MANUAL OF COMPARATIVE ANATOMY

BRELAND

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PREFACE TO SECOND EDITION

The first edition of this manual has been given a very kind reception by numerous teachers and students. During the past few years many users have thoughtfully written the author and have made valuable suggestions for the modification of certain parts. As a result of these suggestions and recent studies, several major changes have been made in the revised edition. These include the use of boldface type rather than italics for the names of structures the first time the names are used, the addition of a section on the pigeon, and a revision in the system of classification that is followed A fourth major change concerns the drawing directions. These instructions were all grouped at the end of each chapter in the first edition. In the revision, the drawing directions have been inserted in the text at the places where the drawings are to be made.

The author wishes to express sincere appreciation to all who have contributed to this second edition of the manual. These include users who have suggested changes and several staff members at the University of Texas. He is especially indebted in this connection to Dr. Clark Hubbs, Dr. Frank Blair, and Homer Phillips.

The writer will greatly appreciate having possible errors or discrepancies called to his attention; he will also be pleased to receive suggestions for the further improvement of the manual.

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AUSTIN, TEXAS
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PREFACE TO FIRST EDITION

This manual has been written with two objectives in mind. First, the intention has been to make the directions so clear that anyone using the guide will be able to find the designated structures with a minimum of outside assistance. It is believed that this is of prime importance, since in large laboratory sections the amount of individual assistance given to the students by the instructors is necessarily limited. The manual is thus based on actual dissections, with the specimens before the author at the time of writing. Some of the directions included have been used in the laboratory as mimeographed sheets; when it has appeared necessary, the additional clarification of these instructions has been made.

The second objective has been to emphasize the comparative importance of the organs and structures that are studied. There is too often a tendency in a study of comparative anatomy for both student and instructor to overlook the comparative significance of the studies and, instead, to concentrate on certain animals or structures for their sake alone. While the latter method possesses certain aesthetic values, the comparative method appears to be much superior. Opportunity is thus frequently taken to compare certain structures with those found in previously dissected animals. In addition, short paragraphs are occasionally inserted to correlate the various systems as found in several forms. It is freely admitted that such discussions are necessarily limited, since this guide is not a textbook. It is felt, however, that the student will derive more of lasting value from his laboratory work if attention is called to the comparative importance of the study while he is actually making the dissections. By way of review and also to provide for the possibility that some of the animals may be omitted in certain courses, some of these brief comparisons are partly repeated under the discussions of the different forms.

In preparing this volume, the author has referred to many different sources. The names applied to the structures and many of the interpretations used have been accepted by comparative anatomists for many years. The author thus makes

no claim to have contributed anything original regarding the data or interpretations contained in this manual. It is hoped, however, that the method of presentation may have a certain value. Within recent years, there has been a tendency among some writers to apply new terms to certain structures and, in some cases, to make slightly different interpretations of homologies from those previously accepted. While these innovations have something to recommend them, the author feels that the established practice should be followed in most cases until the new interpretations and terminology are more commonly accepted. It should not be inferred from the above statements that all homologies of the various structures are accepted without question by the majority of workers. In some instances there has been so much disagreement that the author has been at a loss to know which interpretation should be accepted. In some such instances, no correlations have been attempted; in others, an effort has been made to express the opinion of the majority.

It will be noted that certain animals and certain systems have been studied in considerably more detail than have others. This selection is based upon ease of study and upon the fact that there is a trend toward omission of minute details that do not help the student grasp the larger concepts of the subject as a whole.

More time for study has been allotted to the dogfish and to the cat than to any of the other forms. The dogfish is emphasized because it is believed that in work of this kind the student should have a thorough knowledge of fundamental vertebrate structure in a comparatively simplified form. It is felt that he will thus better understand the complexities of comparable systems in the higher animals. The cat is studied in detail because it represents the fundamental mammalian structure.

The skeletal system has probably been less emphasized in this guide than has any other system. This is because it is comparatively difficult to study and not because it is unimportant. A study of the skeletal system necessitates the preparation of skeletons by students or instructors or the purchase of prepared skeletons. The first method is frequently impracticable because of the time element, and the second is not feasible in many cases because of the expense involved. The cat skeleton is studied in considerable detail because it is quite similar to that of man, and for this reason is considered important for both the general and the premedical student.

The animals more or less accepted as standard in many labora-

tories are the dogfish, an amphibian—usually *Necturus*—and the cat. Although it is agreed that these animals are important, it is believed that certain evolutionary concepts are likely to be missed unless additional species are studied to a certain extent. In addition to the portions of the manual devoted to the above species, sections are also included on *Amphioxus*, the lamprey, the perch, and the turtle. *Amphioxus* is included because certain structures characteristic of vertebrates are present in this animal in a greatly simplified form. The lamprey is in many respects the most primitive of living vertebrates; yet, despite its primitiveness, certain definite specializations are present. These facts well illustrate the concept that extremes of both primitiveness and specialization may be present in the same animal. The turtle, as a representative of the class Reptilia, exhibits the beginnings of certain tendencies that are carried to completion in the higher animals. The section devoted to the perch is quite short and has been included because of the presence of certain ambiguities in bony fish as compared with other vertebrates. Any of these animals may, of course, be omitted at the discretion of the instructor.

The author has deemed it advisable to be definite with respect to the type of drawings to be made and to include in each case a list of labels that should be present. By this method more uniformity will be attained in the drawings presented by the students. Such a list of labels is helpful, for the student is frequently at a loss to know what labels should be placed on a given drawing. Moreover, if drawings are to be graded, the list of labels furnishes one definite criterion for both student and laboratory instructor. This is important in the interests of uniformity of grading when a large number of laboratory instructors are teaching the same course. Some laboratory instructors prefer to use prepared outline drawings, rather than to have the students make the drawings themselves. The drawings called for and the list of labels have been prepared with this possibility in mind, so that in most cases the required drawings will be essentially the same as those illustrated in the better series of outline drawings now on the market. A book of drawings such as "Outline Drawings for Laboratory Studies in Comparative Anatomy" by W. C. Senning, published by McGraw-Hill Book Company, Inc., New York, will prove helpful. Certain drawings may easily be omitted or modified to conform to different types of course.

The author wishes to express his appreciation to Doctors William Jackson Dobson, Griff Terry Ross and Ardell Nichols Taylor, who have been of great assistance in the preparation of this manual. Several of the dissecting techniques that are used were developed by these men in their laboratory teaching. They also made helpful suggestions in the writing of the manual. In this connection, the author is especially indebted to Dr. Dobson, who read the entire manuscript and who made valuable contributions to its content and organization. Dr. Dobson also corrected the proofs of the manual and prepared the index.

In a manual of this kind, errors and omissions frequently occur despite all precautions. If such discrepancies are discovered, the author will appreciate having them called to his attention.

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AUSTIN, TEXAS
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INTRODUCTION

Laboratory Materials. Certain laboratory and dissecting materials are essential for all courses in comparative anatomy. The requirements for different courses are variable, but the suggested list below is considered necessary for most of them. Unless otherwise directed, each student should obtain the following equipment:

1 metal-handled scalpel.
2 dissecting needles, or "teasers."
1 pair of heavy scissors with one point sharp and the other point blunt.
1 heavy probe.
1 light probe, sometimes called an "olive-pointed probe."
1 pair of straight-pointed forceps.
1 combination lock to be used on locker.
1 3H drawing pencil.
1 6-inch ruler.
1 Artgum eraser.
Drawing paper. The amount to be obtained will vary in the different courses.
1 piece of cheesecloth about 1 yard square to be used for wrapping about specimens.
2 small towels.
1 piece of good soap.

It will be noted that for most of the laboratory exercises specific drawings are called for, and a list of labels is given which are to be included in each case. Unless otherwise directed, these drawings should be made and completely labeled as indicated. The student should understand that the list of labels for each drawing does not necessarily include all the structures which should be learned for a particular exercise. While the majority of structures will in most cases be included in these lists, important structures may sometimes be omitted because of lack of space or because they cannot be well illustrated in a particular drawing. Each drawing should be completed before additional work is undertaken.

It is believed inadvisable to give specific drawing directions; many students have had some drawing experience, and instructors vary in their requirements. A few general suggestions, however, may prove helpful. In most instances, drawings should be placed in the center of the drawing plate, with the labels distributed equally along each side. A label should be at or near the same level on the page as the structure to which the lead line will pass. Lead lines from the label to the structures can thus be made parallel to the top and bottom of the drawing plate. If this cannot be done, keep the lead line from the label parallel to the top and bottom of the plate until near the structure, and then make a definite angle in the line so that it will pass directly to the structure to be labeled. When a large number of labels are to be placed in a small area, the student should first estimate the approximate positions of the labels before actually placing them on the page. In this way, unnecessary crowding of labels can be prevented. Do not cross lead lines. The left-hand margins of the labels should be kept straight. It is suggested that labels be made in the singular and that, when there are several identical structures, the lead line be drawn to only one of them. Labels should be printed. They should be begun with a capital letter, and the remainder of the word should be in small letters.

In describing the location of various structures, it is necessary to use certain orienting terms such as left, right, dorsal, or ventral. These terms as applied to the specimens are frequently confusing to the student who is beginning a study of anatomy, for he is usually dissecting from the animal's ventral side. This fact causes the animal's left to be to the student's right side, and vice versa. The student should therefore attempt to orient himself at once with this fact in mind. Unless otherwise indicated, all such terms refer to the body of the specimen. Thus, if the directions state that a blood vessel passes to the left, it means that the vessel passes to the *animal's* left side, rather than to the left side of the student. The principal terms that are used in referring to the various regions of the body are included in the list below. The student should study these terms and become thoroughly familiar with their meaning.

Anterior, or cranial. Toward the head.

Posterior, or caudal. Toward the tail.

Dorsal. Toward the back, or top side, of the animal.

Ventral. Toward the belly, or bottom side, of the animal.

Lateral. Toward the side. Sometimes used to indicate the outer surface of a structure, such as a limb.

Medial. Toward the mid-line of the body. Sometimes used to indicate the inner surface of a structure, such as a limb, as opposed to the outer, or lateral, surface.

Proximal. Near a point of attachment

Distal. Distant from a point of attachment.

Peripheral. Toward the surface.

The student must realize that there is considerable individual variation in all animal structures; because of this, it is not possible to take into account in the directions all the exceptions to the general rule that are likely to be encountered. The student should thus not be unduly alarmed if certain structures in his specimen are not exactly as described in the manual. Anyone who doubts the existence of individual variation should examine the noses of all persons near him and notice whether any two are exactly alike.

CLASSIFICATION OF THE PHYLUM CHORDATA

The systems of classification of the phylum Chordata are somewhat more standardized than they were when the first edition of this book was published. However, there is still some disagreement relative to certain groups. The system used here is one that seems reasonably well accepted by many workers, and it follows closely the scheme advocated by Dr. Alfred S. Romer of Harvard University. Only living groups are included, and in some cases extra categories, such as subclasses and superorders have been omitted. Of the approximately twenty-five orders of living birds that are recognized, only five of the more common groups have been included.

PHYLUM CHORDATA

Subphylum 1. Hemichordata (Enteroptneusta)—the acorn-headed "worms": *Balanoglossus* and its allies.

Subphylum 2. Urochordata (Tunicata)—the sea squirts, or tunicates.

Subphylum 3. Cephalochordata—the lancelets: *Branchiostoma*, commonly called Amphioxus.

Subphylum 4. Vertebrata (Craniata)—animals with a backbone, or the beginnings of one.

Class 1. Agnatha—the lampreys and hagfishes.

Order 1. Cyclostomata—all living agnathans.

Suborder 1. Petromyzontia—the lampreys.

Suborder 2. Myxinoidea—the hagfishes.

Class 2. Chondrichthyes—fishes with cartilaginous skeletons.

Subclass 1. Elasmobranchii—sharks and similar forms.
Order 1. Selachii—sharks and dogfishes.
Order 2. Batoidei—skates and rays.
Subclass 2. Holocephali—the elephant fishes, *Chimaera* and allies.
Class 3. Osteichthyes—fishes with bony skeletons.
Subclass 1. Actinopterygii—fishes without internal nostrils.
Order 1. Chondrostei—*Polypterus*, sturgeons, and spoonbills.
Order 2. Holostei—gar pikes and bowfins.
Order 3. Teleostei—most of the common fishes. Includes perch, trout, bass, catfishes, etc.
NOTE: Some authorities divide this group into many orders.
Subclass 2. Choanichthyes—fishes with internal nostrils.
Order 1. Crossopterygii—mostly extinct, one form, *Latimeria*, recently discovered off the African coast.
Order 2. Dipnoi—the lungfishes.
Class 4. Amphibia—frogs, toads, salamanders, etc.
Order 1. Apoda (Gymnophiona)—the caecilians.
Order 2. Urodela (Caudata)—the salamanders.
Order 3. Anura (Salientia)—the frogs and toads.
Class 5. Reptilia—the reptiles.
Order 1. Chelonia (Testudinata)—the turtles.
Order 2. Rhynchocephalia—*Sphenodon* of New Zealand.
Order 3. Crocodilia—the alligators, crocodiles, etc.
Order 4. Squamata—the lizards, snakes, chameleons.
Class 6. Aves—the birds.
Subclass 1. Archaeornithes—*Archaeopteryx* and a few other extinct forms.
Subclass 2. Neornithes—all living birds and a few extinct species.
Superorder 1. Palaeognathae—ostriches and their relatives.
Superorder 2. Neognathae—all other living birds.
Order 1. Anseriformes—ducks, geese, etc.
Order 2. Falconiformes—hawks, eagles, vultures.
Order 3. Galliformes—pheasants, jungle fowls, domestic chickens, and turkeys.
Order 4. Columbiformes—pigeons and doves.
Order 5. Passeriformes—the songbirds, including sparrows, thrashers, warblers, etc.
NOTE: Eighteen additional orders of the superorder Neognathae are often recognized.
Class 7. Mammalia—the mammals.
Subclass 1. Prototheria—the egg-laying mammals.
Order 1. Monotremata—the duckbill and spiny anteater.
Subclass 2. Metatheria—the pouched mammals.
Order 1. Marsupialia—opossums, kangaroos, etc.
Subclass 3. Eutheria—the placental mammals.
Order 1. Insectivora—shrews, moles, hedgehogs.
Order 2. Dermoptera—the flying lemurs.
Order 3. Chiroptera—the bats.
Order 4. Carnivora—the flesh-eating mammals: cats, dogs, seals, bears, raccoons, etc.

Order 5. Hyracoidea—the conies.
Order 6. Proboscidea—the elephants.
Order 7. Sirenia—the manatees and dugongs.
Order 8. Primates—monkeys, apes, man.
Order 9. Edentata—the armadillos, sloths, anteaters.
Order 10. Pholidota—the scaly anteaters.
Order 11. Tubulidentata—aardvarks.
Order 12. Lagomorpha—rabbits and hares.
Order 13. Perissodactyla—hoofed mammals with an uneven number of toes: horses, rhinoceroses, tapirs, etc.
Order 14. Artiodactyla—hoofed mammals with an even number of toes: cows, pigs, camels, giraffes, etc.
Order 15. Rodentia—the rodents: rats, mice, guinea pigs, squirrels, beavers, etc.
Order 16. Cetacea—the whales.

The student should learn the complete classification of all animals that are studied. The classification of each species is given at the beginning of the section devoted to the particular animal.

CHAPTER I

AMPHIOXUS, OR BRANCHIOSTOMA

Phylum—Chordata
Subphylum—Cephalochordata

In a study of vertebrate zoology or comparative anatomy, Amphioxus is important from several standpoints. It has the three diagnostic features of the phylum Chordata (dorsal hollow nerve cord, notochord, pharyngeal clefts) in easily recognizable form and retains these throughout life. Many of the organ systems found in higher vertebrate animals are represented in Amphioxus in a highly simplified condition, and this helps one to understand better the complex additions and changes found in the more highly developed animals. Because of the similarities in fundamental structure between this animal and vertebrates, it is thought probable that Amphioxus is similar to the unknown ancestor of vertebrate animals. Unfortunately it is not possible to examine here all the systems of Amphioxus, but some of those which cannot be seen by means of the microscope will be briefly mentioned.

Within recent years it has been found that the name *Branchiostoma* was applied to this group of animals before the term Amphioxus was used. The true scientific name is thus *Branchiostoma;* but Amphioxus will be used here as the common name.

In the present study, each student will be given a preserved specimen and slides of stained and cleared whole specimens and sections. Do not at any time press on the cover slip or wipe the slides vigorously. If the cover slip is moved, the slides will be ruined. If the slides apparently need cleaning, ask the instructor to show you the correct method. Use only the *low power* of the microscope. The slides are too thick for high power, and the magnification would be too great for a study of this kind.

External and Internal Anatomy. For this work, use the whole preserved specimen, which is mature, and the stained cleared slide of an immature specimen. The clearing of the specimen on the slide has caused the animal to be semitransparent, so that much of its internal anatomy can be seen. For the external

structures examine both the preserved specimen and the slide The preserved animal should be examined with the unaided eye or with a hand lens if one is available. The slide should be studied with the low power of the microscope.

Identify first the external structures. Locate the anterior end by finding the fingerlike **buccal cirri** (singular, cirrus) that occur in that region. These cirri are probably sense organs. Just dorsal and anterior to the cirri, the anterior end of the body forms a projection, the **rostrum.** The anterior funnel-shaped portion of the body to which the cirri are attached is the **oral hood.** The cavity within the oral hood is the **vestibule.** This cavity is not comparable with a mouth cavity. The mouth will be identified later.

Along the dorsal side of the body locate a semitransparent strip of tissue, the **dorsal fin,** which is strengthened by cube-shaped **fin rays.** Trace the dorsal fin posteriorly until an area is found toward the tail in which no fin rays occur. This rayless fin is the **caudal fin,** which surrounds the posterior end of the body on both the dorsal and ventral sides. Trace the caudal fin anteriorly on the ventral surface, and observe that it is continuous with the anterior fin that has fin rays. This is the **ventral fin.** Note, therefore, that the caudal fin is best identified by the absence of fin rays posteriorly, although there may be a few short rays in its anterior regions. It is sometimes slightly more expanded than are the dorsal or ventral fins. Find the **anus,** the posterior opening of the digestive tract, which opens near the posterior end of the ventral fin. The anus is sometimes difficult to identify as a definite opening, but in most slides the posterior end of the intestine will protrude somewhat ventrally as a darker stained projection. The anus occurs at the end of this projection. Anterior to the ventral fin are the **metapleural folds,** two folds of tissue that do not have definite fin rays. The structure of these folds can probably best be observed in the preserved specimen, since on the slide only the side of one of the folds can be seen. Their relationships with other parts of the body will also be better understood after a study of the cross sections. On the slide, at the region where the ventral fin ends and the metapleural fold begins will be seen a slight indentation, which represents an opening. This is the **atriopore,** through which water passes to the outside after it has circulated through the body.

Look on the side of the body posterior to the atriopore, and find a series of V-shaped markings; these occur all along the body

but can best be seen posteriorly. They represent the muscle segments, or myotomes, which will probably be more evident on the preserved specimen. The small V-shaped marks themselves are **myocommata** (singular, myocomma), or connective tissue, which help to bind the muscles together. The material between two myocommata is a **myotome.**

For a study of the internal anatomy, use only the cleared slide, except that the **gonads,** or reproductive organs, should be located in the preserved specimen. No gonads are present in the specimen on the slide, since it is immature; but the preserved animal is a mature individual, and the gonads appear as little whitish rounded structures along the lateral and ventral surfaces of the body.

Just below the fin rays that support the dorsal fin is the **neural tube,** or nerve cord. This structure can be distinguished from the surrounding material by the presence of a series of darkly stained **pigment spots** along its ventral surface. It is thought that these pigment spots are sensitive to light. Trace the neural tube anteriorly, and locate at its extreme end the **eyespot,** which is darkly stained and somewhat resembles a large pigment spot. It was once thought that the eyespot was sensitive to light, hence the name; but recent evidence indicates that it probably does not function in this capacity.

Ventral to the neural tube is the **notochord,** a cartilage-like structure that runs the length of the body. It is easiest to identify in the rostrum. Examine this region, and observe the elongate projection that is ventral to the eyespot and extends anterior to it. From this point, trace the notochord posteriorly. It is usually stained somewhat differently from the nerve cord. The notochord functions as a support for the body, and its presence is characteristic of all animals belonging to the phylum Chordata. In most of the higher vertebrate animals, the notochord is a complete structure only in the embryo and is later replaced by the vertebrae of the backbone. In some lower vertebrates, as will be seen, the notochord partly persists, even in the adult. The extension of the notochord in Amphioxus anterior to the end of the nerve cord is unusual, since in vertebrate animals the anterior end of the notochord is some distance posterior to the end of the brain. This peculiar relationship between the nerve cord and notochord is responsible for the name *Cephalochordata* (head cord) being applied to the subphylum in which Amphioxus is classified.

There is no definite enlargement in Amphioxus that could be called a brain, but the anterior end of the neural tube is sometimes called the **brain region.** Two pairs of nerves, called **cerebral nerves,** originate from the brain region, but they cannot be seen in the slides.

Turn now to the anterior end and locate again the **vestibule,** the cavity within the oral hood. Some of the details of this region are difficult to see unless the slides are well stained. Within the vestibule, just posterior to the attachment of the cirri to the oral hood, are to be seen several darkly stained fingerlike projections that are directed anteriorly. These projections are connected at their base, or posterior end, to form a structure called the **wheel organ.** The projections, or lobes, bear cilia, the beating of which helps to create a current of water from the outside through the vestibule and on posteriorly.

Posterior to the base of the wheel organ is a membrane, the **velum,** containing an opening, the **mouth.** In the slide, you are looking at the edge of the velum, since it extends across the posterior part of the vestibule, so that it will appear as a line, which is usually stained slightly differently from the wheel organ. The mouth occurs in the center of the velum and thus cannot be seen from this view. The position of the mouth, however, may be designated as being near the center of the velum. Attached to the velum and surrounding the mouth are several **velar tentacles,** which may not appear on the slide or which may show up as small threadlike structures stained about the same color as the velum. The function of these tentacles is probably to prevent undesirable material from entering the mouth.

The mouth opens into the **pharynx,** the large latticed structure just posterior to the velum. Along the side of the pharynx, note the numerous **pharyngeal slits** (openings) and, on each side of these, the solid **pharyngeal bars.**

The pharynx leads posteriorly into the **intestine,** which is a much smaller tube without the latticed walls. Near the region where the pharynx opens into the intestine there occurs a blind outpouching, which extends anteriorly and which may be partly covered by the pharynx. This is the **liver diverticulum,** or hepatic caecum, which is considered to be homologous to the liver of a vertebrate animal. On some slides, the anterior end of the liver diverticulum either will be covered by the pharynx or will itself partly cover the pharynx, depending upon which side of the specimen is being examined. The anterior end of this