Comparative Vertebrate ANATOMY

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by

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New York City

THE UNIVERSITY OF CHICAGO PRESS

Chicago · Illinois

THE UNIVERSITY OF CHICAGO PRESS, CHICAGO 37
Cambridge University Press, London, N.W. 1, England
The University of Toronto Press, Toronto 5, Canada

 Published February 1922. Second Edition September 1942. Sixteenth Impression 1959. Composed and printed by THE UNIVERSITY OF CHICAGO PRESS, *Chicago, Illinois, U.S.A.*

PREFACE TO THE FIRST EDITION

Several years ago the method of procedure in the laboratory work in vertebrate zoölogy in this University was changed from the type plan, then in common use, to the comparative plan. No doubt a similar change has been made in many other institutions. A suitable manual for the comparative method has, however, hitherto been lacking; the present publication attempts to supply this need. There can scarcely be any question of the superiority of the comparative method of study of vertebrate anatomy, for by this method the student not only learns all of the anatomical facts brought out by the type method but he also acquires an understanding of vertebrate and human structure which he is quite unable to attain by the older method of study. In view of the fact that the majority of the students taking courses in vertebrate anatomy at the present time are preparing for medicine, it seems obligatory that they be taught the "history of the human body" as revealed by the study of the anatomy of vertebrates. On the other hand, the comparative method is perhaps faulty in that it may not give the student a clear-cut picture of the characteristics of the various classes of vertebrates. Thus, while the student readily learns the history of the aortic arches, for example, he does not readily associate any particular group of vertebrates with a particular condition of the arches, when the comparative method is followed. This defect should probably be remedied in the lecture part of the course. I have attempted to remedy it to a slight extent by introducing the section on the general features of typical chordates.

In this manual I have attempted not only to give the laboratory directions for the dissection of the various systems, but I have also presented in connection with each system a very brief, generalized, and simplified account of the development and evolution of that system. It has seemed to me essential that such an account precede or accompany the laboratory directions in order to give a significance to the facts revealed by the dissection at the time when the student becomes aware of those facts. As the consultation of other texts during a dissection is inconvenient and time-consuming, I have thought it the most practical plan to include such explanatory matter in the laboratory manual. Simple illustrations have been added to clarify further the explanations. I have not, however, in the least intended that these explanations should take the place of reading in the standard texts of comparative anatomy. The students should understand that additional outside reading is expected of them.

In making such brief and generalized explanations as are given here it is impossible to take into account numerous exceptions and variations. I must therefore ask the indulgence of the expert in vertebrate anatomy for the omission of qualifying clauses in the explanatory accounts of the various systems; in some cases, no doubt, I have been unaware of the exceptions; in others I have knowingly omitted them on the grounds that statements of exceptions are more confusing than informative to the beginner.

To avoid confusion the explanatory matter is printed in slightly smaller type than the directions for the dissections.

I have included in the manual such materials as seemed to me to bear most directly on the story of the evolution of the various systems. I have treated the skeleton and the coelom at greater length than is commonly the case. The prevailing neglect of the study of the skeleton in courses in vertebrate anatomy seems to me unjustifiable in view of the importance of this system in the study of phylogenetic and evolutionary questions. It is true that skeletal material is somewhat expensive to purchase and maintain, but a good many of the more important materials can be prepared by the instructor or students. In presenting the vertebral column I have adopted Gadow's conception of the development of the vertebrae from separate arcualia, an idea also adopted by Schauinsland in his account of the development of the vertebrae in Hertwig's *Handbuch*. The conception would appear to be correct in the main, and at least furnishes a simple explanation for the variety of vertebral columns encountered among vertebrates. The difficulties attending the study of the coelom and mesenteries do not seem to me to justify one in disregarding them. I hope the simplified account I have presented after long study and thought on the matter will aid in the understanding of this complex subject. As to the animals to be dissected, the elasmobranch must naturally form the point of departure in the study of comparative anatomy. I have described the skate in addition to the dogfish, since some teachers prefer it; it is certainly more favorable than the dogfish for the study of the nervous and urogenital systems, but less favorable, in my opinion, for the study of the circulation. The not infrequent scarcity of dogfish in recent years makes it desirable that an alternative form be described. The bony fish is omitted because its specialized structure would confuse rather than aid the student in following out the evolution of the systems. The frog is so often used in general and beginning courses that it seems superfluous to consider it here. Further, the urodeles serve our purpose much better. I should like to have included *Cryptobranchus* as alternative to *Necturus*, but the limits of space forbade. The reptile is important for the purposes of a comparative course, and the turtle is perhaps the most readily obtainable form of sufficient size. The bird has been included since it seemed inadvisable to omit altogether an entire vertebrate class. I have described both the cat and rabbit, as the

former animal, though perhaps preferable in some respects, is not always readily obtainable.

At the University of Chicago the course consists of a brief glance at the external features of the lower chordates and of representative vertebrates; of all of the work given in the manual on the exoskeleton, endoskeleton, and muscles, with the exception of the muscles of *Necturus;* and of the complete dissection of the dogfish, turtle, and mammal, except the peripheral distribution of the cranial nerves in the mammal. The elasmobranch, urodele, and mammal would make a combination nearly as desirable.

The general statements and explanations given in the manual have been taken from standard works and original papers on comparative anatomy, vertebrate zoölogy and embryology, and human anatomy. I have adopted, for the most part, the usual accounts of the evolution of the various systems and parts, not regarding myself as competent to criticize them. In a few cases I have presented some recent views appearing in the literature. The laboratory directions and descriptions of the anatomy of the several animals have, however, been written entirely from the specimens. Practically the whole of the dissection has been performed twice, some of it more than twice. The dissections have been carried on simultaneously with the writing of the directions. In locating and naming the structures I have been assisted by various texts, manuals, and original papers. In a number of cases I have found it desirable to devise additional names or to change old names. I have employed the terms dorsal, ventral, anterior, and posterior as they are used in vertebrate anatomy, abandoning the usage common in human anatomy. This has involved a change in some familiar names, such as that of the "anterior" abdominal vein.

I have made a particular effort to use all technical words in a very precise and exact manner and to define each such word where it first occurs. One is continually surprised and annoyed in a study of vertebrate structure to note the loose and inexact way in which many terms are employed. It is, in fact, practically impossible to find any precise usage for many terms, such as urethra, bulbus arteriosus, peritoneum, olfactory lobe, perineum, and others. In such cases I have been compelled to adopt such a definition as seems consistent with the majority of the anatomical facts.

I have attempted nothing in this manual but a plain account of the anatomy of the several animals, which account the student follows. This "verification" type of laboratory manual has been recently subjected to much criticism, much of it, in my opinion, undeserved. The critics seem to forget that the student is not in reality engaged in "verifying" the statements in the manual; he is engaged in learning the anatomy of an animal by the shortest and easiest route, a route which the critics themselves would follow if confronted with an animal with which they were not familiar. It is my opinion

that human beings in general see chiefly that which is pointed out to them; this has been proved over and over again in the history of biology. The large number and complexity of the anatomical facts to be acquired, the limited time allowed for their acquisition, the large size of the classes, and the limited number of laboratory assistants available seem to me to necessitate that detailed and specific laboratory directions be provided. If the directions are not given in the manual, then the laboratory instructors are compelled to provide them verbally. Personally I am unable to see any pedagogical difference between directions and explanations written in the manual and those given out verbally by the instructor, but I do see a great deal of difference as concerns the time, patience, and energy of instructors and students. Our experience with laboratory manuals of the type in which the burden of discovery is left to the student is that the student becomes highly dissatisfied and that the instructors are brought into a state of irritation and fatigue by the continuous demands for assistance with which they are bombarded. Frankly, I believe in the conservation of instructors, and have written this manual with that end in view. In place of inserting questions in the laboratory manual our method is to hold thorough oral quizzes on the laboratory and textbook work at frequent intervals.

Although a number of drawings are called for in the manual, it is probable that each instructor will prefer to decide for himself what drawings are to be made. Drawings might profitably be omitted altogether, their place being taken by rigorous practical individual quizzes on the dissected specimen.

I am indebted to a number of authors and publishers for permission to reproduce figures from their publications. Due acknowledgment is made in the legends to these figures. I have not listed the numerous original papers to which I have referred, since most of them are given in the bibliographies appended to Kingsley's *Comparative Anatomy of Vertebrates* and Goodrich's account of the fishes in Part IX, first fascicle, of Lankester's *A Treatise on Zoölogy*. I am indebted to Dr. C. R. Moore, Dr. B. H. Willier, and Dr. J. W. Buchanan for calling my attention to errors and omissions in the first draft of the manual which has been used in the laboratory under their direction during the past two years. My thanks are also due to Mr. Kenji Toda for his patience and skill in drawing the illustrations. Finally, I wish to acknowledge the fact that the previous organization of the laboratory work along comparative lines, chiefly through the efforts of Dr. J. W. MacArthur and Mr. J. G. Sinclair, has facilitated the task of preparing this manual.

So laborious has been this task and so great is the number of facts to be considered that I can scarcely hope to have avoided errors, omissions, and statements lacking in clarity. I shall be more than grateful to have my attention called to them.

L. H. HYMAN

UNIVERSITY OF CHICAGO
November 1921

PREFACE TO THE SECOND EDITION

First of all I wish to thank the many users of the first edition of this book. Their generous opinion of its worth has enabled me to live a life of singular freedom and to devote myself exclusively to scientific research and writing.

In this revision not much change has been made in the laboratory directions. These were originally written directly from the dissections, and it has been deemed unnecessary to repeat the dissections. Some changes of terminology have been introduced, and errors have been corrected wherever my attention was called to them by teachers. Some new material has been introduced, especially in the skeletal and muscular systems; and, as before, directions for this have been written from the specimens themselves.

The revision concerns chiefly the textual material, which has been thoroughly revised and considerably expanded with the intention that the book shall now serve as a text as well as a laboratory manual. It is believed that students will not need to purchase any accompanying textbook, although a selection of books on comparative vertebrate anatomy and vertebrate zoölogy should be on hand for reference and consultation. The considerable enlargement of the chapters on general features and external anatomy of chordates was made with the same idea in mind—a more thorough covering of the field of vertebrate zoölogy so that an additional textbook is unnecessary. This material also was written from the specimens, and it is hoped that a variety of vertebrates will be available for study by the student while engaged on these chapters.

In the first edition I was content to adopt and present the standard explanations and stock evolutionary stories found in textbooks of the subject. The years between, however, have taught me to suspect all standardized accounts copied into a succession of college textbooks. These stories of the evolution of the vertebrate organ-systems stem mostly from the great group of German comparative anatomists of the last half of the nineteenth century. These men were pioneers and constructed their evolutionary series on the basis of incomplete and scattered evidence. Their views can no longer be accepted without critical examination. The textual material of the present revision is based wholly on the study of original literature and advanced treatises. In place of the impression of a static subject wherein everything has been worked out, gained from the usual textbooks, it aims to give the student a picture of a vast field full of controversial issues and unsolved problems, depending for their solution on future painstaking embryological and anatomical researches. An army of devoted workers is necessary for elucidating these many questions; but nowadays—alas!—all young biologists

want to be experimentalists, and hardly anyone can be found interested in the fields of descriptive embryology and anatomy.

Not only has the textual part of the book been much expanded, but a number of new figures have been added and some old ones, deemed erroneous, dropped out. Some of these figures are original; others are taken from the literature. Text and figures, it is hoped, will give as adequate and modern an account of the vertebrates and the evolution of their systems as can be expected within the limits of an undergraduate college course. It is obviously impossible to cover such a huge subject satisfactorily except in a treatise of several large volumes.

To such a treatise—the great German *Handbuch der vergleichenden Anatomie der Wirbeltiere*, edited by Bolk, Göppert, Kallius, and Lubosch—I wish to express my indebtedness. This work is indispensable to the student of comparative vertebrate anatomy and must serve as a guide in beginning the study of any system. It is a bottomless source of information on any facts one might want to know, although less satisfactory, perhaps, in giving connected accounts of the evolution of the systems. I also here wish to express my admiration for the comparative anatomists of the Russian school headed by the late A. N. Sewertzoff and my indebtedness to their numerous valuable and stimulating publications.

The bibliographies, apart from the references from which figures were taken, are limited to the more recent or more important papers or those dealing directly with the animals dissected. The *Handbuch* mentioned above has extensive bibliographies, as do also Goodrich's valuable book *Studies on the Structure and Development of Vertebrates* and other large works listed in the bibliographies.

I have always believed that zoölogy is best studied and learned not out of books but by actual experience with and handling of material. This book tries to teach comparative vertebrate anatomy by means of real specimens, and it is to be hoped that ample material will be available during the laboratory study. On the same ground I have avoided giving any illustrations of the animals under dissection and, in general, hope that the student will learn the story of the evolution of the various vertebrate organ systems by comparing their condition in the different animals dissected rather than by looking at diagrams in books.

Thanks are expressed to all those who have called my attention to errors in need of correction; to the departments of ichthyology, herpetology, and comparative anatomy of the American Museum of Natural History, especially to Messrs. Nichols, Bogert, and Raven, for unfailing courtesies and assistance and the loan of specimens; to Dr. F. A. Beach, in charge of the department of animal behavior, for generous accommodations in his depart-

ment and ever ready co-operation; to Mr. Lester Aronson for a critical reading of the last chapter; to the librarians of the splendid library of the American Museum of Natural History for their inexhaustible patience and cheerful aid in the finding of references; and to my friends for encouraging me to complete this almost hopeless task. For I confess, apologetically, that I am not a student of vertebrate anatomy; and more than once I threatened to "bog down" in the vast complexities of a vast subject which was far from my preferred field of work. My task might be described as making molehills out of mountains, of trying to cull from the immense material and literature of vertebrate anatomy a few of the more important facts and concepts. I hope I have not done too badly with them.

LIBBIE H. HYMAN

AMERICAN MUSEUM OF NATURAL HISTORY
March 1942

GENERAL DIRECTIONS

Supplies

1. Dissecting instruments necessary for the course are:
Medium-sized scalpel.
Fine scissors.
Coarse scissors.
Stout probe for dissecting.
Long, slender probe for probing.
Medium-sized forceps with straight points.
A towel and a laboratory coat or gown to protect the clothes are desirable.
Bone scissors or forceps will be provided in the laboratory.

2. Drawing materials necessary for the course are:
Drawing paper, No. 6. This paper must be stiff and hard and have a smooth surface.
Hard drawing pencil, No. 3.
Eraser.
Ruler.
Red, yellow, and blue pencils.
Pad of emery paper to sharpen the hard pencil.

3. Obtain the supplies named above and present yourself with a complete outfit at the first laboratory period. Do not handicap yourself at the start by neglecting to provide yourself with the necessary materials.

Drawings

1. All drawings **must** be made with a hard pencil on good quality drawing paper, unless otherwise specified. Colors are to be used only when specified in the directions. Shading, crosshatching, etc., are undesirable and are to be avoided. Drawings made otherwise than as here specified will not be accepted.

2. Drawings are to be line drawings only—that is, only the outlines of the structures are to be drawn. Every line must represent a structure actually present on the specimen. Lines must be smooth and clean. Correct proportions are of the utmost importance and are to be obtained by use of a ruler. In making a drawing it is best to outline the drawing first with very light lines, correcting these until accurate appearance and proportions are obtained. Then erase the light lines until they are barely visible and go over them with a well-sharpened pencil, making the final lines firm and clear.

3. Drawings are not to be diagrammatized unless so directed in the manual. Many students do not seem to understand the difference between a diagram and a drawing. As an illustration, Figure 14 in this book is a diagram and Figure 13 is a drawing of the upper half of the same structures represented in the diagram. The latter shows what the object actually looks like; the former is for purposes of explanation only.

4. All drawings must be made **directly from the object** with the object before the student and completed in the laboratory. The making of rough sketches in the laboratory to be "improved" elsewhere is unscientific, inaccurate, and absolutely not permitted.

5. Remember that the prime requisite of a drawing is accuracy. A drawing is for the instructor a record of what you have actually seen upon your specimen. If you have not dissected the structures called for, then it is obvious that you cannot draw them accurately. Poor laboratory work invariably reflects itself in the quality of the drawings.

6. Drawings must contain all of the details mentioned in the manual. If, after honest effort and with the aid of the laboratory assistants, you are unable to identify certain structures, omit them from the drawing and make a note to the effect that you were unable to find them. An unreasonable amount of time should not be spent in locating small or unimportant details.

7. All drawings must be thoroughly labeled. Every drawing must be completely labeled regardless of whether the same structures have already been labeled in some preceding drawing. Labels are to be written or printed in hard pencil parallel to the top and bottom edges of the page, and lines drawn with a ruler from the labels to the parts indicated.

8. Draw on the right-hand surface of the page only.

9. Remember that the laboratory instructors are familiar with all of the figures in the various textbooks and that undue resemblance between your drawings and such figures will reflect upon your honesty and raise a suspicion that you have not been exerting yourself in the laboratory.

10. The drawings will be called in at intervals. The dates on which they are due will be announced in advance by the laboratory instructors.

Notes and Quizzes

1. No notes are required in this course. The notebooks will consist of drawings only.

2. Oral and written quizzes upon the subject matter of the laboratory work are to be expected at any time. These quizzes will deal with the anatomy of the animals you are dissecting and with comparative anatomy. You will be expected to know thoroughly the animals and materials which you dissect and study in the laboratory, and to be able to compare them with one another, stating resemblances and differences. You will be required to exhibit your dissections and to be able to identify the structures present on the dissections.

3. An important quiz will follow the completion of each section of the laboratory work and will deal with that section.

4. Reading in the textbooks of comparative anatomy is expected as a part of the laboratory work. Quizzes will include material in such textbooks.

Dissection

1. Dissection does not consist in cutting an animal to pieces. Dissection consists in separating the parts of an animal so that they are more clearly visible, leaving the parts as intact as practicable.

2. In dissecting an animal very little cutting is required. Cleaning away the connective tissue which binds together and conceals structures is the chief process in dissection. In doing this, use blunt instruments, as the probe, forceps, or fingers. Avoid the use of scalpel and scissors. You will probably cut something you will need later on. In short, do not cut; separate the parts.

3. Have the animal firmly fastened. Smaller animals are generally pinned to wax-bottomed dissecting pans. Larger animals, such as are used in the greater part of this course, are tied to screw eyes in the corners of the dissecting pan. Put the particular part you are dissecting on a stretch.

4. Do your own dissecting. Do not watch somebody else do it. Begin at the most easily accessible point of the system you are studying and follow out your structure, cleaning away the tissues that conceal it.

5. Exercise patience and care. Clean the structures by small portions.

6. Follow the directions precisely. Do not cut anything or remove anything unless specifically directed to do so.

7. Your laboratory grade is partly determined by the kind of dissections you make.

Materials

1. But one specimen of each animal is allowed to each student. Each student will be given the necessary specimens and will retain them to the end of the course. Do not discard any animal until the manual so directs.

2. The smaller materials which are provided for the class as a whole should be returned to the bottles or jars from which they came as soon as you have finished studying them.

3. The larger specimens will be kept in large cans. Each table will be allotted the necessary number of cans. Students will attach tags bearing their names to their specimens and will keep them in the cans when they are not in use.

4. Specimens must always be kept moist and must never be allowed to dry up, as this ruins them for dissection. Do not go away and leave your specimens out on the table. When ready to leave the laboratory, wrap the animals in moistened cheesecloth provided in the laboratory and put them into the cans. See that the cans are always covered.

5. Students who, through their own carelessness, render their specimens unfit for further dissection will have to pay for new specimens.

6. The skeletal material provided in this course is expensive. Handle it with care. Be particularly careful with skeletons preserved in fluid.

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