History Survey, who have been kind enough to read chapters of this book in manuscript.

Full advantage has been taken of the generosity displayed by fellow authors and publishers in allowing the reprinting of illustrations from other texts. The usual acknowledgment is made in the legend of each figure borrowed from other sources; but the author's debt to Professors Holman and Robbins, who have generously permitted the reproduction of many figures from their textbook of General Botany, is particularly heavy. The original drawings have been prepared by the skilful hand of Mrs. Katharine Hill Paul.

CONTENTS

ERRATA

Page 17. Transpose *hepatic* (line 6) and *hepato-portal* (line 7).
" 81. Transpose *anion* (line 6) and *cation* (line 8).
" 96 and 97. Transpose *somatic* (bottom) and *germinal* (line 3).
" 106. Transpose *ectoderm* (line 19) and *endoderm* (line 23).
" 167. Line 11. For *18½* read *8½*.
" 278. Fig. 183 Transpose legends for *D* and *E*.

CHAPTER I

INTRODUCTION

The customary method of introducing the reader to a new subject is by means of a definition, such as "**Biology** is the science of life." A definition, however, is but a formal invitation to further acquaintanceship, and like many other formulae it is valuable only as it is used with discretion. If it were possible to tell in a single sentence all that Biology has come to mean, the reader might save his time by stopping at this point.

The Science of Life. — What is meant by the science of life? Without attempting to add another to the long list of formal definitions, let us say simply that we use the word science to mean "what we know about" a subject. And what do we know about life? That is a question man has asked since first he began to think. To primitive man life was associated with motion. In his myths and magic rites we find evidences of his belief in the animate nature of rock and stream, of wind and of rain. And though later speculation distinguished living plants and animals from all other objects of nature, the line of demarcation was not so sharp but that a belief in the origin of life from inanimate matter was quite as reasonable as in the obvious transformation of the living body into a lifeless mass. So, down the ages, those ancient mysteries of birth, the origin of life, and of death, its cessation, have challenged the attention of priest, philosopher, and scientist alike.

Content. — Plants and animals, to the best of our knowledge, are the only natural objects in which life is manifest. So Biology becomes the study of plants and animals. But the variety of life as it is expressed in a world of **organisms** (living things) is scarcely imaginable. Aristotle, "the father of Biology" (384–322 B.C.), was acquainted with some five hundred different **species** (kinds) of animals, while his pupil and co-worker Theophrastus (370–285 B.C.) described some five hundred plants. Two thousand years later Linnaeus (1707–1778) named about five thousand species of animals and approximately as many species of plants in the tenth edition of his "Systema Naturae"

(1758). He modestly estimated that the number of species described by him was less than half the number actually in existence. As a matter of fact a conservative calculation of the number of species described up to the present time gives us approximately a million species with a ratio of three animals to one plant.

FIG. 1. — Aristotle (384–322 B.C.), the father of Biology. (From Locy, "Main Currents of Zoölogy," Henry Holt and Co.)

Divisions. — In the university at Upsala, where Linnaeus taught, he was Professor of **Natural History,** a subject which included the animal, vegetable, and mineral kingdoms. Such a domain became too large and unwieldy, and now each kingdom is allotted to a separate science, **Zoölogy, Botany,** and **Geology** respectively. Lamarck (1744–1829), a great speculative zoölogist, recognized the essential similarity of plants and animals as living things and coined the word Biology[1] for the study of their common properties.

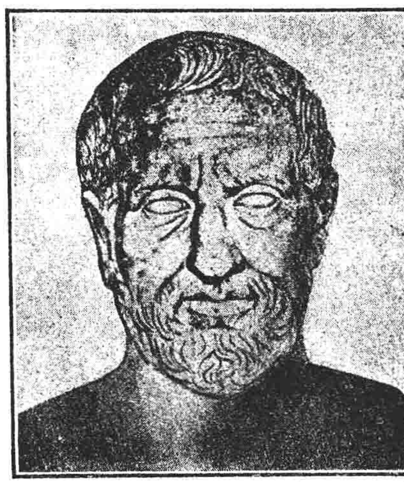

FIG. 2. — Theophrastus (370–285 B.C.), pupil and successor of Aristotle. Author of the first treatise on plants. (From Locy, "Growth of Biology," Henry Holt and Co.)

On the other hand, the detailed investigations of botanists and zoölogists resulted in the establishment of many special divisions of these sciences. This specialization has continued until the list of so-called biological sciences is too lengthy for enumeration at this point. It is well to note, however, that some, like **Bacteriology,** the study of bacteria, and **Entomology,** the study of insects, represent still further subdivision of Botany and Zoölogy, respectively. Others, like **Genetics,** which deals with the variation and inheritance of individual characteristics,

[1] Also used by Treviranо (1802).

collect their information from study of both plants and animals. The growing importance of these latter sciences emphasizes the fundamental unity of plant and animal life which is the proper field of **General Biology.**

The Organism. — The problems with which Biology deals center about the individual organism and the species, respectively. The organism demands our attention first, as it is in the organism alone that life is manifested. What is an organism? The word

Fig. 3. — Linnaeus (1707–1778), the founder of modern classification and nomenclature. (From Holman and Robbins, "A Textbook of General Botany," John Wiley and Sons, Inc.)

implies organization, or the arrangement of parts for particular purposes. Aristotle pointed out the dual aspects of the subject, the one dealing with the form (structure) of an object, the other dealing with its function (activity). Accordingly there have arisen two biological sciences known as **Morphology** and **Physiology,** respectively. The first deals with the question "How is the organism constructed?"; the other attempts to answer the query "How does it work?" The division is really a formal one, for the two sciences are interdependent, and each is incomplete without the other. In spite of the logical connection between these two divisions, they were almost completely separated during the past century, principally because of a difference in method. The method of Morphology was primarily the description and comparison of observed forms and structures. The method of Physiology was primarily that of experimentation. This is but natural. The obvious way of studying a new organization is to examine its structural composition and to compare this with familiar organizations, but in order to see how it works the skeptical observer will try it on something new. The experimental ideal is to have all the conditions of the experiment so carefully controlled that it can be repeated under the identical conditions with the identical result. At the present time Morphology and Physiology are moving closer together, and each is applying the methods of the other school, as witnessed by the appearance of books on Experimental Morphology and Comparative Physiology. The study of the organism is incomplete without a knowledge of the way in which it came into existence. This is the province of the biological science known as **Embryology,** which deals with the origin and development of the individual organism. This subject is intimately related to both Morphology and Physiology, for the development of form and the development of function go hand in hand.

FIG. 4. — de Lamarck (1744–1829), an early evolutionary biologist, best known for his theory respecting the inheritance of acquired characteristics. (From Pirsson and Schuchert, "A Textbook of Geology," John Wiley and Sons, Inc.)

Physico-chemical Viewpoint. — The study of the individual organism is rapidly passing from the hands of the morphologist and physiologist into those of the chemist and physicist. Or rather the biologist is learning Chemistry and Physics. It was not so long ago that the term Organic Chemistry stood for a fancied distinction between the chemistry of the compounds found in the bodies of plants and animals, and other so-called inorganic substances. It is the fundamental postulate of modern

Biology that the structure and activity of the organism are subject to the same laws of Chemistry and Physics as are all other forms of matter and energy. Needless to say, the boundary between the inorganic world and the organic has not yet been crossed: living matter has not yet been built up from lifeless ingredients. But many organic substances have already been synthesized in the chemical laboratory, and the physicist has simulated many of the so-called vital phenomena. This physico-chemical interpretation of Biology (sometimes called the mechanistic conception of life) may not survive the test of long-continued experimentation and comparison, but it has already proved extremely fruitful and alone holds out hope for future investigation.

The Species. — Like produces like. The developing embryo gradually assumes the forms and functions characteristic of its parents. It is through this process of reproduction that the characteristics of the kind of plant or animal are transmitted from generation to generation. The species, then, is an aggregate of similar organisms presumably descended from a common ancestor. Linnaeus, who invented the modern system of naming and classifying plants and animals, employed the species as the smallest unit of his scheme. The species were arranged into **genera** (singular, **genus**), these into **families**,[2] and families into **orders.** Orders were grouped to form **classes,** and these were united into **phyla** (singular, **phylum**), or divisions of the plant or animal kingdom, as the case might be. With the enormous increase in the number of described species since the time of Linnaeus, the need for further subdivisions has been recognized in the creation of subspecies, subgenera, subfamilies, suborders, subclasses and subphyla. Some students of classification have even gone so far as to advocate superspecies, etc., to make the filing process more complete. Tables of classification are provided in the Appendix. It is to be remembered, however, that there is nothing sacred about these; they represent only a convenient method of pigeon-holing information so that it will be readily accessible, while the terminology concerned offers many memory-saving devices to the student of Latin and Greek, who may remember that **Spermatophyta** means seed plants and that **Insectivora** stands for insect-eaters.

Nomenclature. — In referring to plants and animals, Linnaeus invented what is known as the **binomial** system of nomenclature, in which the name of the genus (in the form of a Latin noun) is

[2] This group was not used by Linnaeus but was introduced by Batch (1780).

followed by the name of the species (as a qualifying adjective or the genitive case of a noun derived from the name of some person whom the describer wished to honor). Thus the name of the common leopard frog of Eastern North America is written *Rana pipiens*, as though we wrote the name of an individual as *Smith john.* There are supposed to be no duplications in the list of generic names, and no duplications of specific names within a given genus. In this way there is a sufficient number of combinations so that each kind of plant and animal may have a distinctive name. The use of the binomial does away with the ambiguities resulting from the use of the popular or vulgar name of an organism. Thus in America we speak of " corn " where the English use the term " maize," both meaning the plant *Zea mays.*

It must constantly be borne in mind that the species is not a natural but an arbitrary grouping. Many species contain more or less sharply defined subdivisions known as varieties or subspecies. The question then arises as to whether the subspecies should not be considered as independent species. The expert student in the group has his own ideas as to the relative importance of the various characteristics used for purposes of classification, and according to whether he is a " lumper " or a " splitter " there will be fewer or more species in the field of his specialty. Thus there appear to be two types of the American garden toad. The one specialist will call them *Bufo americana,* var. *americana,* and *Bufo americana,* var. *fowleri*; the next knows them as *Bufo americana* and *Bufo fowleri.*

FIG. 5. — Gregor Mendel (1822–1884), whose breeding experiments laid the foundation for modern Genetics. (From Curtis and Guthrie, "A Textbook of General Zoölogy," John Wiley and Sons, Inc.)

Problems of the Species. — With these finer distinctions of the professional **taxonomist,** as the expert in classification is called, we are not concerned. As long as there are different kinds of plants and animals we shall need names for them, and the Linnaean system of nomenclature still meets the immediate needs of the general biologist. But the existence of these different kinds of animals does present problems of particular interest. How do species maintain their existence? How do they originate? The science of Genetics, which deals with the variation and inheritance of specific characters from generation to generation, dates only from the rediscovery in 1900 of the results obtained by the Abbot Gregor Mendel (1822–1884) in his monastery garden. **Ecology,** or the study of the relationships between species and the environment, is based on the concept of the biotic community, or assemblage of plants and animals, laid down in 1909 by Warming. The origin of species is the subject of **Evolution,** which Charles Darwin (1809–1882) made his own. Each of these biological sciences has its own methods of investigation and each has made contributions to our knowledge of the species, which, composed of innumerable individuals, past, present and future, and affected by the many factors of a changing environment, represents a temporary aspect of organic evolution.

FIG. 6. — Charles Darwin (1809–1882), author of "The Origin of Species through Natural Selection." (From Pirsson and Schuchert.)

Applied Biology. — The application of the methods and principles of Biology has proven invaluable in many practical ways. In this general field of applied Biology, interest centers in research applicable to Medicine, Public Health, and Sanitation; to Agriculture which is concerned with the biological products of the soil and Aquiculture which deals with the biological products of the waters; to the conservation of natural resources, and other fields which will be indicated in the concluding chapter. But pure Biology, devoted to the acquisition of knowledge for its own sake, has its applications no less than has applied Biology. The theory of Evolution, for example, pervades the writings of psychologists, educators, and sociologists, and the philosopher who neglects the contributions of Biology is rare indeed.

CHAPTER II

A VERTEBRATE ANIMAL

Before commencing an examination of biological principles, it is necessary to gain some acquaintance with biological facts. The individual organisms with which Biology deals are either animals or plants, and these are the tangible units with which biologists work. Since we ourselves are animals and have some practical knowledge of our own bodies, it will be proper to commence our study with an account of an animal rather than of a plant, even though the structure of the plant is less complex. And because our own bodies are highly organized into specialized parts and regions, we select a highly organized animal, the frog, also a vertebrate animal, instead of a simpler and smaller, but more unfamiliar organism.

In the account that follows we shall examine the activities of the frog's body. These center around three main functions: **metabolism,** or the changes in chemical composition undergone by foreign substances taken in as food; **irritability,** or the transformations of energy manifested in the work done by the organism as it responds to external stimulation; and **reproduction,** or the ability to detach portions of the body which develop into replicas of the parent organism.

Throughout this discussion it must be borne in mind that we are dealing with the organism as a whole. Although we shall have to mention smaller units, such as **organs, tissues,** and **cells,** these exist in nature only as parts of the living organism, just as in chemistry atoms, the smallest units of the chemical elements, are naturally found combined in molecules, the smallest units into which chemical compounds can be subdivided and still retain their chemical properties.

THE FROG

This familiar animal has long played the martyr's rôle in the biological laboratory. Generally easy to obtain in numbers, convenient in size, clean and familiar, it affords exceptionally favorable material for dissection, experimentation, and field observation. Although there are still many problems connected with the frog, so much has been learned from the study of this one species that it may well be considered a biological classic.

Species. — Nearly two hundred species of frogs, not including the toads and tree frogs, have been described, but the common frog in North America (excluding the Pacific coast) is the leopard frog, *Rana pipiens* (Fig. 7). These frogs appear in the early spring in our ponds, soon after the tree toads and peepers. In or near these ponds they may be found until late autumn, when they burrow in the mud to spend the winter in a condition resembling suspended animation which is known as hibernation.

Habitat. — If you approach the pond soon after the ice has melted you will hear a chorus of sounds among which may be distinguished the croaking of the leopard frog. As you draw nearer, the chorus dies down. A series of splashes indicates that the singers are taking to the water, diving deep and swimming beneath its surface. If you wait quietly you will see some swimming along with a stroke curiously reminiscent of the ancient breast stroke of our swimming schools, or floating easily with nostrils barely lifted above the water. Perhaps one may crawl out upon the bank and hop along the edge. Watch carefully and you will see some incautious insect suddenly disappear, snapped up by a lightning-like movement of the tongue. Specimens are easily captured while this congregation of frogs is assembled during the spring mating season, but when it is concluded they will disperse in all directions, each to take up a hermit's life.

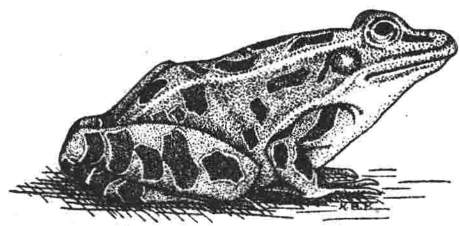

FIG. 7. — *Rana pipiens*, the leopard frog. $\frac{1}{2}$ natural size.

Shape of the Body. — If we catch a specimen, after a few frantic struggles to escape it will often lie quietly in the hand while a few observations are made. The body is bilaterally symmetrical, that is to say, right and left sides are practically mirror images of each other. We distinguish a head at the anterior end, but unlike most vertebrates the frog has no tail at the posterior end. The back (**dorsal** surface) is easily distinguished from the belly (**ventral** surface) not only by the difference in color and markings but by the fact that nostrils, eyes, and ear drums are located on the dorsal side.