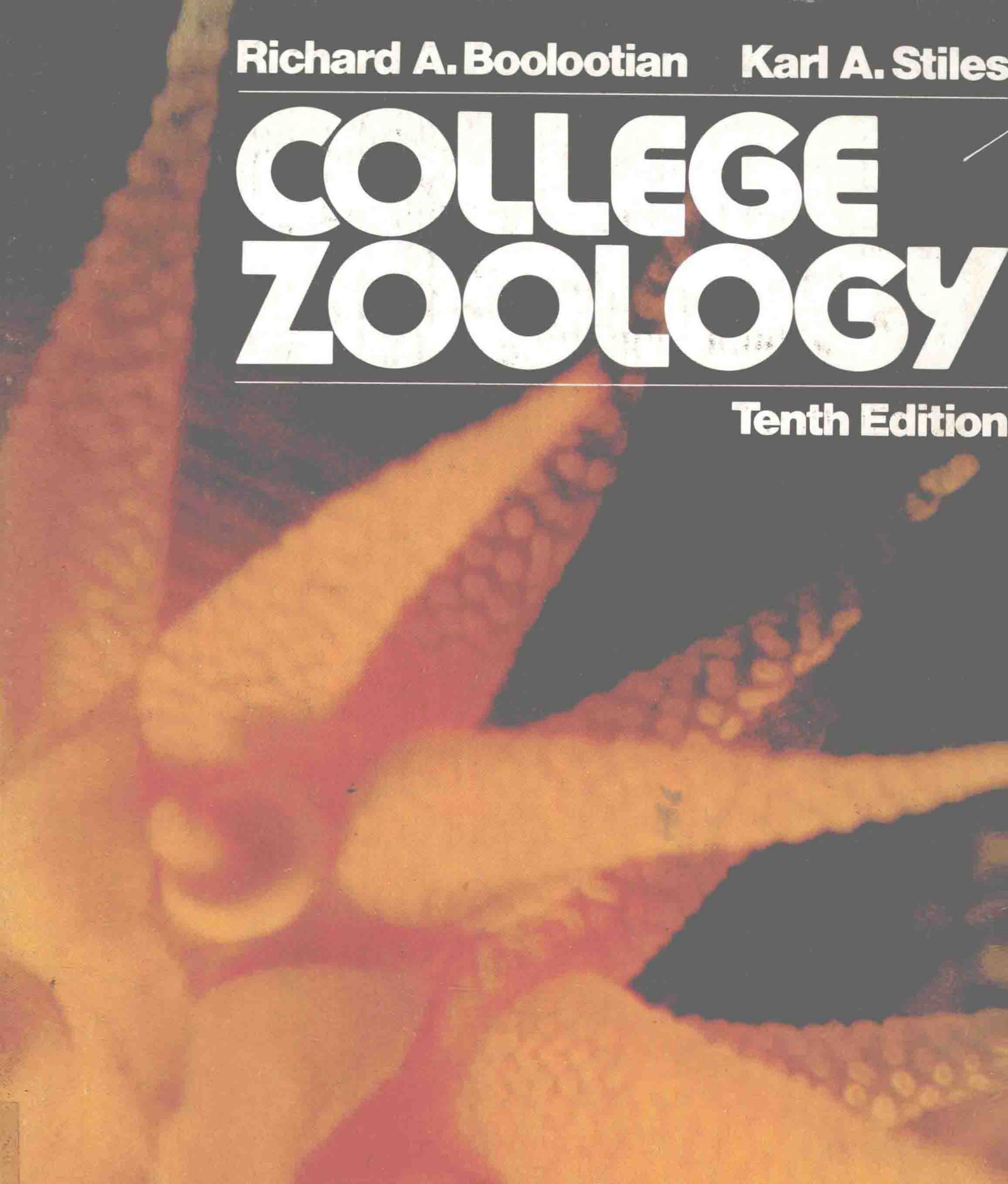
Richard A. Boolootian Karl A. Stiles

COLLEGE ZOOLOGY

Tenth Edition



Tenth Edition

COLLEGE ZOOLOGY

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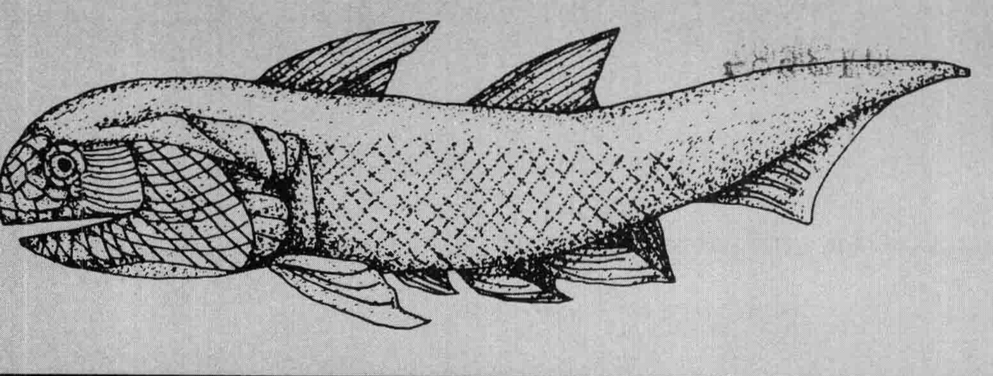
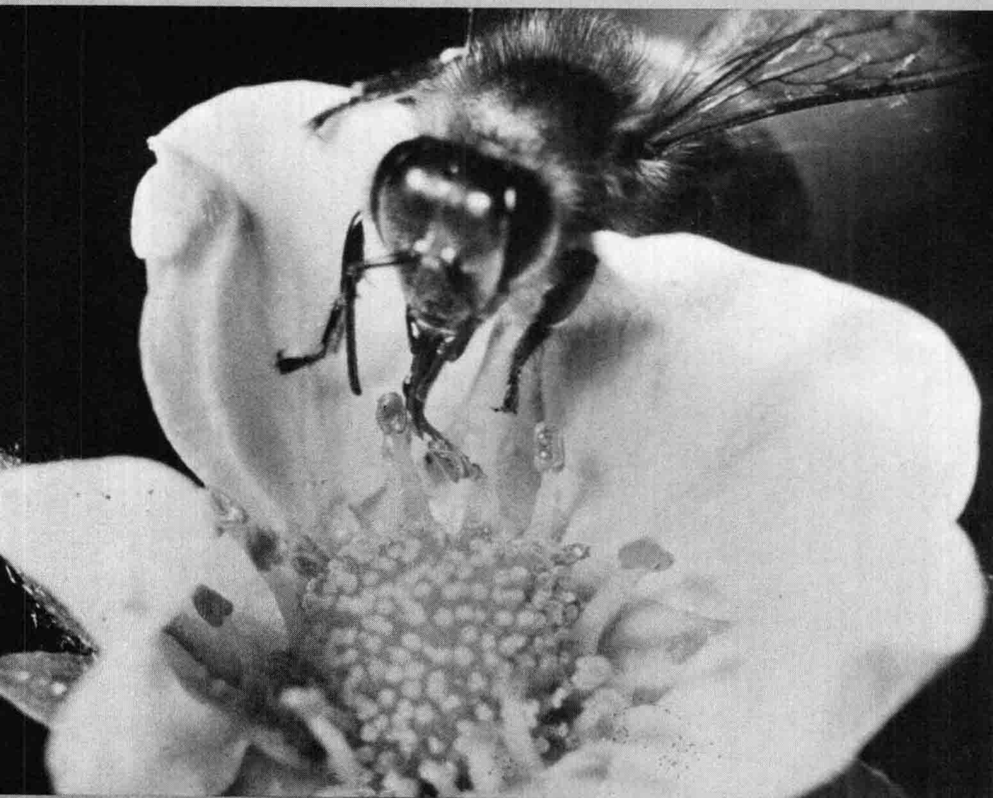
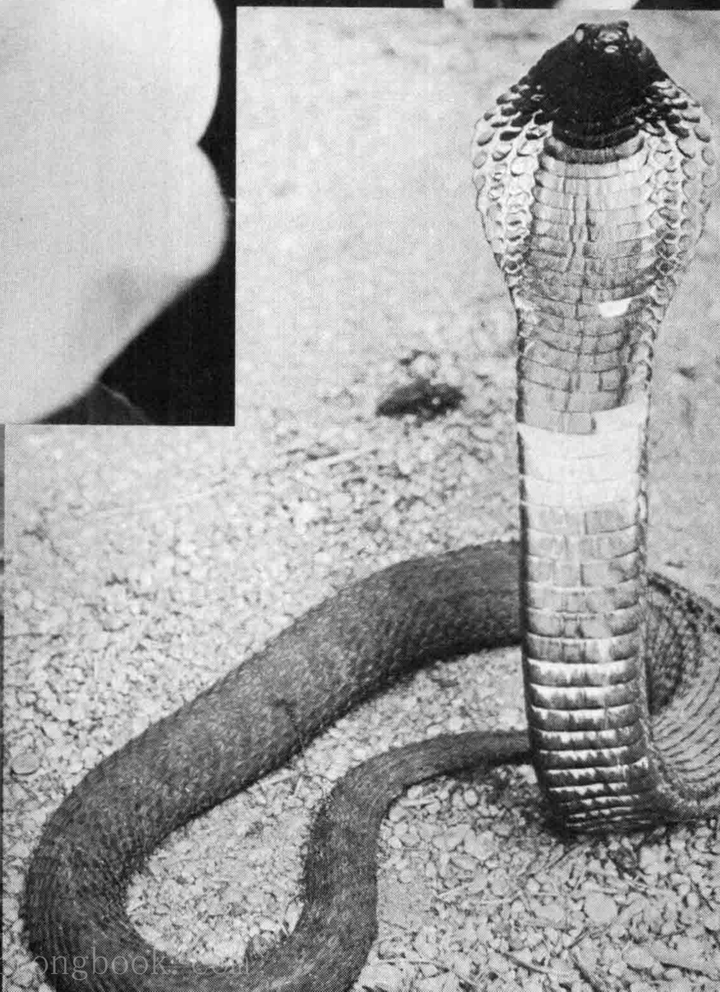
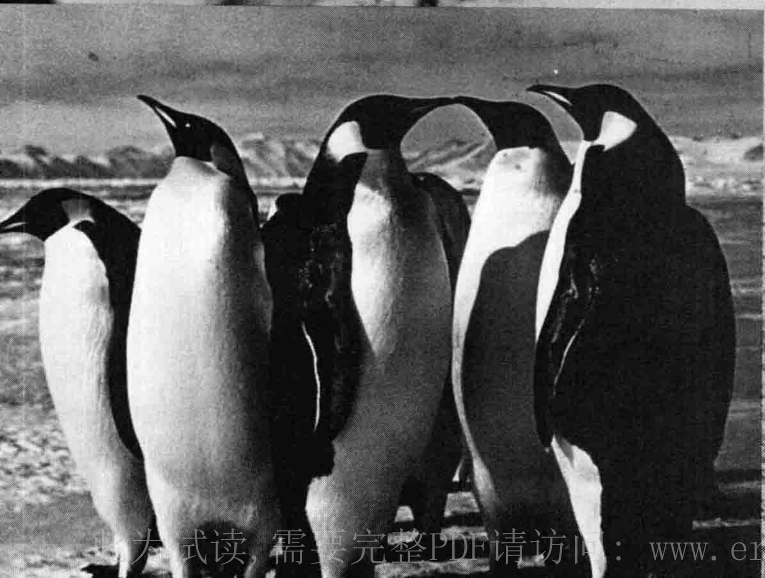


to
Mary Jo

Preface

It is compelling yet comforting to note the evolution of *College Zoology*. First written in 1912, this text is in its tenth revision as the body of biological information has increased. Material has been added, expanded, and deleted over the years. But more than a simple update of the facts, each new edition of the text presents a more finely honed and developed knowledge of zoology.

As you study zoology and meet the myriad of organisms that once lived or with whom you presently cohabit the earth, keep in mind the unifying themes that connect all living things: respiration, reproduction, motility, and irritability. Examine all organisms as to how they eat, breathe, move and reproduce. Notice how these phenomena become increasingly diverse and complex as you move up the evolutionary tree.

Zoology is a dynamic discipline. Advances in research elucidate finer measures of biological similarity and diversity between animals. Zoologists experiment daily and postulate new hypothesis. Issues of concern for human health and welfare change as everyday life becomes more complex. Although this text retains the same basic approach as past editions, new facts and theories are presented, outdated sections have been deleted, and several chapters have been reorganized. New headings have been employed to better organize the chapters. For example, the organization of headings concerning anatomy and physiology of a phylum, class or representative species was made more consistent among all chapters. These changes improve the overall organization and avoid the neglecting of minor phyla and organ systems that were discussed in less detail.

The text is divided into four parts, containing forty-two chapters, followed by a classification appendix and a glossary.

Part I, Molecules, Cells and Tissues, introduces basic principles of living organisms, namely cell chemistry, morphology, histology and organology. New information and diagrams on nucleic acids, lipids, proteins, and membrane structure are included.

Diversity and adaptation are covered in Part II. Taxonomic and phylogenetic treatments have been updated. The order of chapters now reflects the increasing evolutionary complexity in each group discussed. In the phylum by phylum discussions (Chapters 5–23), consistent descriptions of representative species preceed the more comparative "Origins" and "Relationships" sections. New sections on Phylum Gnathostomulida and Phylum Priapulida are included.

In the class by class discussions of the chordates (Chapters 24–30), the increased familiarity of these organisms allows an evolutionary discussion to introduce each chapter. In addition, new information concerning chordate evolution, especially on the reptiles, mammals and birds, has been added. New views on the origins of birds and endothermy are included. Chapter 30 has a new section on Order Pinnipedia and Order Lagomorpha.

Part III, Morphology, Physiology, and Continuity of Animals (Chapters 31–39), presents updated information about animal behavior, a survey of the organ systems, and discussions of genetics, including a discussion of molecular genetics, heredity and embryology. New information has been added to the discussion on the molecular mechanisms of muscle contractions and nervous control. There is increased emphasis on the lymph system and an additional section on the immune system.

The treatment of zoogeography and ecology, evolution, and *Homo sapiens* comprise Part IV, Species Dynamics (Chapters 40–42).

I am personally indebted to Peter Dalby, Ernest C. Ander-

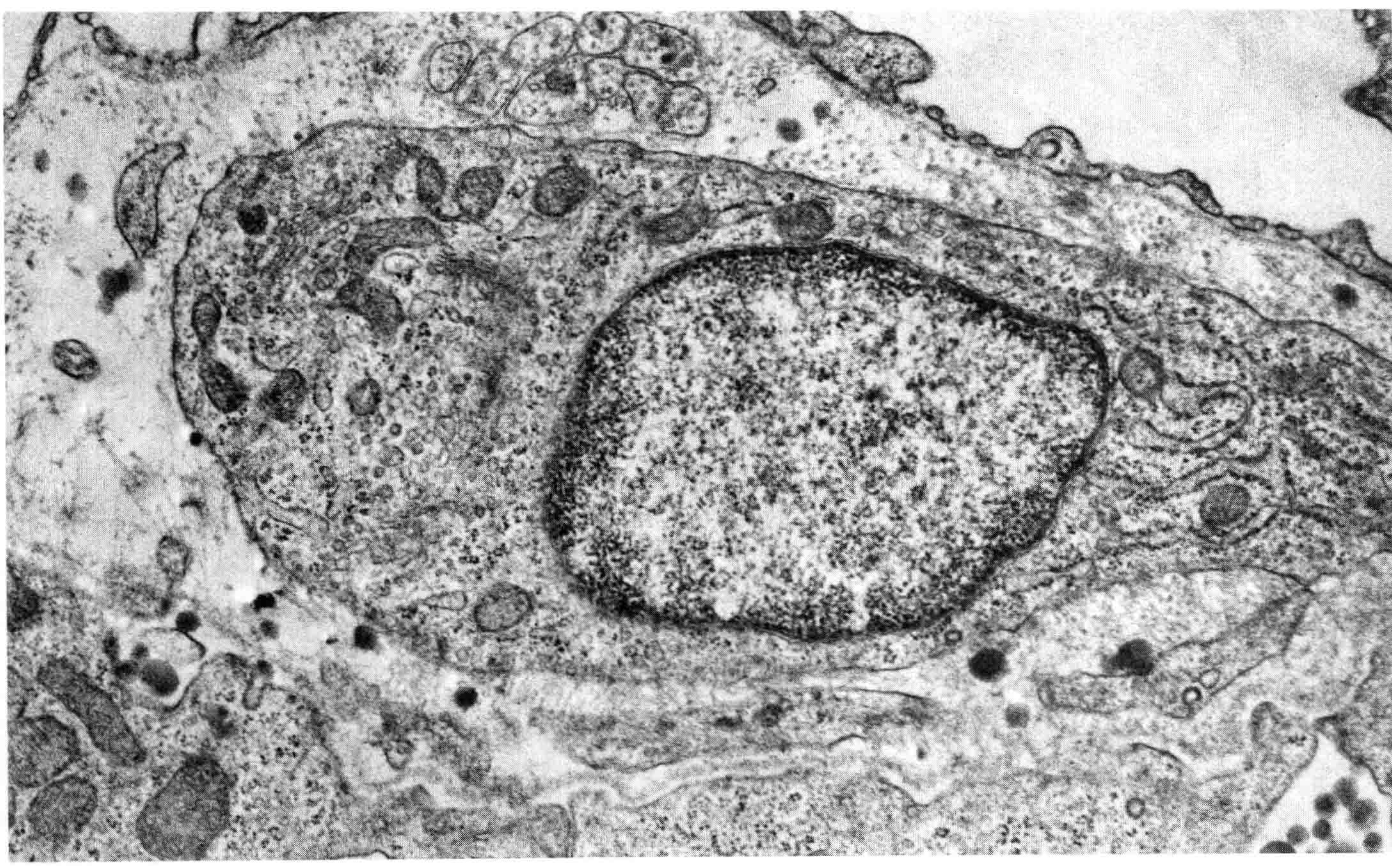
son, and Walter K. Taylor, who offered invaluable comments during the writing of this edition. I am especially grateful to Professor Harold L. Zimmack for his careful reviews of the galleys and page proofs. To Thomas Broderick and Charles Manske, I extend my appreciation for their superb work on manuscript research and preparation. To Kathleen Marce, my sincere thanks for her administrative talents which served to expedite the publication of *College Zoology*. And to my wife, my deepest gratitude for her continued support.

Because the author has been the final judge for all that is presented in this book, he alone is responsible for errors or misinterpretations of facts. Suggestions for improvement are not only welcome, but greatly appreciated.

R. A. B.

Contents

Molecules, Cells, and Tissues



1

Introduction

Prehistoric cave paintings provide us with some of the first evidences of human self-awareness relative to the rest of the animal world. Hunting scenes depict bison, horses, reindeer, and other prey, even dolphins, though the interpretation of such figures is open to some dispute. Some say that they may have been purely representational paintings; others believe that such scenes served as a medium for casting magic spells. In any event these paintings indicate a differentiation of the human mind from the natural and physical environment. Since then, our dependence and awe of the animal world has never ceased, but our perspective has become increasingly particularized and specialized.

The beginnings of human involvement with animals was mainly based on various kinds of dependence. At first, animals provided primarily food, but soon they were also used for the construction of hide-covered shelters; for clothing in the form of furs, wool, and hides; and for transportation. The transitions of man from hunter to shepherd to farmer are milestones along the road toward civilization.

Animals have also been worshipped through the ages. The ancient Egyptians venerated Hathor, the goddess of love, who was represented variously as having the horns, ears, or the entire head of a cow. The Minoan culture in early Greece, about 200 B.C., worshipped the Minotaur, a diety that was half man, half bull. In India even today cattle are considered sacred by the Hindus.

In addition, animals have been important to man in other ways. Human affection for animals has existed since ancient times; the companionship of a pet is highly valued by many. Animals have also served as scientific inspiration; airplanes and jets are patterned after birds, submarines after fish. One important modern use of animals is in scientific research. Hundreds of thousands of studies using animals have contributed to health improvements for people and domesticated animals. Practically every medication presently available was tested first on animals to determine probable effects and toxicity. The recent interest in environment and wildlife protection and other nature-oriented activities reflects an appreciation of animals as part of a delicately balanced global ecosystem.

Modern zoology can trace its roots back to Aristotle, the natural philosopher, who lived in Athens in about 350 B.C. Aristotle based his theories of the living world upon extensive empirical observations. He collected animals and plants and compared their external body forms, internal anatomies, behaviors, and embryological developments. From such observational data he distinguished patterns that allowed him to classify some 540 animal species according to gradations in structural organization. When Aristotle began to study animals carefully, looking for similarities and differences among them, he generated a classification scheme *(taxonomy)*. Today this scheme reflects evolutionary relationships that are intimately mingled with form–function considerations. More than a million types of animals have now been identified and described, and new ones are rapidly being added to the list. The taxonomy used today is of a different nature than that employed by Aristotle; Aristotle's scheme was essentially descriptive, whereas modern taxonomists look to traits and principles of anatomy and physiology that reflect evolutionary relationships.

It is important to remember that zoological studies include not only those of animals but also those of humans, as humans are a significant link in the evolutionary chain. Some human characteristics, although not totally unique to us, are much more developed; these include our ability to construct and implement complex tools, our capacity to communicate and deal with abstractions, and our ability to manipulate our environments.

Scientific Method

The scientific method is an important part of the science of zoology, and one objective of any zoology course is to understand and experience this method of discovery. The scientific method is a system of inquiry composed of five steps: observation, problem, hypothesis, experiment, and theory. Its aim is to predict the principles and forces that underlie what we observe.

The scientific method begins with *observation*. A phenomenon is noticed either directly by the senses or indirectly by instruments that extend the range of our receptors. The mind of the scientist becomes activated; he or she wants to know *how*, *what*, and *why*.

From the observation, a *problem* is recognized. One asks a question about the observation. This question must be both relevant and testable.

The third step of the scientific method is the formation of a *hypothesis;* that is, one "guesses" what the answer to the problem might be. The hypothesis is based on the researcher's training and intuition. It is not critical to the scientist that the hypothesis be correct, for either a refutation or a confirmation will help to answer the problem.

Next the hypothesis is *tested*, either through pure observation or, more frequently, through *experiment*. An experiment is simply a group of observations that are made in a specified fashion. The scientist attempts to hold all conditions constant except the one that he or she is testing, so that any result observed can be attributed to that variable. In addition, these results almost invariably are compared with those of a *control*. A control is, in the case of a zoological study, an animal or group of animals similar to the experimental organism, but on which no manipulation occurs. The control is an attempt to produce a natural state against which the results of the experimental manipulation may be compared. In some cases an animal may act as its own control if base rates (data on the animal before manipulation) are considered. All experiments must be repeated. Repetition by the original investigator and also by independent researchers ensures that the observed results are reliable and not due to chance (luck) or artifacts (errors).

When all the data are tabulated and analyzed, a *conclusion* based on these results is reached, and the hypothesis is either accepted or rejected. Note that the hypothesis may be refuted by one contrary case but that supportive evidence cannot prove a hypothesis; it can only give credence to it. Experimental evidence for a hypothesis is the basis for the final step in the scientific method: the formulation of a *theory*. Theories are statements about the probabilities of future observations of the tested phenomenon. All theories are broader than the specific conditions tested in the experiment. Theories are predictions of the principles and forces that underlie what we observe.

Functioning within the strict confines of the scientific method requires a particular set of attitudes on the part of the experimenter. These include intellectual honesty, open-mindedness, caution in reaching conclusions, and vigilance in searching for flaws in hypotheses, theories, evidence, and conclusions. Ancient philosopher-scientists constructed broad, sweeping generalizations and then tried to fit their observations of the natural world into this preconceived framework. Modern science attempts to do just the opposite; theories are constructed from observations whose underlying causes are tested to the greatest degree of confidence by experiments. Scientific inquiry is thus a dynamic process. The results of each tested observation suggest theories and future observations that provide an increasingly greater probability of our predicting the "how," "what," and "why" of the phenomena that we observe.

General Characteristics of Animal Life

The study of zoology is practically limitless in its complexity. To the diversity of contemporary animals may be added the fossil record of nearly 4 billion years of evolution. Nevertheless, some characteristics are shared by all animals.

All animals are composed of *cells,* small volumes of protoplasm enclosed within a membrane. Living things show a constancy of morphology (form), and so animals can usually be distinguished from each other because of their characteristic structures. Morphology also clearly distinguishes (in most cases) plants from animals; plant cells have thick cell walls, and many manufacture food through photosynthesis. Most zoologists agree that form and function are inseparable. In a sense, form is the evolutionary outcome of demands placed on the organism by the environment. This point will become more obvious as the student becomes familiar with the classification categories.

Animals and even their individual cells respond quickly to certain changes in their environments, such as fluctuations in temperature or blood solute concentration. This capacity to respond is referred to as *irritability.* Most animals can move at least part of their bodies. *Locomotion* of the entire body is a trait of the majority of animal species.

A major distinction between living systems and nonliving matter is *metabolism,* the process transforming environmental material into specifically organized and active substances, combined with the ability to break down such substances when necessary and derive usable energy from them. The building-up process, or synthesis, is called *anabolism;* the breaking-down process is called *catabolism.*

Living systems also have the capacity for *growth,* although the capacity has definite limits (see Chapter 3). Growth is the result of anabolic activity. Nonliving things may increase in size or mass, but, because the new material is merely added to the outside, the term growth is inappropriate for the inorganic realm. Other metabolic processes (catabolism) must exist to liberate the stored energy for a variety of life activities other than growth. The body must be fed and maintained, injuries must be healed, old or dead cells must be replaced, waste materials must be removed, and so on. An organism is by nature a dynamic *steady-state system;* that is, energy is always expended to maintain the complex ordered structure of an organism. Growth will occur only when internal synthesis exceeds the maintenance requirements of the organism, all of which occur at the expense of energy extracted from the environment via *metabolism.*

Living organisms are usually capable of *reproduction.* This is the process whereby new individuals of the same species are formed, either sexually or asexually (Chapter 38).

Certain characteristics are shared by all animals: a cellular structure, consistent morphology, adaptation of form and function to environmental demands, irritability, locomotion, metabolism, growth, maintenance, and reproduction.

Maintenance of the Species

Just as individual animals do not live isolated from their physical and biological environments, so too does each belong to the historical continuity of life. Every animal belongs to a *species,* a population of potentially interbreeding individuals that resemble one another more closely than they do members of other species. The success of any species is measured in terms of its capacity to produce new individuals that will manifest its traits (characteristics). Assuming that each individual is equipotent in terms of reproductive ability, there still exist potential hindrances to perpetuation of the species.

There must be sufficient food, and, almost as important, there must be sufficient living space. Species require suitable *habitats* in which to live. Marine animals do not, for example, roam throughout the ocean; they are restricted to specific habitats by such factors as water temperature and water depth. The physical environment of this planet provides three major habitats for life: marine, freshwater, and terrestrial. Each presents a very different array of environmental demands to which animals must adapt. A fourth major habitat is provided by the bodies of living animals ans plants. Indeed, the body surfaces and internal organs of living organisms provide the greatest diversity of habitats on the planet. It is not surprising that these habitats have been invaded by a bewildering variety of *parasites* that gain food and shelter at the expense of their *host.* A lack of either food or space will cause reduction in population size or even extinction of the species.

Reproductive success is influenced by competition with other species within the same habitat. Competition for food and living space is often severe, but so too is *predation* by members of other species. Every species is equipped with a bewildering constellation of morphological and physiological adaptations that help to ensure its viability through its reproductive lifetime. Animals must also be able to contend with parasitic organisms and, in some cases, coexist with other organisms in symbiotic and other relationship forms in which both parties benefit. For example, microorganisms within the stomachs of a cow digest the cellulose in the grass that the cow ingests, and then the cow digests them.

The Realm of Zoology

Scientific observation has uncovered so many aspects of animal life that zoology has diversified into a myriad of allied sciences (Fig. 1-1). Each of these subdivisions has direct relevance to every member of the animal kingdom, and it is the zoologist's job to coordinate the data of these allied disciplines to formulate a universal view of the animal kingdom.

The function of this text is to introduce you, the beginning student, to the fascinating yet sometimes confusing world of animals by presenting current basic information in this realm of science, known as *zoology*, the study of animals.

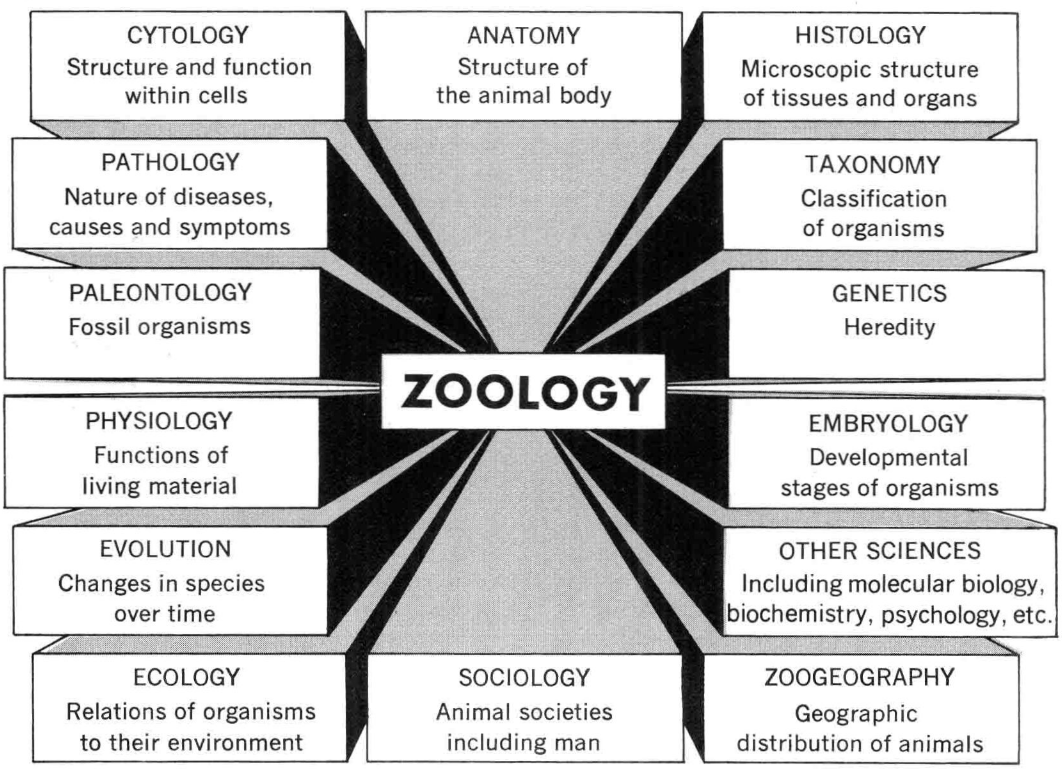
The author believes that certain areas of zoology merit separate consideration, apart from the standard taxonomic considerations. These include animal behavior; body systems such as the skeletal, digestive, circulatory, reproductive, and nervous systems; and such topics as genetics, embryology, zoogeography, ecology, evolution, and human biology.

The Value of Zoology

As you undertake the study of zoology, its value to your everyday life will become evident.

Zoology has both direct and indirect application to all the sciences listed in Figure 1-1, but its relevance

Figure 1-1. The main subdivisions of zoology with descriptions.



does not stop there. Medicine, dentistry, optometry, animal husbandry, agriculture, and many other disciplines partially rely on, and interact with, zoology. Zoology can offer much to the understanding of current world problems such as population growth, famine, war, space travel, pollution, energy sources, and, most important, the coexistence and survival of humans and other species on this earth.

General Information for the Student

Zoology is a vast science, and no single text can present an all-inclusive view of the animal kingdom. Many details are not provided in this textbook, for the following reasons:

1. Some zoological data are clearly beyond the scope of this introductory text.
2. Many aspects of zoology are still unknown—zoology is a dynamic field of scientific inquiry.
3. The scope of zoology—animals and their interrelationships with their environments—is in a constant state of flux; evolution is an ongoing process.

At various points in the text, in-depth information about particular subjects is presented. Usually the student is not required to "know it cold" but, rather, to understand the implications of what is presented. Such detailed treatments are included to point out trends, culminations of trends, or general zoological principles. For example, in Chapters 2 and 3, the student will learn about subcellular organelles called mitochondria. It will be noted that mitochondria function in energy metabolism and that, generally, more mitochondria are present in relatively active cells. The student will then be expected to predict where mitochondria concentrations would be high, and where they would be low. As an example, a spermatozoan (Chapter 38) has a tail that whips about, pushing the sperm forward; the middle piece of the sperm is composed of vast amounts of mitochondria that provide energy for the tail locomotion. Thus students should attempt to integrate such general principles with their developing awareness of the particulars of the animal kingdom.

The sets of *review questions* at the end of each chapter are important aids to such comprehensive understanding, for they frequently require an integration of concepts. Some knowledge of taxonomy (naming and classification) and nomenclature (vocabulary) will be necessary as well, but their true utility comes in providing the framework for the communication and synthesis of general zoological concepts, particularly when different animal groups are compared and contrasted.

One appendix and a glossary are included in the text. The *classification appendix* is more exhaustive than the taxonomy information supplied in the body of the text and can serve as a quick reference throughout your study of zoology. The concluding extensive glossary provides concise definitions of zoological terms. The *index* at the end of the book cross-references topics for easy location in the main body of the text.

The author's final suggestion is to look for trends throughout the text. That will make zoology easier to comprehend and more relevant to human concerns. Aim for intuitive understanding rather than for mechanical recitation of facts. The science of zoology will become more intriguing, and this deeper level of comprehension of its intricacies will prove useful to your understanding of life.