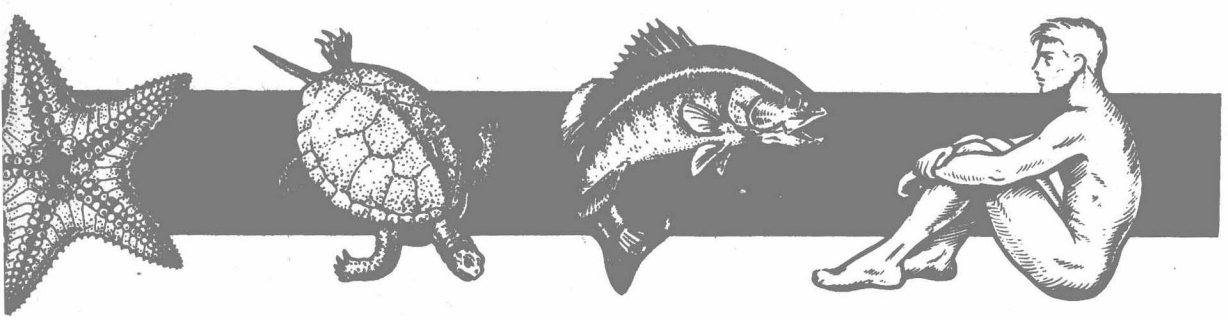
GENERAL ZOOLOGY



GAIRDNER B. MOMENT Goucher College

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EDITOR'S INTRODUCTION

The science of Zoology embraces a bewildering array of species — over a million of them, in all probability — as well as innumerable facts about them and the relationships between them. Nevertheless, zoology cannot stand apart from the other life sciences; it is part of a greater whole, the science of biology. As one penetrates the minuteness of an animal cell, analyzes its chemical composition and physical organization, and notes its beautiful relation of function to structure and its ways of reproducing itself and handing on its characteristics to new cells, the similarities of all living things become unmistakably evident. Again, as one gropes outward from the individual animal to a comprehension of its behavior in a community of living things and to a comprehension of its evolution as a species adapting itself in time and space, it becomes equally evident that no animal is an island, but each is a part of a continent, the slightest and remotest change in which affects it.

The teaching of zoology must above all else be oriented in these larger ways. It requires to be a part of biology, not a self-limited discipline. Encyclopedias and compendia have their useful places, but not as textbooks for the instruction of students in the nature of a science which is ever reaching out to encompass further relationships, big and little. The present textbook admirably fulfils this primary requirement of a good zoology text, perhaps because it has been written by a teacher whose outlook is primarily biological, in the broadest sense, but especially because the writer worked out his ideas first of all in a textbook of general biology, one long recognized as outstanding.

There is a second requirement of a good zoology textbook, and indeed of any science text. It must delineate its subject as a science, as a body of knowledge arrived at by careful observation and controlled experiment, through the correction of numberless errors, and often through the ultimate synthesis of apparently contradictory views into more perfect theory. If there is anything that perverts the true nature of science, it is a book that seems to say to its reader: "Take this as truth. Here are all the latest facts and the most up-to-date information, vouched for on the authority of the great scientist, Professor So-and-so." If seekers after scientific truth are in some measure to attain it, they must learn the nature of scientific methods and must absorb the dedicated spirit of a Darwin or a Huxley. They must come to see the importance of suspended judgment and of the open mind. They must perceive how our present concepts grew into being and what is the evidence upon which they rest.

This spirit pervades the present book and renders it unique among zoological texts. Fortunate the student who can thereby be helped to achieve an insight into what science truly is. Whether he becomes a zoologist or not, he will certainly be an informed citizen and a liberally educated man.

H. Bentley Glass

The Johns Hopkins University

PREFACE

The plan of this book, like the trident of Neptune, has a handle and three prongs. The handle is the orderly presentation of the animal kingdom, phylum by phylum. Students will always need to know what animals there are, what they are like, and how they are related to each other. Classification forms the international framework of both zoological knowledge and zoological research.

The first prong on this handle is a sharp insistence on those aspects of zoology which are of human importance. They are many and great — in economic affairs, in medicine, in our thinking about man himself. The second prong is an emphasis on the recent discoveries and the new insights that have been won in many fields of zoological research but giving special prominence to two areas. The most outstanding advances during the past decade have clearly been in the fields of biochemistry and of animal behavior. The present and future importance of these fields can scarcely be exaggerated, hence the prominent position accorded to them throughout the text. The third prong is an attempt to give the student a strong sense of the methodology and of the great tradition of our science which is one of the major forces shaping Western civilization.

Surely it is in a proper balance of these three aspects of zoological study — its human importance, the new knowledge in the rapidly advancing fields of biochemistry and animal behavior, and a sense of the living tradition of zoology itself — that a much needed scientific wisdom is to be found.

As any zoologist would under like circumstances, the author found that each chapter threatened to grow into a book. Many hard choices had to be made about what to include and what to leave for supplemental reading. All the chapters adhere to a general pattern, but for each group of animals special emphasis is given to topics of particular importance or scientific relevance in that particular group. For example, muscle structure and physiology, and also nerve-muscle reflexes, are discussed extensively with the amphibians, on which most of the basic research has been done and which are clearly the most satisfactory for student use in the labora-

tory. At the same time, relatively little is said about muscles of the reptiles, rather, attention is given to the problems of longevity and senescence. For these problems will inevitably become more and more important with the steady advance of medicine, and the reptiles present special advantages in the study of them.

Anglicized names are preferred whenever possible. When the Latin form is used for a phylum or a class, the older terminations are employed. For orders and families the growing trend toward standardized endings has been followed. Orders are designated by the termination *-iformes* because it is distinctive, easily remembered, can be readily anglicized as *-iform,* and is already widely adopted for orders among birds, fishes, and other groups. The ending *-idae* is used for families for similar reasons. Of course the stems of the names remain unchanged.

It is a pleasure to thank Professor H. Bentley Glass of the Johns Hopkins University for his expert and conscientious work as editor. I am also happy to acknowledge the aid of Mr. Hervey Brackbill, Professor D. E. Davis of the Johns Hopkins School of Hygiene and Public Health, and Professor S. F. Osler of Goucher College who generously read and criticized chapters in their respective specialties. I also owe a debt of gratitude to all those who have so readily contributed photographs for which credit is given elsewhere in this book, but I am under especial obligation to Dr. William Amos, Dr. E. B. Harvey, Mr. George Lower, Dr. Roman Vishniac, and the United States Fish and Wildlife Service. The superb and authoritative drawings of Mr. Elmer Smith of the Museum of Comparative Zoology of Harvard University speak for themselves. It has been a delight as well as an immense advantage to work with Mr. Smith. Finally, I wish to acknowledge the constant help of my wife, Ann Faben Moment, the cheerful interest of my children, and the insights I have gained from teaching two decades of students both men and women.

GAIRDNER B. MOMENT.

BALTIMORE, MARYLAND

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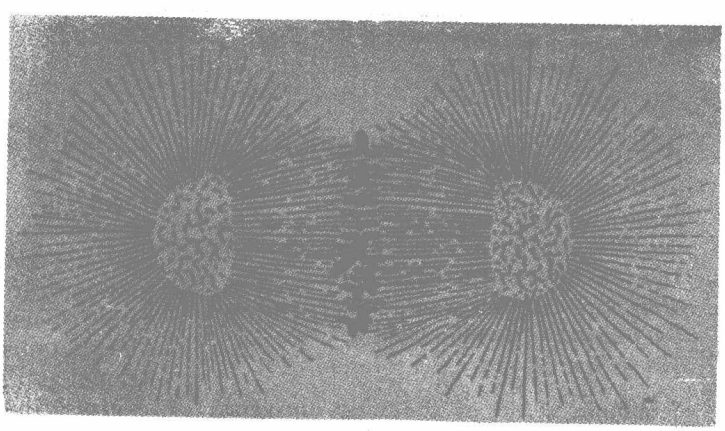
PART 1 SOME BASIC CONCEPTS



Mitosis in the sea urchin egg. From a modern American classic by Edmund Beecher Wilson (1856–1939). Ever since the summer of 1875 when Oscar Hertwig first clearly saw the events of fertilization while studying sea urchin eggs, these cells have remained standard research material for the investigation of the physics and chemistry of life.

ZOOLOGY, THE SCIENCE OF ANIMAL LIFE

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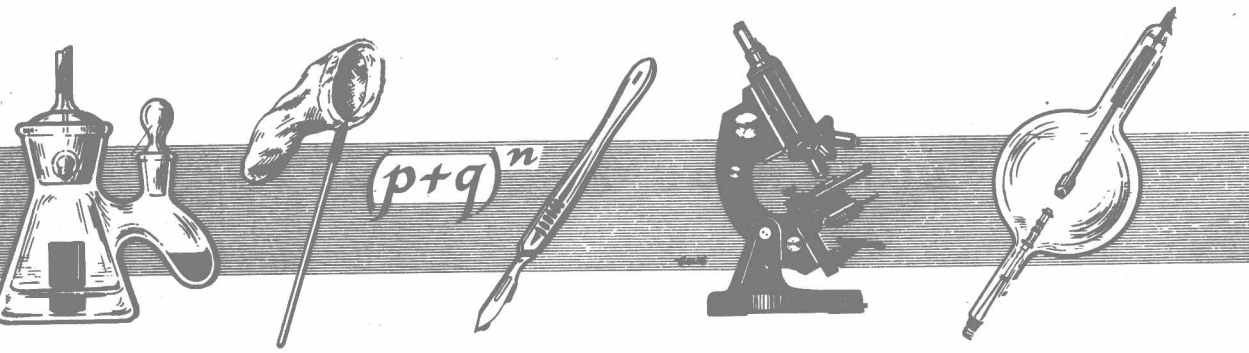

OBJECTIVES OF ZOOLOGICAL STUDY

Diverse motives have impelled men to study animal life. In different parts of the world, and in different centuries, one or another of these motives has become predominant, but in general, four main objectives can be distinguished.

Economic. One of the most universal of these objectives is the economic. Every modern nation — whether capitalistic, communistic, socialistic, democratic, or authoritarian — maintains special research stations to discover and develop new types of animals or better ways of caring for them. "What is the best way to feed a pig?" is typical of the thousands of practical questions that arise. Zebu cattle from India are being crossed with Jersey and Holstein breeds from Europe in attempts to combine general hardiness against heat and poor food with superior milk and beef qualities. Russian zoologists have crossed the one-humped camel with the two-humped camel and produced a larger, tougher draft animal than either parent. Most nations with seacoasts, even Italy and Israel on the Mediterranean, invest huge sums in marine research to help uncover the mysteries of the sea, and thereby enable their fishing fleets to improve their catch. It is even supposed by a few enthusiasts that it will someday be possible to plant and harvest on the

seas as on the land. Most research programs, however, have limited objectives, such as determining the optimum feed for cattle or the most effective poison for an insect pest.

Medical. A second universally understood motive is the medical one. So deep set is the unity of life that discoveries made on one animal can be applied to others far removed in the animal kingdom and even to man himself. There are certain problems requiring experiment with a warm-blooded mammal, perhaps a dog or a monkey, before any conclusions can be applied to human beings; but the basic investigations can often best be carried out on cold-blooded animals like frogs or starfish.

The modern theory of the way the heartbeat is controlled was formulated, in good part, from work on the heart of *Limulus,* the horseshoe crab. The ideal place to study nerve conduction is not in the nerve of a man or a frog but in certain giant nerve fibers of *Loligo,* the squid, a close relative of the octopus. At first sight what animals could possibly be more different from man than the one-celled protozoans, *Amoeba, Paramecium, Tetrahymena,* and their like? Yet the requirements for vitamins and other dietary constituents of these organisms are almost identical with those of man. This is not to say that one-celled animals living in a test tube of water will soon replace white rats as the standard test animals for nutritional studies; yet important new facts are now being uncovered in these microscopic animals that are of wide and perhaps universal importance among animals. In a thousand different ways zoological knowledge aids healthy and abundant living.

Psychological and Sociological. A third general objective of zoological studies is the attempt to gain greater insight into the problems of psychology and the social sciences. The behavior and personality of men and women cannot be adequately understood without a knowledge of their nervous systems, their endocrine glands, and even of their general bodily conformations. It would be hard to name a topic about which

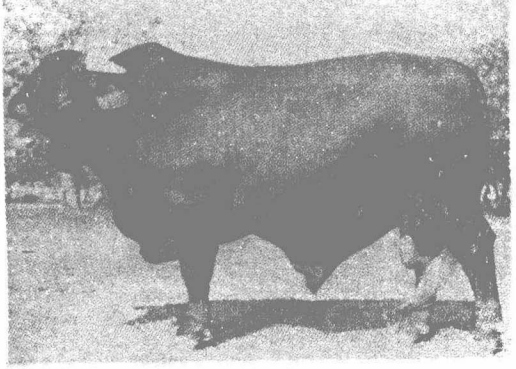

Fig. 1–1. Two-year-old bull, the result of crossing Asiatic heat-resistant cattle with European beef cattle (Santa Gertrudis).

there has been a greater spate of nonsense, both well-meaning and of evil intent, than about the relationship between human heredity and human character. Animal behavior has always been a study of great fascination for its own sake. Recent discoveries about the animal nervous system and the rise in the past decade of a new school of thought about animal psychology seem likely to result in important revisions in the field of human psychology.

Lure of the Unknown. The economic and medical objectives are compelling, and the desire to create a basic foundation on which to build an understanding of psychology and sociology is widespread and enduring. Yet all together they do not explain the sustained drive that, generation after generation, has pushed forward the boundaries of zoological knowledge. There is a final factor that must be reckoned with. As Aristotle, the ancient Greek philosopher and founder of the scientific study of animals, said, "All men by nature desire to know." This desire to know ranges all the way from a simple curiosity about the number of humps on the offspring of the cross between a one-humped and a two-humped camel — (the answer is one hump) to a bold intention to plumb the depths of the universe and fathom the secrets of the life that is in it. This thirst to know and to understand is as natural to man as the desire for food or air. It is one of the characteristics that distinguish man from what our ancestors called "the beasts."

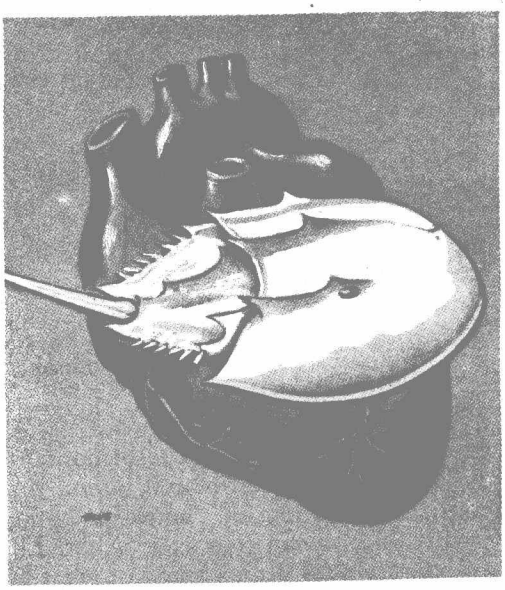

Fig. 1–2. *Limulus,* the horseshoe crab, through which some principles governing the action of the human heart were discovered.

The motivations of zoologists, like those of other men and women, vary from one individual to another and are often mixed. The urge of the stamp collector or the detective story addict may predominate in one case while those of the ambitious surgeon or the lover of beauty and the creative artist predominate in another. Bertrand Russell, probably the most eminent of modern mathematicians and philosophers, once said that if knowledge be true and deep it brings with it a sense almost of comradeship with other seekers after truth in other lands and distant times. The feeling of partnership in a long tradition of human enterprise plays an important role in the progress of zoology.

Truth and Motivation. It is essential to remember that the general objectives and the personal motivations of investigators are no test whatever of the truth or falsity, the importance or triviality, of a discovery. The validity of Mendel's laws of heredity is completely independent of the nationality, religion, skin color, or table manners of Gregor Mendel. We do not know whether Mendel spent those long hours in his garden crossing peas primarily as refreshment from the routines of monastery life, because he was fascinated with the problem of inheritance, as some sublimation of an interest in sex, or through a determination to show that an Augustinian could make scientific discoveries of the first rank. Some, all, or none of these factors may have been involved. The only relevant question is whether or not his experiments can be repeated and whether his conclusions hold for other organisms besides peas.

The importance of objectives lies in their ability to lead an investigator toward certain discoveries and to blind him to others. There is an old saying in German laboratories that you can make a discovery without meaning to but not without knowing it. This is another way of saying that lucky accidental discoveries come to prepared minds. Many a bacteriologist had seen that troublesome mold, *Penicillium,* ruin his cultures of bacteria before Alexander Fleming had the insight to see that in this obstacle to routine bacteriological research lay a spectacular method of curing bacterial diseases.

CLASSIFICATION: TAXONOMY

Essential to any useful science of zoology is some system of classification. The number of animal types presents a bewildering jungle of thousands, tens of thousands and, in some groups, hundreds of thousands of different kinds. Over 14,000 species of bony fish have been described, nearly 2,000 species of tapeworms, well over half a million species of insects. From whatever point of view zoology is approached, whether that of agriculture, medicine, economics, or pure research, a science of classification is necessary to bring manageable order out of this confusion.

If an insect, for example, is destroying crops or transmitting a human disease, the first thing that must be done is to determine definitely what kind of insect it is. Only then can the accumulated knowledge of

entomology — the science dealing with insects — be brought to bear on the case. Only by knowing with certainty the species of the animal under observation can any new discoveries about it be integrated into the great body of scientific knowledge. Thus taxonomy, as the science of classification is called, forms the indispensable framework of zoological science.

A further aspect of taxonomy must be recognized. The naming of animals appears to fill some deep and all but universal human desire. It will be recalled that in the Biblical story of creation, one of the first acts of Adam was to name the animals.

Since the era of the American Revolution taxonomy has become increasingly concerned with animal relationships. At first the similarities between different kinds of animals were not thought of as due to descent from common ancestors. Under the leadership of the great Swedish naturalist, Carl Linnaeus, (1707–1778), and the anatomists Georges Cuvier (1769–1832) in France and Richard Owen (1804–1892) in England, the similarities between animals were regarded as the expression of a logical relationship, just as different kinds of triangles, quadrilaterals, or other geometrical figures are related. There is some truth here. How much? This is a hard question, perhaps a deep-reaching one, and it remains still unanswered.

With the publication in 1859 of the *Origin of Species* by Charles Darwin (1809–1882), the study of classification became part of the study of evolution. Ever since, taxonomic arrangements of animals have been intended to reflect evolutionary relationships. The closer two kinds of animals are thought to be to a common ancestral population, the closer they are placed on the taxonomic scale.

PRESENT SYSTEM OF CLASSIFICATION

The present-day system of classification is an indispensable tool for all branches of biological science. At its base is the **binomial** or **Linnaean system** which was established by Carl Linnaeus in the eighteenth century. According to this scheme each distinct kind of animal receives two names which together constitute the scientific name of the species. Thus all men and women belong to the species *Homo sapiens*, all wood frogs to the species *Rana sylvatica*. The name written first is the name of the genus, which is defined as a group of related species. Most frogs belong to the genus *Rana*. Following the generic name is the specific name. The wood frog bears the specific name *sylvatica*. Note that the generic name is capitalized while the specific name is not. Both names are italicized unless part of a title. The word species is the same in both singular and plural. Specific names are commonly adjectives referring to some characteristic of the species; thus *sylvatica* (of the woods) is the specific name for the wood frog, and *pipiens* (chirping) for the common laboratory frog. However, the specific name may be taken from a person as in the case of *Rana catesbeiana*, the bullfrog (whether male or female), which is named after Mark Catesby, an early American naturalist.

This system is an international one, the same in Baltimore as in Bombay. The rules governing the use of the binomial system, as well as the way in which species and genera are organized into larger categories, are formulated by the International Commission on Zoological Nomenclature. This commission is controlled by the International Congress of Zoology, a voluntary organization meeting from time to time in various parts of the world.

The form of both generic and specific names must be Latin. The scientific name of an animal should be followed without punctuation by the name of the zoologist who first described and named the species and by the date on which he published his work. Thus *Felis leo* Linnaeus (1758) indicates that the lion was so named by Linnaeus himself in 1758. *Felis oregonensis* Rafinesque indicates that the puma of the Rocky Mountains and Pacific Coast was named by Constantine Rafinesque — a Turkish-born American naturalist of French and German ancestry.