Introduction to
Animal Biology

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PREFACE

Introduction to Animal Biology was written in direct response to the demand for a short text to accompany a one-term course in zoology. It is designed to present to the beginning college student the principles of animal biology needed to appreciate the world in which we live and to be used as a foundation for students who plan to continue studies in the biological sciences. Although this text is based upon the fifth edition of our larger *General Zoology, Introduction to Animal Biology* is more than a simple abridgment of that text. To introduce a fresh perspective, a careful selection of the most important concepts and examples in each chapter was made by one of us who had not written the chapter originally. The subjects retained were then reviewed by all of us and reorganized and rewritten as deemed necessary. Each part thus emerges as more of a combined effort than has been true in the earlier editions of the larger book. Not all sections have been reduced to an equal extent, for we recognize that some parts are of greater importance in a one-term treatment of the subject than are others. In addition, we have made improvements in the coverage of certain subjects, we have updated material and we have made some changes in the organization of the subjects within the text. Despite the necessity for brevity in a short text, we have attempted to highlight the major principles and concepts of zoology, to emphasize adaptive design in functional morphology, to direct the attention of the student to major trends in the evolution of processes and of animal groups and to provide some sense of diversity within the major phyla of animals. For each topic we have tried to provide an overview to which factual detail may be appended and related.

The unifying theme throughout this text is the common problems at the cellular, organismal and population levels that are faced by all animals from the simplest to the most complex. All are composed of cells and we begin Part I by exploring the common problems of exchanging materials between cell and environment, of obtaining energy and of synthesizing a variety of molecules. Part II deals with the common physiological problems that all animals must meet to survive and with the similarities and differences in the way this is accomplished by different animals. All animals must be protected and supported, move, exchange gases, transport materials within their bodies, control and regulate their internal environment, sense changes in their internal and external environment and make appropriate responses. All must be able to reproduce their kind if the species is to survive. Part III considers the hereditary factors that enable animals to perpetuate their kind and, at the same time, provide variability so that the group can evolve and adapt to its ever-changing environment. Evolution has resulted in the tremendous adaptive diversity that is explored in Part IV. Members of each phylum have occupied all of the habitats and niches that their basic morphology and physiology permit. Part V considers the population level of zoology. The behavioral interactions of animals with other members of their own and different species are considered in Chapter 36 and the ecological interactions of animals and plants with each other and with their chemical and physical environment are dealt with in the concluding chapter. We have included a glossary at the end of the book that provides the derivations and meanings of the more important zoological terms. An additional feature of this book is the series of colored pictures of selected animal types that should assist the student in appreciating what the animals look like in their native environment.

We are deeply grateful for the care and artistry with which Susan Heller, Ellen Cole, William Osborne and Mary Ann Nelson prepared the line drawings for this text. We are indebted to Aldine Publishing Company, Vernon G. Applegate, Robert S. Bailey, Betty M. Barnes, Russell J. Barnett, Angus Bellairs, Kurt Benirschke, C. M. Bogert, Roger K. Burnard, S. H. Camp and Company, Austin H. Clark, Cleveland Aquarium, Allan D. Cruikshank, H. R. Duncker, Earl R. Edmiston, Alfred Eisenstadt, Frank Essapian, Don Fawcett, D. Fraser, W. H. Freeman Company, Golden Book Encyclopedia of Natural Science, J. N. Hamlet, Harcourt Brace Jovanovich, Harper & Row, Fritz Goro, C. Lynn Haywood, A. A. Knopf, Herbert Lang, Terry L. Maple, MBL-Woods Hole, Daniel Mazia, Jacques Millot, James W. Moffett, Daniel Moreno, Peter Morrison, W. W. Norton and Company, Jean Luc Perret, J. D. Pye, Col. N. Rankin, E. S. Ross, P. R. Russell, Hugh Spencer, E. P. Walker, L. W. Walker, Time-Life Books, John Valois and Weidenfeld and Nicholson, who have kindly permitted us to use certain of their drawings and photographs.

Our special thanks are due to Robert Lakemacher, Biology Editor, who assisted with the planning for this book and with the completion of the manuscript and its preparation for publication. We are indebted to the many members of the staff of the W. B. Saunders Company who have given so liberally of their time and care in preparing this revised edition. We want especially to thank Miss Patrice Lamb for her part in the preparation of this edition. Finally, we want to express our thanks to Kathleen Callinan for her assistance in preparing the Index.

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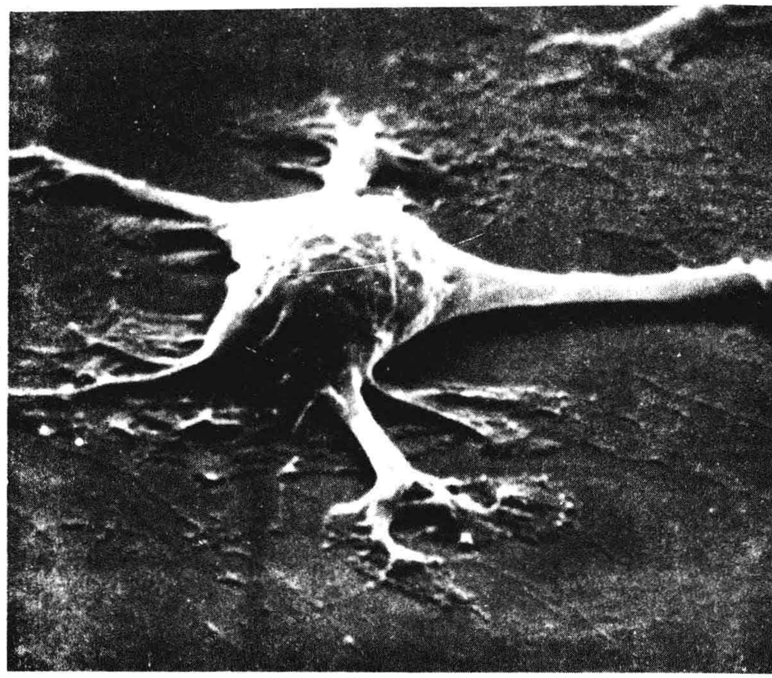

Part One

THE CELLULAR BIOLOGY OF ANIMALS

Chapter 1

INTRODUCTION: THE PHYSICAL AND CHEMICAL BASIS OF LIFE

1.1 ZOOLOGY AND ITS SUBSCIENCES

Zoology, one of the biological sciences, deals with animals and the many different aspects of animal life. More than one million different kinds of animals have been described and classified. Each of these kinds has become adapted, through a long evolutionary process, to the particular set of environmental circumstances under which it survives best. In addition to the ones living at present, a host of other kinds of animals have lived in past ages but are now extinct.

Modern zoology concerns itself with much more than the simple recognition and classification of the many kinds of animals. It includes studies of the structure, function and embryonic development of each part of an animal's body; of the nutrition, health and behavior of animals; of their heredity and evolution; and of their relations to the physical environment and to the plants and other animals of that region. Zoology is now much too broad a subject to be encompassed by a single scientist or to be treated thoroughly in a single textbook. Most zoologists are specialists in some limited phase of the subject. The sciences of **anatomy, physiology** and **embryology** deal with the structure, function and development, respectively, of an animal. Each of these may be further subdivided according to the kind of animal investigated. **Parasitology** deals with those forms of life that live in or on and at the expense of other organisms. **Cytology** is concerned with the structure, composition and function of cells and their parts, and **histology** is the science of the structure, function and composition of tissues. The science of **genetics** investigates the mode of transmission of characteristics from one generation to the next and is closely related to the science of **evolution,** which studies the way in which new species of animals arise and how the present kinds of animals are related by descent to previous animals. The study of the classification of organisms, both animals and plants, is called **taxonomy.** The science of **ecology** is concerned with the relations of a group of organisms to their environment, including both the physical factors and the other forms of life which provide food or shelter for them, compete with them in some way or prey upon them.

Some zoologists specialize in the study of one group of animals. There are **mammalogists, ornithologists, herpetologists** and **ichthyologists,** who study mammals, birds, reptiles and amphibians, and fishes respectively; **entomologists,** who investigate insects; **protozoologists,** who study the single-celled animals; and so on.

Advances in chemistry and physics have made possible quantitative studies of the molecular structures and events underlying biological processes. The term **molecular biology** has been applied to analyses of gene structure and function and genic control of the synthesis of enzymes and other proteins, studies of subcellular structures and their roles in regulatory processes within the cell, investigations of the mechanisms underlying cellular differentiation and analyses of the molecular basis of evolution by comparative studies of the molecular structure of specific proteins — enzymes, hormones, cytochromes, hemoglobins—in different species.

1.2 THE SCIENTIFIC METHOD

The ultimate aim of each science is to reduce the apparent complexity of natural phenomena to simple, fundamental ideas and relations, to discover all the facts and the relationships among them. The essence of the scientific method is the posing of questions and the search for answers, but they must be "scientific" questions, arising from observations and experiments, and "scientific" answers, ones that are testable by further observation and experiment.

There is, however, no single "scientific method," no regular, infallible sequence of events which will reveal scientific truths. Different scientists go about their work in different ways. The ultimate source of all the facts of science is careful, close observation and experiment, free of bias and done as quantitatively as possible. The observations or experiments may then be analyzed, or simplified into their constituent parts, so that some sort of order can be brought into the observed phenomena. Then the parts can be reassembled and their interactions made clear. On the basis of these observations, the scientist constructs a **hypothesis,** a trial idea about the nature of the observation or about the connections between a chain of events or even about cause and effect relationships between different events. It is in this ability to see through a mass of data and construct a reasonable hypothesis to explain their relationships that scientists differ most and that true genius shows itself.

The role of a hypothesis is to penetrate beyond the immediate data and place it into a new, larger context so that we can interpret the unknown in terms of the known. There is no sharp distinction between the usage of the words "hypothesis" and "theory," but the latter has, in general, the connotation of greater certainty than a hypothesis. A **theory** is a conceptual scheme which tries to explain the observed phenomena and the relationships between them, so as to bring into one structure the observations and hypotheses of several different fields. The theory of evolution, for example, provides a conceptual scheme into which fit a host of observations and hypotheses from paleontology, anatomy, physiology, biochemistry, genetics and other allied sciences.

A good theory correlates many previously separate facts into a logical, easily understood framework. The theory, by arranging the facts properly, suggests new relationships between the individual facts and suggests further experiments or observations which might be made to test these relationships. A good theory should be simple and should not require a separate proviso to explain each fact; it should be flexible, able to grow and to undergo modifications in the light of new data. A theory is not discarded because of the existence of some isolated fact which contradicts it, but only because some other theory is better able to explain all of the known data. A hypothesis must be subject to some sort of experimental test — i.e., it must make a prediction that can be verified in some way — or it is mere speculation. Conversely, unless a prediction follows as the logical outgrowth of some theory it is no more than a guess.

The finding of results contrary to those predicted by the hypothesis causes the investigator, after he has assured himself of the validity of his observation, either to discard the hypothesis or to change it to account for both the original data and the new data. Hypotheses are constantly being refined and elaborated. There are few scientists who would regard any hypothesis, no matter how many times it may have been tested, as a statement of absolute and universal truth. It is rather regarded as the best available approximation to the truth for some finite range of circumstances.

The history of science shows that, although many scientists have made their discoveries by following the precepts of the ideal scientific method, there have been occasions on which important and far-reaching theories have resulted from making incorrect conclusions from erroneous postulates or from the misinterpretation of an improperly controlled experiment! There are instances in which, in retrospect, it seems clear that all the evidence for the formulation of the correct theory was known, yet no scientist put the proper two and two together. And there are other instances in which scientists have been able to establish the correct theory despite an abundance of seemingly contradictory evidence.

The proper design of experiments is a science in itself, and one for which only general rules can be made. In all experiments, the scientist must ever be on his guard against bias in himself, bias in the subject, bias in his instruments and bias in the way the experiment is designed.

Each experiment must include the proper **control group** (indeed some experiments re-