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Principles of ZOOLOGY

second edition

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Principles of Zoology

Preface

The authors firmly believe that all students, in obtaining a liberal education, should have an opportunity to become acquainted with the life sciences. They also believe that such an opportunity can be provided in a single introductory course for students who plan to major in zoology as well as for those who will take no further work in the field. The purpose of this book is to present the basic facts and principles of animal science, to familiarize the student with the vertebrate organism with some emphasis on the human, and to show the great diversity in the animal world by means of a survey of the entire animal kingdom.

The major problem in the preparation of a beginning text in any field is the choice of materials. Since coverage of all phases of zoology is a necessary prerequisite, each phase must receive no more than its just share of the available space. The authors believe that they have struck a reasonable balance, but those who use the text may wish to modify the emphasis by omission of some sections. The organization is such that this can be done without loss of continuity. Those students who wish to delve more deeply into any specific area are guided to additional sources by references at the end of each chapter. A special group of references to *Scientific American* articles is included where appropriate.

Throughout the text, illustrations have been used with two purposes in mind. First, to augment the text and clearly demonstrate the material under discussion. In addition, the figures dealing with details of the anatomy of specific organisms will be quite helpful in laboratory studies.

We are convinced that the cell concept and the concept of organic evolution should be primary, integrating principles throughout the book. In the study of different animal groups, emphasis is placed on their anatomy, physiology, reproduction, and development. Their phylogenetic relationships and their ecological interactions with other organisms are also discussed.

The authors have tried a variety of approaches in the presentation of this material during the past forty years. We recognize the pedagogical advantage of proceeding from the known to the unknown. We have found, however, that starting immediately with the familiar vertebrate animal, without any previous study of the cell, makes the study of structure and function of whole organisms difficult and unsatisfactory. Accordingly, we are convinced that it is necessary to start with a study of cells and their chemistry. In the discussion of the chemistry of cells and in consideration of their function throughout the book, it is essential to make use of certain basic concepts of physics and chemistry. It has been our aim to present these concepts in such a way that beginning students, without any previous study of the physical sciences, can readily understand them and thus appreciate the dependence of the life sciences on the basic physical sciences.

Following the introduction which discusses the nature of the science of zoology (Chapter 1) and reasons for its study (Chapter 2), Part I deals with the Dynamics of Molecules, Cells and Tissues. Chapter 3 is concerned with the nature of matter and in particular with the constituents of living material. This paves the way for the structure of cells and tissues in Chapter 4 followed by a discussion of basic energy sources and the mechanisms whereby living cells store and utilize energy in Chapter 5. In Chapter 6, on bioinformation, the background is given for future discussions of the transfer of information between cells in an individual as well as between generations in the hereditary process. Part I ends with a chapter on cell division, both mitosis and meiosis, along with a discussion of chromosomes, the carriers of the genetic material from cell to daughter cell and from parents to their offspring.

In Part II, Problems that Organisms Face, the major emphasis is on vertebrates with the human as the main example. Comparison with other vertebrates is included where appropriate. Material included in this section involves protection, support and locomotion; nutrition; gaseous exchange and the elimination of metabolic wastes; transport and other functions of the blood including an updated discussion of immune reactions; coordination by hormones and by the nervous system; and a final chapter on learned behavior.

Part III, Continuity of Species, deals with reproduction, development, and genetics. Following chapters on reproduction and on development, classical Mendelian as well as neo-Mendelian concepts are introduced. Then, there is a treatment of the mechanisms of mutation, both chromosomal and gene, the molecular basis of phenotypic change, and the mode of gene action. The last chapter of Part III is concerned with human and applied genetics. It includes a discussion of the roles of heredity and environment, the relation of genes to disease, and the controversial topic of genetic engineering. A discussion of the application of genetic methods to agriculture and the effect of such practices on the world's food supply ends the chapter.

Part IV, Diversity and Adaptation in Animals, is a detailed study of the animal kingdom. Following a chapter on classification, 12 chapters are devoted to the invertebrate phyla. The treatment of each phylum includes a characterization of the phylum, accompanied by a diagrammatic representation of its most distinguishing features. Each class is also characterized and an illustration of a representative member of the class is shown. There is a thorough discussion of each class, using a representative member as an example. The discussion includes anatomy, physiology, reproduction and development, ecology, and phylogenetic relationships. A resumé of the taxonomy of the classes is included down to the order level. Where appropriate, important parasitic species which affect humans are treated in some detail. In connection with the study of the invertebrates, there are over 250 figures, most of them especially drawn for this text, to enable the student to gain some familiarity with these groups—many of which may be entirely new to him.

Five chapters are devoted to the vertebrates, one to the fishes and one to each of the other four classes, amphibians, reptiles, birds, and mammals. The discussion of each group includes their basic diagnostic traits and their relationships to other groups; variations in form and function within the group; structural and behavioral similarities and diversities; and important interactions with other animals including humans. A survey of the classification of each group with appropriate examples is also given. Part IV ends with a chapter on phylogeny including a phylogenetic tree.

Part V, Dynamics of Species, is concerned with some basic and unifying biological principles, utilizing the background obtained from preceding chapters. Throughout the book, evolutionary relationships have been stressed, and the first three chapters of Part IV build upon that base to present the concept of organic evolution. Chapter 40 deals with evidences of evolution from a variety of sources, including important evidence from the now generally accepted concept of continental drift. A survey of current thinking on human evolution is given in Chapter 41, followed by a chapter on the mechanisms of evolution and the origin of life. Chapter 43 contains a thorough discussion of animal behavior, including sections on innate behavior and its modification, genetic aspects of behavior patterns, the evolution of behavior in certain groups, and various types of rhythmic behavior such as circadian rhythms. Three chapters on ecology follow. The first introduces basic species ecology, the second deals with interspecies and ecosystem ecology, and the third with human ecology. The latter takes up many of the pressing environmental problems that beset society today. The final chapter surveys further problems facing humankind in the last quarter of the twentieth century and beyond. Food production, the population explosion, control of disease, and the rapid depletion of our natural resources are all related to our survival.

The study of the life sciences is ever changing and we have tried to indicate this fact wherever appropriate. That many unsolved problems remain is emphasized as is the increasing use of the experimental approach to many problems. Whereas much of the material is based on the cumulative knowledge of the past, an effort has been made to introduce significant new developments that are pertinent to an introductory course. We have also placed some emphasis on the methods used in arriving at many of the important concepts and generalizations.

In this second edition the treatment of the classes of vertebrates has been expanded from a portion of one chapter to five chapters. Behavior is now covered by two chapters instead of one, and instead of a single chapter, ecology now is covered in three chapters. Additional material on ecology has also been added to the discussions of each of the major groups of animals. New illustrations and photographs, many of the latter taken especially for this book by one of the authors, have been added to increase the clarity of presentation. There has also been a general updating of information in all chapters, reflecting the additions to our knowledge since the publication of the first edition.

Although we have tried to be accurate and up-to-date in our statements, we realize the impossibility of completely avoiding errors. Therefore, we will greatly appreciate having our attention called to any errors in fact or any questionable statements. For their helpful reviews of the manuscript, we wish to thank Harold R. Bancroft, Memphis State University; Mark C. Biedeback, California State University, Long Beach; Edward C. Brown, Holyoke Community College; William A. Elmer, Emory University; George L. Harp, Arkansas State University; Grover C. Miller, North Carolina State University; Morgan E. Sisk, Murray State University; James C. Underhill, University of Minnesota; Sandra Winicur, Indiana University at South Bend.

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Crawfordsville, Indiana *W.H.J.*
*Ithaca, New York** *L.E.D.**
August, 1976 *E.C.W.*
T.A.C.

Principles of Zoology

Contents

1 What is Zoology

Suppose that you, the reader, were a space traveler from a more distant body approaching the Green Planet, Earth. The view from thousands of miles out in space would be that seen by the astronauts of the 1960s and early 1970s: a montage of blue, green, and white. Only upon close approach to the earth would the first contact with the organisms detailed in this text be made: an occasional high-flying bird of class Aves might be seen. A low-altitude trip around the earth would be necessary to gain some sense of the biotic world. If the space traveler had no greater sensory powers than the average current human inhabitant of the earth, then forests and the world of plants would be more impressive than the world of animals upon the first contact with this planet. Although the traveler might see herds of animals in Africa and the arctic tundra, penguins in Antarctica, and so forth, in addition to high-flying birds, the first impressions, on a purely qualitative basis, would be oriented toward the world of plants which clearly dominate the terrestrial landscape. Additionally, the traveler from outer space undoubtedly would be impressed by the contrast of great cities against the surrounding countryside, lakes, rivers, and oceans. The cities and their elaborate interconnecting sinews of superhighways would tell the visitor that some ingenious form has been able to change locally and selectively the face of the green planet and provide the great contrasts apparent between the cities and their surroundings.

The space traveler might, upon landing, decide to explore the phenomena associated with the world of animals from protozoa to humans. Such a task would involve many avenues and would call upon many resources and talents. Perhaps the facts, principles, and theories set forth in this text would simplify the overall task and provide some guidelines for understanding animals and their interactions with their environments.

LIFE ON EARTH

Although there may be life on other planets, life on the earth is the source of our direct information of life processes. Life on earth is confined to a thin shell on its surface. Life's main abundance is at the interfaces among the sky, sea, and land. At great heights the conditions are unfavorable for life; temperatures are too low, carbon dioxide and oxygen are in low concentrations, and cosmic radiation is too high. The depths of the earth are penetrated by organisms, but no one knows just how far. Eventually, light becomes a limiting factor to life in the deep and dark places of the earth. Organisms that live in these places are dependent on energy sources made available by organisms that do live in light.

The biosphere, this thin shell of sky, sea, and land, depends on the sun, directly or indirectly. Life does exist virtually everywhere in the biosphere, even in hot springs and polar regions. Where does life not exist? Certainly not in the hot ash of a volcano and probably not in the polar ice packs that have been frozen for centuries. The diagrammatic view of the biosphere in Figure 1.1 emphasizes it as a "thin slice of life" relative to the total mass of land, sea, and sky.

Life is not equally distributed over the earth. This applies to all organisms, not only the human population. *Biomass* is the term applied to the living material present in a given area. The total biomass of the earth has never been measured, but for small regions the biomass can be deter-

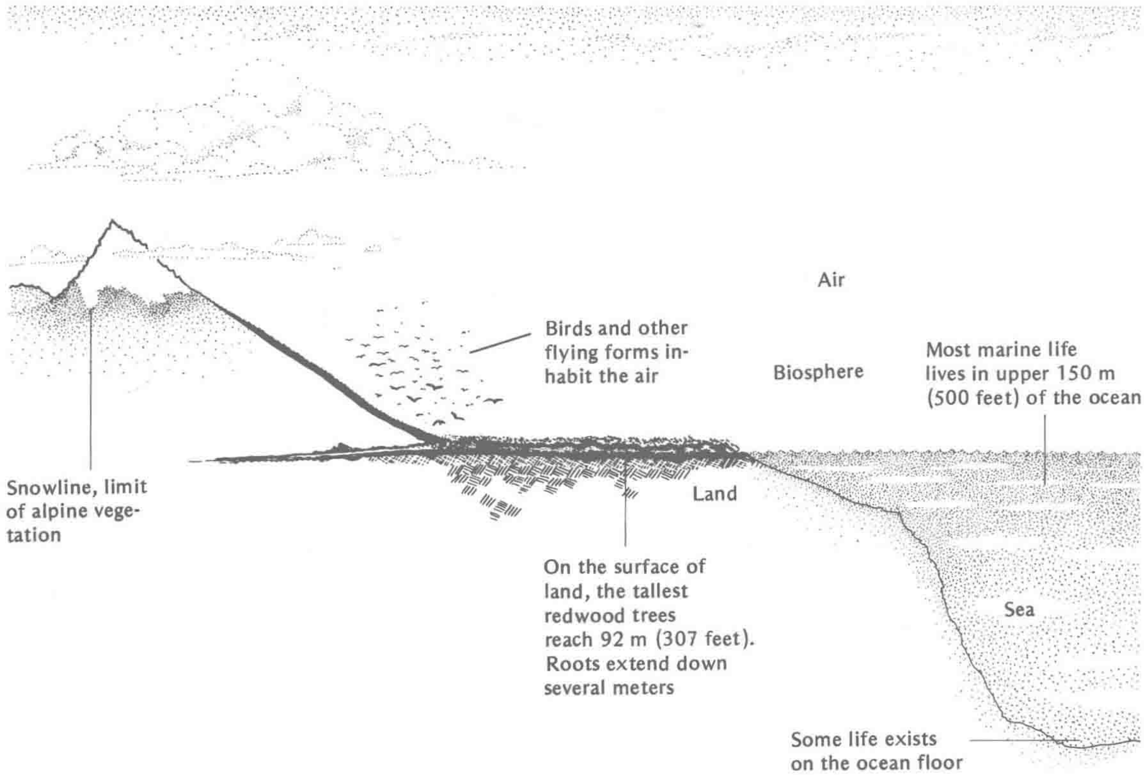

Figure 1.1 Biosphere. Living organisms are present in great numbers and diversity in a small part of the earth and its atmosphere. This has been called "the Thin Slice of Life."

mined or at least estimated. Such measurements and calculations substantiate what one would expect. Some parts of the biosphere contain and produce more biomass than others. In addition to being heterogeneous in quantity, the biomass produced in various regions is also heterogeneous in quality. The availability of light, water, oxygen, carbon dioxide, and minerals in addition to a proper temperature affects the kinds of materials produced by the living organisms of a region.

Biomass production depends fundamentally upon photosynthesis, the mechanism for conversion of light energy into chemical energy. The green plants and other organisms that carry out photosynthesis are called *autotrophs*. The *heterotrophic* organisms, mainly animals, are those that cannot synthesize their own food and must feed upon autotrophs (or other heterotrophs). A fundamental flow of energy and nutrients is thus set up in the life process on the earth. A steady supply of new energy from the sun pushes these cycles. The discipline of ecology studies the interrelationships of organisms and cycles (Chs. 44–46).

SCIENCE AND ZOOLOGY

The word *science* is derived from the Latin verb *scire*, "to know." Originally science meant a state of knowing as opposed to a state of believing. In general, science is related to knowledge which is derived from observation, study, and experimentation. Twentieth-century citizens are constantly exposed to the term science and, in general, science is highly regarded. Any individual in this modern, urban-oriented society would have a difficult time avoiding close contact with science—from the scientific information that influences political discussions of global and supraglobal importance to the "science" involved in a television or newspaper advertisement.

Since science is an inextricable part of our lives, it behooves the twentieth-century citizen to gain some understanding of it. The authors feel that a course *in* science is the best way to learn *about* science. The individual who asserts that he or she is not "going into science" is only preparing him- or herself for a rude awakening. The philosopher, writer, politician, artist, sociologist, and so forth must deal with various aspects of science. Science is creating new solutions to old problems, new methods for implementing old solutions for old problems, and also, new problems. Newspapers, magazines, the visual media, and the study of many areas of science and technology (Ch. 2) illustrate this point. A specific example is the article, "Impact of Space Research on Science and Technology" (see Newell and Jaffe, Suggestions for Further Reading).

Although many people have given definitions of science, none of the definitions has been all-inclusive and entirely satisfactory. Science includes both organized knowledge and the processes which lead to that organized knowledge. Some fields of science deal predominantly with the conservation and transmission of knowledge, while others are involved with new investigations. In the study of science, formal course work in undergraduate curricula is involved mainly with what is already known. At the graduate level, original investigation is heavily emphasized. There is no established time as to when and how the student should be introduced to the investigative aspects of science. Many scientists feel that the investigative aspects are by far the most interesting and they would like to introduce the student to this aspect of science as soon as possible. The first course in a subject necessarily involves a large body of factual information and time is often not available for original experiments. However, in the introductory course the time-honored questions are always appropriate: "How did this come about?," "What is known and not known about this topic?," "How can the unknown become known?," and so forth.

SIZES OF ANIMALS

Clearly, a distinguishing and obvious characteristic of an animal is its size. Animals range in size from about 3 micrometers (μm) (1 $\mu m = 10^{-6}$ m) in length for the smallest protozoans to about 30 meters (m) (about 100 ft) for the blue whale. Thus the zoologist finds a range in size of about thirty million fold. The blue whale weighs as much as 150,000 kilograms (kg) (330,000 pounds or 165 tons), dwarfing any other animal that lives or has ever lived. A newborn blue whale is larger than a full grown elephant and is reported to consume as much as 455 kg (1000 pounds or ½ ton) of milk per day.

The techniques for studying the smallest protozoan and the largest mammal must vary greatly. Zoologists are specialized with respect to the types of organisms that they study, not only on the basis of the organism's size, but also with respect to its structure or morphology, physiology, ecology, and other attributes or "life styles."

DISTRIBUTION OF ANIMALS

Animals are distributed in various regions on the earth, called biomes. The *biome*, the largest land unit which is recognized conveniently, is characterized by a particular general type of vegetation. Some primary examples of biomes are the coniferous forest, desert, tundra, tropical rain forest, grassland, chaparral, deciduous forest, and savannah (Ch. 44). Additionally, some workers consider the sea as another biome since it is an easily recognizable unit. Although some animal species are cosmopolitan and normally live in more than one biome (protozoans of the same species may be found on every continent), the restricted distribution of most animals to a particular biome emphasizes the interrelationships of the plant and animal worlds, often in highly sophisticated and poorly understood ways.

PROBLEMS THAT ANIMALS FACE

Every animal, whether it be a protozoan or a blue whale, faces certain fundamental problems:

1. Obtaining, storing, and utilizing food
2. Exchanging gases and eliminating wastes
3. Transporting materials in their bodies
4. Coordinating their activities
5. Receiving environmental stimuli
6. Responding to environmental stimuli (behavior)
7. Supporting themselves
8. Moving (locomotion)
9. Protecting and defending themselves
10. Reproducing, developing, and maintaining their species

Parts II and III discuss these problems and some of the major solutions to them. Part IV describes the fantastic diversity found in the animal world; this diversity is a reflection of the diversity by means of which the above problems have been solved.

WHAT IS LIFE?

Zoology is a science that deals with animals and animal life, and the student of zoology should have an understanding of the meaning of the term *life*. Unfortunately, there is no good definition of life. Although one has no difficulty distinguishing between a familiar plant or animal and a rock, other distinctions may not be so obvious. For instance, after a frog has had its brain destroyed, it will die eventually. At what precise point does the frog cease to live? Directly related to this seemingly pedestrian question is the medical–legal question of human death: when is a human legally dead, and therefore, at what point may human organs be taken for transplantation? The processes that are agreed generally to be characteristic of all living organisms are metabolism, growth, reproduction, irritability, and evolution. The consideration of these characteristics illuminates the concept of life more than any single definition can.

All chemical processes that occur in living organisms are grouped under the general term *metabolism*. Metabolism which converts food into a part of the organism is constructive ("build-up") metabolism, or *anabolism*. That action by which food or body constituents are broken down with the release of energy is destructive metabolism, or *catabolism*.

The analogy between a living organism and a machine is not completely accurate, but can be useful. In a relatively complex machine (an automobile or a motorcycle, for example) fuel is burned with the release of energy. This energy is used to move the machine, and waste products are expelled in the exhaust. Fuel is not used in a machine for replacement of parts; worn parts are replaced in a separate, and often expensive, operation. In organisms food is taken in and burned to release energy, and waste products, including heat, are eliminated. However, in addition, food taken into the body is chemically processed and transformed into materials that become part of the organism.

The ratio of anabolism to catabolism in an organism is controlled by several factors: exercise (work), efficiency of the body machinery in carrying out each process, food intake, and nutritional value of the food. If the amount of food that is made a part of the organism is greater than the amount of body structure that is broken down, there is an increase in the mass of the organism. This phenomenon of *growth* of an organism, whether it be localized in one part of the anatomy or experienced by the whole organism, is different from that which occurs in the nonliving world. Growth in nonliving things such as mineral crystals results from additions to the surface, much like additional layers of snow that increase the size of a rolling snowball. On the other hand, growth in an organism involves the addition of new materials to those already present within the body. This is growth from within. Everyone can attest to the phenomenon of growth from within because they have experienced it.

The third characteristic of organisms is the potential for *reproduction*. Each living thing reproduces offspring of its own kind. The new individual may be produced from a part of the old one (asexual reproduction), or it may be produced by a union of two sex cells formed by two individuals normally of the same species (sexual reproduction).

What has been said about reproduction as a criterion of life does not always apply. In the highly organized societies of the social insects some individuals—the workers—are naturally sterile. For example, a honeybee colony consists of a queen, thousands of sterile female workers, and a small number of male drones. A queen mates only once in her lifetime of 10 to 15 years, and she lays both fertilized and unfertilized eggs. The unfertilized eggs develop into drones; the fertilized eggs develop into females. If the female *larvae* are fed a rich diet they develop into fertile queens, but if they are fed a restricted diet they develop into sterile workers. The developmental environment of these workers has negated their potential of reproduction. The same is true for humans who are sterile because of some environmental accident or some inherited malady, for example, castration caused by an accident, or sterility resulting from a hormonal imbalance.

Living things respond to certain changes in the environment; when these changes elicit a response in an organism they are called stimuli. Changes in light intensity, temperature, pressure, and the chemical nature of the air or water are examples of stimuli that elicit responses in living organisms. Some specific examples are insects flying toward a light, animals seeking shade on a hot afternoon, eyes being inflamed in an area of highly polluted air, wild deer fleeing from the hunter's foot sounds, and a dog's ability to follow the trail of a rabbit. This property of organisms to respond to stimuli or changes in the surroundings (environment) is known as *irritability,* and it is usually associated with movement. Types of animal responses are considered in Part II in some detail. Irritability enables living things to *adapt* to changes in the environment. Nonliving things also may be affected by changes in the environment, but such changes and movements are not adaptive.

The final characteristic of living organisms is *evolution,* that is, living organisms change in the characteristics that specify their forms and functions. Organisms undergo changes in their genetic material (mutate); these changes are passed on to the offspring and to succeeding generations. Such changes are the raw materials for evolution. Those mutations which provide an adaptive advantage to an organism will result in the organism contributing a greater number of offspring to the next generation than other members of the population. Thus the property of evolution is a function of populations of organisms and not of individual organisms. (An analysis of evolution is presented in Part V.)

In addition to the five functional characteristics, living organisms are characterized by their structure (body forms), their organization, and their composition. The structure of each organism is no haphazard array of materials. The organism is put together in quite a precise manner, and deviations from the precise order often result in severe incapacitation or death. This text discusses the organization of various organisms at several levels; indeed, there is a system of progressive organization called a *hierarchy of organization.* This hierarchy runs from *atoms* and *molecules* to *cells,* the units of structure and function of organisms. Cells are organized into *tissues,* which are groups of like cells that are structurally modified to perform a particular function. Tissues are combined into *organs,* and a number of organs functioning together constitute an *organ system.*

An organism, then, is composed of a certain number of organ systems that are integrated in the structural and functional organization of the individual. The hierarchy of organization of living things can be extended to the *supraorganismic* level. Organisms affect and are affected by each other; the relationships among organisms depend on both physical and biotic factors. Organisms of the same kind constitute *populations;* several specific populations living in the same environment are called *communities.* The community with its nonliving environment constitutes an *ecosystem.* As mentioned earlier the large, easily recognizable regions of the world (such as grasslands, coniferous forests, and deserts) are called biomes. This text emphasizes this hierarchy of organization from atom to biome.

WHAT IS BIOLOGY? WHAT IS ZOOLOGY?

Biology is the science of living things. The word biology is derived from the Greek *bios,* meaning "life," and *logos,* "the study of." Historically, knowledge about living things was developed somewhat independently by students of plants and by students of animals. As a result, many biologists think of two main subdivisions of biology—*botany,* the study of plants, and *zoology,* the study of animals. Other biologists feel that there are really three types of organisms—plants, animals, and microorganisms—and consider *microbiology* to be a major subdivision of biology. Table 1.1 gives some areas of study according to the taxonomic-based division of biology. This list is not comprehensive, but it gives some idea of the "natural areas" that have arisen according to the classification scheme. Included in Table 1.1 are the origins of these terms. This way of subdividing biology is sometimes called the *vertical method.*

The other major method of subdividing biology into disciplines is based on an operational or functional approach which cuts across taxonomic lines. Some of these are listed in Table 1.2. This type of scheme is sometimes called the *horizontal method* of organization. Since the scope of biology has practically no boundaries, many of the important advances, particularly in the past few years, have been made by workers who defy categorization into a particular branch of biology. How does one classify an individual who studies conditions for the origin of life on the primitive earth—biochemist, evolutionist, microbiologist, philosopher, or jack-of-all-trades?

Table 1.1 The Vertical Method of Subdividing Biology

DISCIPLINE	WORD ORIGIN	MEANING OF PREFIX	THE STUDY OF:	
Anthropology	Gk. *anthrōpos*	Man	Natural history of man	
Mammalogy	L. *mamma*	Breast	Mammals	
Ornithology	Gk. *ornis*	Bird	Birds	
Herpetology	Gk. *herpeton*	Reptile	Reptiles	Zoology
Ichthyology	Gk. *ichthys*	Fish	Fishes	(Gk. *zōon,* animal)
Entomology	Gk. *entomon*	Insect	Insects	
Helminthology	Gk. *helmins*	Worms	Parasitic worms	
Protozoology	Gk. *prōtos* *zōon*	First Animal	Protozoa	
Bacteriology	Gk. *baktērion*	Small rod	Bacteria	
Virology	L. *virus*	Poison	Viruses	Microbiology
Phycology	Gk. *phykos*	Seaweed	Algae	
(Algology	L. *alga*	Seaweed	Algae)	Botany
Mycology	Gk. *mykēs*	Fungus	Fungi	(Gk. *botanē,*
Bryology	Gk. *bryon*	Moss	Mosses and liverworts	pasture) or
Pteridology	Gk. *pteris*	Fern	Ferns	Phytology

Table 1.2 The Horizontal Method of Subdividing Biology

DISCIPLINE	WORD ORIGIN	MEANING OF PREFIX	THE STUDY OF:
Morphology	Gk. *morphē*	Form	Form and structure
Anatomy	Gk. *ana*	Up	Organisms as determined by dissection
	tomē	Cutting	
Histology	Gk. *histos*	Tissue	Tissues by microscopy
Cytology	Gk. *kytos*	Hollow vessel	Cells
Physiology	Gk. *physis*	Nature	Functions and activities of cells and organisms
Taxonomy	Gk. *taxis*	Arrangement	Classification
Ecology	Gk. *oikos*	Household	Relationships between organisms and their environment
Genetics	Gk. *genesis*	Descent	Heredity and variation
Embryology	Gk. *embryon*	Embryo	Formation and development of organisms
Paleontology	Gk. *palaios*	Ancient	Fossils and fossil impressions
	on	Being	
Evolution	L. *evolvere*	To unroll	Descent of species
Zoogeography	Gk. *zōon*	Animal	Distribution of animals
	gē	Earth	
	graphein	To write	
Phytogeography	Gk. *phyton*	Plant	Distribution of plants
	gē	Earth	
	graphein	To write	
Biochemistry	Gk. *bios*	Life	Chemistry of organisms
	chemeia	Transmutation	
Biophysics	Gk. *bios*	Life	Biological phenomena in terms of physical principles
	physis	Nature	
Immunology	L. *immunis*	Free	Resistance of organisms to infection
Radiobiology	L. *radius*	Ray	Effects of radioactivity on biological material
	Gk. *bios*	Life	
Endocrinology	Gk. *endon*	Within	Study of hormones and their effects
	krinein	To separate	
Psychobiology	Gk. *psychē*	Soul	Related areas of psychology and biology
Limnology	Gk. *limne*	Lake or marsh	Freshwater lakes, ponds, and streams

Because workers have become specialized in various aspects of biology, many investigations are carried on by *team research* in which zoologists, botanists, microbiologists, chemists, physicists, physicians, and mathematicians collaborate.

With the advent of many new research techniques and a resultant explosion of knowledge, there has been a tendency to divide biology into a new set of horizontal categories consisting of *molecular biology, cellular biology, developmental biology, organismal biology,* and *population* and *community biology.* This method of division will be called *modified horizontal* because the categories are more inclusive than those in the horizontal method of division. Several college biology curricula have been organized along the lines of the modified horizontal method. Molecular biology encompasses biochemistry and biophysics, and presumably can be said to include all aspects of biology which take a molecular approach to the problems and their solution. Cellular biology simply may include all approaches to structure and function of cells. Included are the chemical and physical organization, energetics, transport, mobility and stabilizing mechanisms of cells, growth and division, differentiation, and development. Developmental biology is much broader than the traditional embryology; it includes development from the molecular level to gross structural levels. The phenomena of regeneration, wound repair, and aging are included in developmental biology.

It is obvious that there is considerable overlap among molecular biology, cellular biology, and developmental biology. All of them involve investigations at the molecular level, and all involve the flow of information in biological systems; the term *molecular genetics* is often used to refer to these aspects of biology.

Organismal biology focuses on whole organisms. It is concerned with such matters as functional and developmental anatomy, phylogeny, comparative physiology, psychobiology, and ecology. Population and community biology involve a part of traditional ecology. In this field the primary concern is with the structure and dynamics of populations, communities, ecosystems, and with the ecological aspects of natural selection.

The three methods of dividing biology—vertical, horizontal, and modified horizontal—do not delineate many aspects of applied biology. Biology interacts with the space sciences, earth sciences, mathematics, physical sciences, social sciences, and humanities. Among these applied fields are animal husbandry, plant breeding, medicine, agriculture, pharmacology, conservation, horticulture, bioclimatology, and many others.

CONCEPTS OF ZOOLOGY

This introductory chapter has touched on several areas of zoology as a discipline; the vastness and complexity of the discipline are apparent. It is reasonable for one to wonder at the outset if the concepts of zoology can be stated in a brief outline. These concepts should be fundamental ideas that serve as the skeleton of zoology. The following twelve concepts would be suggested by most professional zoologists.

1. Living systems obey the laws of chemistry and physics.
2. All organisms are composed of cells and cell products (the cell concept).
3. Living cells are able to convert energy from one form to another.
4. Metabolism is catalyzed by enzymes which are under genetic control.
5. Many vitamins are related structurally to coenzymes.
6. Hormones regulate many cellular and organismal activities.
7. As a result of evolution, living systems are organized, structurally and functionally, from atom to biome to carry out a variety of specific functions.
8. Control or regulatory mechanisms exist at all levels of organization.
9. Life comes only from living things by reproduction (biogenesis rather than abiogenesis).
10. DNA is the genetic material (RNA serves this role in certain viruses), and genetic potential is transmitted from generation to generation through genes (gene theory).
11. The primary factor in organic evolution is the number of offspring which survive and become parents of the next generation.
12. Organisms interact with their biological and physical environments.

The remainder of this chapter is devoted to the exploration of each of these concepts in anticipation of the remaining chapters.

Concept 1 The rapid increase in understanding many aspects of zoology has led to the idea that biological systems obey the laws of chemistry and physics without invoking a vitalistic force. Some basic chemistry and physics are discussed in Chapter 3. Other aspects of chemistry and physics are discussed in chapters where they are related particularly to the subject matter.

Concept 2 The cell concept (all organisms are composed of cells and cell products) was formulated by Schleiden and Schwann, a botanist and a zoologist, respectively, in 1838 and 1839. Cells are discussed specifically in Chapter 4 as seen by the light microscope and as revealed by the electron microscope and many other modern techniques. As special functions are taken up in many other chapters, the characteristics of the specialized cells which perform the specialized functions are explored.

Concept 3 Living organisms are able to convert one form of energy to another. Cells which carry out photosynthesis convert light energy into chemical energy. All cells carry out some type of food breakdown. In these processes the chemical energy stored in the food is released with the production of heat, waste products, and energy. The energy is often released in the form of adenosine triphosphate, ATP. ATP can be used to drive most biological processes: cell division, transport across membranes, bioluminescence, synthesis of many compounds by the organism, muscular contraction, and nervous transmission, to name a few. The major concepts involved in biological conversion of energy from one form to another are found in Chapter 5, Bioenergetics. Energy conversion in biological systems is pertinent to many other processes, and the energetic considerations of these processes are taken up in the appropriate chapters.

Concept 4 The metabolic basis of living systems has had an interesting history. The concepts of enzymology, the study of biological catalysts, are

1. All enzymes are proteins or mainly proteins.
2. Enzymes are specific in function.
3. One region of an enzyme, its *active site,* is crucial to the enzyme's activity. The substrate (s) is (are) bound to the three-dimensional active site during the enzyme's activity.
4. The function of an enzyme, like that of all catalysts, is to lower the energy barrier to the reaction.

The fundamentals of enzyme action are set forth in Chapter 3. Enzymes, like other proteins, are under genetic control. This means that each