A LABORATORY MANUAL of *CRYPTOBRANCHUS ALLEGANIENSIS* Daudin

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PREFACE

Cryptobranchus alleganiensis Daudin illustrates the anatomical change from the lower to the higher vertebrates in a very satisfactory manner. In classes of comparative anatomy or vertebrate zoology, where a number of forms are used and gradual stages shown, *Cryptobranchus* shows a nice step between *Necturus* and the frog; while in the classes where only a few forms are used, and these studied intensively, *Cryptobranchus* makes a remarkably clear transition between the shark and the mammal.

Although this manual is presented as a type study, it is so planned that it is adaptable to the comparative method. Each system is a unit and includes questions that have been designed to draw out the relationship of *Cryptobranchus* to the shark and the amphioxus, which are the types used in preceding studies.

The manual is the outgrowth of the use of this species for several years in classes of comparative anatomy at the University of Wichita, during which many specimens were under close observation. A mimeographed manual used in classwork was corrected and revised repeatedly, until the material was presented as the result of years of co-operative study in the first edition. The present edition has been further revised, though not extensively.

A bibliography of the literature relative to *Cryptobranchus* is appended. Some of the articles and books were used as references in this manual, but much of it is literature relative to amphibians in general for collateral reading.

Thanks are herewith tendered to the students of the Department of Zoology of the University of Wichita for their careful dissection and vigilance in verifying statements and discovering variations in specimens, as well as in helping to clarify the directions given.

H. E. B.

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INTRODUCTION

Cryptobranchus alleganiensis Daudin is distributed in the streams of western New York and central Pennsylvania and Georgia, and westward to Louisiana, Missouri and Iowa. It is of large size: approximately 480 mm. including a tail of 160 mm.

This genus of the Amphibia belongs to the order Urodela,[1] as it possesses a tail in the adult stage. It is of the suborder Derotremata,[2] in which the gills are lost in the adult but usually the clefts remain. The family Cryptobranchidae has a tail with a dorsal and a ventral finfold, as well as a pronounced lateral fold from "neck" to tail concealing the gill clefts or the region for them. The legs are not rudimentary and possess a fold on the posterior (or lateral) margin. The front feet possess four toes and the hind feet five toes.

There are two genera in the family: *Megalobatrachus japonica* Hoeven (the giant hellbender), found only in Japan and China and characterized by the absence of gill clefts and the presence of only two branchial arches; and *Cryptobranchus,* characterized by the presence of a single pair of gill clefts (frequently only one cleft, and this on the left side) and four branchial arches. There are two species in the genus *Cryptobranchus*: *alleganiensis* Daudin, the hellbender (in which the gular region is pale), and *bishopi* Grobman (the Ozark hellbender),[3] in which the gular region is blotched with black.

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1 Parker and Haswell, *Text-book of Zoology.* (All references cited in footnotes are listed in the Bibliography.)

2 *Ibid.*

3 Sherman C. Bishop, *Handbook of Salamanders.*

Chapter I

EXTERNAL FEATURES

COLOR.—The body of *Cryptobranchus alleganiensis* Daudin, commonly known as the hellbender, is slate gray in color and, in a strong light, has a brownish cast with a few irregularly scattered small spots of reddish brown. Reese[1] states that the color varies from nearly black to a greenish brown as well as a reddish cast with dark irregularly scattered blotches.

INTEGUMENT.—The integument is heavy and glandular, especially in the region of the junction of the tail with the trunk. Microscopic examination of the integument reveals the glandular formation to be similar to that of the frog. There does not seem to be any gross hornification.

BODY REGIONS.—The body is possessed of four regions: head, neck, trunk with appendages, and tail. The *head* is extremely depressed and almost as broad as the trunk. The mouth is wide and when opened exposes the entire oral and pharyngeal cavities. The eyes, very small and bullet-like, are situated upon the top of the head toward the lateral margins and are embedded between folds of integument. The eyes are lidless and covered with epithelium which forms a transparent membrane, the cornea, and is continuous with the epithelium of the head.[2] In life these eyes are flashes of light, and they stare at an observer in a compelling manner while the salamander moves its head from side to side and snaps its jaws

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[1] Albert M. Reese, "Enteron and Integument of *Cryptobranchus*."
[2] Reese, "The Eye of *Cryptobranchus*."

with apparent ferocity. The nostrils are extremely small and are situated close together upon the cephalic margin of the head just above the upper jaw. These nostrils communicate with the oral cavity by small posterior nares set caudo-laterad to the external position. There is no external evidence of ears, although the animal is possessed of auditory organs. The orifice is completely covered with integument and is located caudad of the quadrate process.

The *neck* is very short and thick, making only a slight demarcation in the body outline. Upon either side is a single gill slit which is difficult to find, as it is hidden in integumental folds. These slits open into the pharyngeal cavity.

The *trunk* is depressed and is very flat across the dorsum. The dorsal and ventral planes slope gradually toward the head. The trunk possesses heavy lateral folds, one of which extends down each side for the entire length from gill slit to tail. This fold is often fluted and wrinkled and possesses many oil and slime glands. Upon the venter of the trunk and caudad of a line joining the pelvic appendages are two elevations between which is the opening of the cloaca. This opening leads into an internal pocket, the cloaca, into which open the rectum and the tubes of the urinogenital system.

The *appendages* are short and in preserved specimens appear to be of little use; but in life the animal draws these legs under the body, straightens them, and raises the body off the substratum.[3] This habit, combined with the wagging of the head and the snapping of the jaws, exposing a cavernous buccal cavity, justifies the name "hellbender." In swimming, the legs serve no function, the tail being the propelling organ. The front legs bear four toes and the hind legs five toes, and both pairs of legs have post-axial folds of skin which frequently include the fifth digit.

The *tail* is approximately round at the junction with the trunk but becomes compressed very rapidly in a caudal direction and has prominent dorsal and ventral "finfolds."

[3] Our observation at the vivarium in the University of Pennsylvania differs from Wilder's observation of the giant salamander which did not lift itself from the substratum (B. G. Wilder, "Habits of *Cryptobranchus*").

[STUDY I: Draw the lateral aspect of the specimen, locating and labeling all structures described above.]

Questions

What is the color of the body?
Is there any difference in the color of ventral and dorsal surfaces? Why?
What is the general shape of the body?
How does this differ from the general shape of the shark or the perch?
Name and describe the body regions.
Compare the walking habit with the swimming habit.
What is the lateral fold?
Name the body openings and locate them.
How do these body openings compare with body openings of the shark?
How do the regions of finfolds and appendages compare with finfolds in the amphioxus and fins in the shark?

Chapter II

LABORATORY PREPARATION OF THE SKELETON

The exoskeleton of *Cryptobranchus*, as mentioned in Chapter I, is practically absent, but the endoskeleton is strong and easily available to the student who wishes to prepare his own specimen. The axial skeleton is almost entirely bony, while the appendicular is, for the most part, cartilaginous. While care is necessary in preparing skeletons, there is no better way to gain concrete information as to the relation of the different parts of the framework of the body, and time spent in this way is worth while.

Examine carefully a prepared specimen of the entire skeleton and X-ray photographs; compare regions with the preserved specimen and learn the names of its parts.

Appendicular Skeleton

As the pelvic girdle is very delicate and easily broken, it is advisable to remove this as the first procedure. If the skin of the specimen has not been removed it should be partially removed at this time. Cut a small slit through the skin in the median line of the venter between the front legs, and with forceps lift the skin in this region. With a sharp scalpel or scissors (using always an upward stroke so that structures underneath the skin are not damaged), cut along the mid-ventral line forward to the tip of the jaw and tailward to the opening of the cloaca, being sure that nothing but skin lies in the line of the cutting instrument. Make a median dorsal incision of the skin of the back from the tip of the

jaw to the region of the junction of the tail with the body. Connect the mid-ventral incision and the mid-dorsal incision by transverse incisions of the skin midway between the front and hind appendages.

Beginning at the mid-ventral corner of the caudal half of the skin, pull the skin caudad and laterad, holding back the tiny shreds of muscles and connective tissues with the dull side of a scalpel. Remove the shallow muscles from between the hind legs and expose the cartilaginous pelvic plate.

Extending cephalad from this plate in the median line of the body is the extremely delicate ypsiloid process.[1] This is difficult to remove unbroken and attached to the pelvic plate, but it can be done. Carefully pick away the shreds of the three caudal myotomes of the rectus abdominis muscle in the median line; gradually this Y-shaped cartilage will be exposed.

Return to the pelvic plate and, by picking away muscles, determine the attachment of the femur (the large bone of the hind leg), but do not remove the appendage. Dorsad of this femoral attachment will be seen a slender bone extending dorsad and caudad. This is the ilium, which forms the attachment of the girdle to the vertebral column and allows the legs to function as propelling organs in walking. Remove the muscles upon the dorsal and lateral surfaces of the vertebrae of this region until four or five are clearly exposed. Determine the vertebra which has a heavy pair of ribs turning ventrad to unite with the ilia. This is the sacral vertebra and should be freed from the vertebrae immediately in front and behind it. Cut away the mesenteries attached to the internal and lateral faces of the girdle, and it may now be removed from the body and further cleaned.

The appendages may now be observed carefully and the pre-axial and post-axial sides determined and noted in a careful sketch. The cleaning of girdles and appendages is made easier if the appendages are removed; but if they are

[1] I. L. Whipple, "The Ypsiloid Apparatus of Urodeles."

removed, the exact relation between the head of the femur and the socket in which it articulates, the acetabular fossa, should be noted and sketched. The muscles attached to the girdle may now be trimmed away and the appendages skinned and muscles removed. In skinning the digits, do not overlook the distal row of phalanges; they are minute and easily destroyed. In the region of the ankle are small cartilages, and it is best to pick the muscles away under a low-power dissecting microscope. If the muscles stick or become dry, the parts may be placed for a few days in soap solution and then further cleaned and placed into 10% formalin to preserve. Cartilaginous parts will clean easily if allowed to stand overnight in soft water in an incubator set at about 40° C.

Remove the skin from the pectoral region of the specimen by pulling the ventral corners cephalad and laterad. Determine the pre-axial and post-axial margins of the appendages and sketch before skinning. Use the same care on these digits as in handling the pelvic appendage.

Upon the ventral surface of the body between the appendages are the coracoid plates of the pectoral girdle. One coracoid plate overlaps the other. Compare specimens with those of other members of the class and determine if "left over right," or vice versa, is the regular order. Lying between the caudo-ventral borders of the coracoids is a sternum, irregularly circular or semi-triangular in shape and attached to the coracoids by delicate membranes. Make a sketch of the relation of the coracoids to each other and to the sternum.

Slip a scalpel under the exposed coracoid plate; lift it gently, freeing it from the underlying muscle. Pick away the muscles from the region of attachment of the appendage and observe that it is articulated with the girdle in a fossa, termed the glenoid fossa. From this fossa a narrow cartilage extends cephalad and another extends dorsad. These are parts of the pectoral girdle. Free the entire pectoral plate from the muscles which bind it to the body, observing that there is no skeletal attachment to the vertebral column.

Remove the appendage, if you wish or leave it attached. Clean as directed for the pelvic girdle and place in the formalin jar. Remove the other half of the pectoral girdle from the specimen, also the sternum, and clean and place them in formalin.

Axial Skeleton

Visceral Arches of the Skull.—Remove the muscles from the ventral side of the mouth and neck region, exposing the bones and cartilages of the visceral basket. Visceral arches II to VI lie between the rami of the lower jaw, elements of which are the remnants of old arch I. The second visceral arch, or hyoid, follows the mandibular curve. Mesad of arch II lie the elements of visceral arches III to VI, sometimes called branchial arches 1 to 4. Branchial arch 1 is composed of a single pair of elements which is attached to a median plate.

Mesad of branchial 1 is a long, slender bone with several distal elements, one very small cartilage and three longer elements. The long, slender bone is ceratobranchial 2, and the one very small element is ceratobranchial 3. The three medium-length elements are the epibranchials of 2, 3, and 4. These last three cartilages enter the gill region upon the sides of the neck. Determine the position of the gill slit in relation to these epibranchials and sketch the condition.

These arches may be removed by cutting the membrane which holds the hyoid arch to the mandible and severing the muscle attachments in the neck region. Note especially the relation of the hyoid arch to the mandible, caudad of the articulation of the mandible with the cranium. Find the tiny arytenoid cartilages guarding the opening to the respiratory tract. These represent branchial arch 5, or visceral arch VII. This entire set of cartilages and bones should be placed in formalin and not cleaned until it is time to draw them, as the parts are easily separated and relations lost.

Cranium.—Pry open the mouth and determine the rela-

tion of the nostrils to the oral cavity. Remove the muscles of the neck region and determine the articulation of the cranium with the vertebral column. Cut through the membrane which holds the cranium to the first vertebra, and cut across the oesophagus and other viscera attached to the oral and pharyngeal cavity. The cranium and lower jaw are now free from the body. Scrape and clean away all the tissues and muscles of the head except the membrane of the orbits upon which the little bullet-like eyes rest.

The mandible articulates with the cranium at the lateral prominences termed "quadrates." Caudad of this articulation is a region which will require careful attention. This is the otic capsule and bears upon its lateral face an opening capped by a tiny circular bone held into the opening by a circular ligament. Avoid removing the cap if possible but if it is removed, put the cap into a vial of formalin and place in the formalin jar. This cap is the operculum, which bears the columella, the first of the ear bones to locate in the otic region.

Boil the cranium for half an hour in a soap solution; then clean away the remaining muscle. There is a heavy membrane supporting the lower jaw, and this may now be cut away and the articulation of jaw and cranium observed. Upon the mandible is a lump of cartilage cephalad of this articulation. This is Meckel's cartilage, which represents the old arch I of the shark. If the elements of the ramus are separated, a slender splinter of cartilage will be found extending from this exposed piece of Meckel's into the cavity between the elements. A small ossified region will be located as part of Meckel's cartilage and forming the articulating surface. This is articular.

Separate the jaw and the cranium. Clean the jaw and lay it away to dry. Place a piece of match or a wood splinter between the caudal ends of the rami, or the drying will alter the shape of jaw.

Cut into the membrane of the orbit and note that this membrane is double in the cephalo-mesal region, leaving space for the olfactory bulb. Clean the orbit now and remove

all shreds of muscle from the cranium. With forceps probe into the hole (*foramen magnum*) at the caudal end of the head and remove the brain, as its presence will discolor the specimen. Wash the cranium carefully and put it away to dry.

VERTEBRAE.—The regions of the vertebral column now remain to be cleaned. Observe that upon the dorsal side of the vertebrae is a canal in which runs the spinal cord. Pull out this cord and run a fine wire through this canal, placing a small block of wood to represent the sacral vertebra, which is attached to the pelvic girdle. The caudal region is less liable to falling apart than the trunk, because of the added support of the haemal arch, but care should be exercised that the order of the vertebrae is not confused.

Ascertain the position of the transverse processes of the trunk vertebrae and the extent of the ribs. The flesh may now be cut from the sides of the vertebrae; take care that the ribs are not damaged. Remove as much muscle as possible from all sides of the vertebrae (trunk), and cut between each pair of transverse processes with ribs attached.

Remove the muscle from one side of the tail and expose the vertebrae. Observe the ventral arch or canal in which run blood vessels. Observe that caudally the vertebrae become smaller and finally are mere slugs of cartilage with neither neural nor haemal canals. Upon how many caudal vertebrae are there transverse processes? Upon how many are there ribs? Pick away as much muscle and membrane as possible and determine how many of the vertebrae are bony.

Cut the strip of bony vertebrae from the others and string in proper relation to the trunk vertebrae. Boil these vertebrae in soap solution for thirty minutes and clean; several boilings may be necessary before cleaning is completed. When they are cleaned, lay them away to dry but do not remove the wire, as this determines relationship. Clean the cartilaginous vertebrae by soaking in soap solution at about 40° C and cleaning a little each day.

The first vertebra, the one which articulates with the head, is the cervical, or "atlas." There is usually one sacral vertebra, although one or two trunk vertebrae may fuse to it.

In case time is not allotted for making a skeleton, the student should study the preceding outline while referring to a prepared specimen, X-ray photographs, an unskinned specimen, and student skeletal material until the relationships in the framework of this form of amphibian are ascertained.

Questions

How many trunk vertebrae are present?
How many caudals?
How many of these possess canals?
How many vertebrae in the skeleton?

Chapter III

THE SKELETAL SYSTEM

A. AXIAL DIVISION OF THE SKELETON

Vertebrae

The vertebral column is composed of thirty-nine to forty-two vertebrae: one cervical (atlas), eighteen trunk, one sacral (a variation may occur here, as one or two trunk vertebrae may fuse with the sacral), and nineteen to twenty-two caudals. There are fifteen caudal vertebrae showing haemal and neural arches and four or more vertebrae which are mere segments of cartilage with the nerve cord running dorsad and the blood vessels running ventrad in normal condition. These last few segments give support to the end of the tail, which is the important instrument in swimming.

Place the string of vertebrae before you, and bring out the cartilaginous vertebrae which you placed in formalin. Count the vertebrae, remembering that the sacral is with the pelvic girdle in the formalin jar. The spool-like structure of a vertebra is the centrum and indicates the ventral side of a trunk vertebra. Dorsad of the centrum is the neural canal, formed by the neural arches of each vertebra. Determine the number of vertebrae cephalad of the sacral vertebra. Caudad of this vertebra, the ventral side is modified to form the haemal arch, which in the first few caudal vertebrae may appear as projections from the centrum, the arch being incomplete. Further caudad, this arch becomes complete and encloses the caudal artery and vein.

Note carefully the method by which each vertebra articulates with the one cephalad and the one caudad to it. Examine the centrum and observe that both ends are hollow. This makes the vertebra amphicoelous. When the vertebrae were cleaned, small cones of cartilage were found in these hollow ends; the cones represent the notochord and also form the pads between individual vertebrae.

Examine the vertebra that articulates with the cranium, the "atlas" or cervical. Orient this vertebra by placing the caudal edge of its centrum exactly vertical and to the right. Upon the cephalic face are the two cranial articulations, the *anterior articular surfaces,* between which lies the cephalic limit of the centrum. Dorsad of this centrum is the *neural canal,* through which the nerve cord passes. The sides of this arch are made by *neural plates* which unite dorsally to form a *neural spine.* On either side of this spine, and upon the posterior (caudal) margin, the neural arch expands to form the *posterior zygapophyses,* by means of which the vertebra articulates with the first trunk vertebra. (In rare cases the "atlas" may possess rudimentary transverse processes.)

[STUDY II: Draw the lateral (Figure 1), the cephalic (Figure 2), and the caudal (Figure 3) aspects of the cervical vertebra, labeling all regions mentioned in the descriptions.]

All the trunk vertebrae possess ribs, and the form of the eighteen does not vary except in a gradual increase in size caudally. Select a trunk vertebra with the ribs intact and examine. The centrum is hollow at both ends. What is the name of this type of vertebra? By observing the string of vertebrae, determine the anterior or cephalic end of this vertebra, and orient it by placing the anterior end to the left and the centrum toward the bottom of the paper. Dorsad of the centrum is the *neural canal.* The *dorsal spine* is scarcely visible in the prepared specimen, as it is cartilaginous; however, it does appear as a slight elevation in the median

line and as a prominence at the caudal border of the dorsum of the vertebra.

The cephalic projections of the neural arch are the *anterior zygapophyses* and the dorsal surfaces, which are flattened to receive the posterior zygapophyses of the vertebra just cephalad to it. The posterior or caudal projections of the dorsal plate of the neural arch are the *posterior,* or caudal, *zygapophyses,* the ventral surfaces of which are flattened to articulate with the anterior zygapophyses of the vertebra just caudad to it.

Outgrowths of neural plate and centrum appear to have fused to form the *transverse process* with which a rib articulates. Observe the specimen in caudal aspect. On either side of the centrum, and apparently passing through each transverse process, is a small canal, the cephalic opening of which may be seen on either side of the centrum about one third of the length of the centrum from its cephalic face. This is the *vertebrarterial canal,* the floor of which is formed by the *horizontal lamina* and the dorso-lateral border by the transverse process, or the *dorsal-lamina.* Within the mesal wall, or the *vertical lamina,* of the neural arch is a small foramen through which a branch of the vertebral artery reaches the spinal cord. Upon the distal margins of the transverse processes are two small fossae, the dorsal one termed *diapophysis* and the ventral one *parapophysis.* Into these fossae articulate the two small heads of the rib, the *tubercular,* or dorsal, *head* articulating with diapophysis, and the *capitular,* or ventral, *head* articulating with parapophysis. The rib is a slender structure projecting caudo-laterad and ending in a small cartilaginous tip.

[STUDY II: Draw the dorsal (Figure 4), the lateral (Figure 5), and the caudal (Figure 6) aspects of the trunk vertebra with rib attached, labeling all regions described above.]

The sacral vertebra is built upon the same plan as that of the trunk vertebrae, with the exception of the heavier trans-

verse processes and ribs which turn ventrad to articulate with the ilia of the pelvic girdle.

[STUDY II, Figure 7: Draw the lateral aspect of the sacral vertebra, labeling all structures and regions as in the trunk vertebra.]

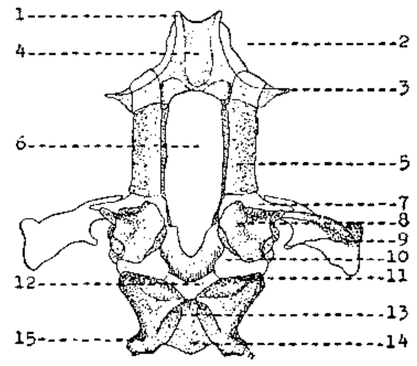
The caudal vertebrae show a progressive change. The first caudal usually shows two small projections ventrad from the centrum, leaving an incomplete haemal arch, and a neural spine little changed from the condition in the trunk vertebrae. The second caudal has a closed haemal arch with a haemal spine pointing caudo-ventrad and a prominent dorsal spine, upon either side of which are the posterior zygapophyses. Only the first eight caudal vertebrae bear transverse processes, the first few of which bear tiny ribs, these decreasing in size with each vertebra until no rib is found. Is there a vertebrarterial canal in the caudal vertebra? How do the anterior zygapophyses differ from those of the trunk vertebrae?

[STUDY II, Figures 8-11: Draw the third and ninth caudal vertebrae in lateral and in caudal aspects, labeling all described regions (if present) under trunk vertebrae as well as under caudal vertebrae.]

THE SKULL

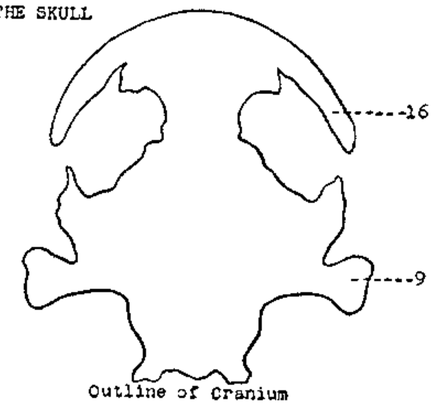
THE CHONDROCRANIUM.—The chondrocranium, although preceding the bony cranium in formation, can best be understood in terms of the cranium, as the chondrocranium is the cartilaginous framework upon which the cranium is builded. To prepare a chondrocranium for study, remove the cranium of a preserved specimen, or a freshly killed specimen, if possible, and clean away all the tissue except the membrane of the orbit. Soaking a few days in soap solution will not impair the material, and it will aid in the removal of the muscles. Do not allow the specimen to become dry at any time, and when it is clean, place it in a Petri dish and cover with a solution of one part 10% nitric acid and one part 95% alcohol. Allow this to stand covered until tests show that the

PLATE I THE SKULL



Dorsal Aspect of Chondrocranium and the Quadrates.

Figure 1



Outline of Cranium

Figure 2

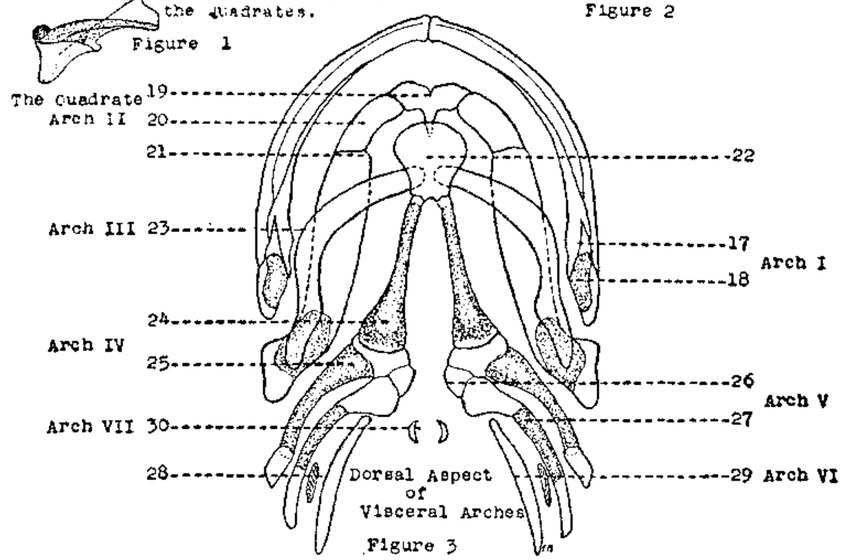


Figure 3

(Plate I, Figures 1-3)

1—trabecula
2—olfactory capsule
3—antorbital process
4—ethmoid plate
5—orbitosphenoid
6—basicranial fenestra
7—post-orbital process
8—pro-otic bone
9—quadrate
10—otic capsule
11—exoccipital
12—synotic tectum
13—basal plate
14—basioccipital
15—exoccipital condyle
16—maxilla
17—Meckel's cartilage
18—articular
19—basihyal
20—hypohyal
21—ceratohyal
22—anterior basibranchial
23—ceratobranchial 1
24—ceratobranchial 2
25—epibranchial 2
26—ceratobranchial 3
27—epibranchial 3
28—gill slit
29—epibranchial 4
30—arytenoid cartilage

bone is soft and very pliable.[1] Wash the specimen carefully for fifteen minutes in running water, and with extreme care peel off the membrane bones one at a time, preserving each one for replacement in case a question of relation of parts should arise. See the list of bones at the end of the discussion of the skull for the names of the membrane bones.

A longer but easier and more exact method of preparation is maceration. Place an uncleaned cranium in a stone or glass jar and fill the jar with water. Cover it loosely and set it aside until the flesh and membrane bones fall away. The chondrocranium will be intact, with the exception of the quadrate, which may be found either only slightly attached or free. It is partly ossified and is easily discerned to have a location overlapping the pro-otic ossification. (This method will take about six months at normal room temperature.)

If prepared specimens of the chondrocranium are provided, study the cranium and visceral arches; then return to this study. If demonstration specimens of chondrocrania are used, be extremely careful in handling the material, because it is not easily prepared and a perfect specimen requires much time, patience, and skill.

STUDY OF THE PREPARED CHONDROCRANIUM.—The chondrocranium is composed of both cartilage and cartilage bone, the cartilage having been replaced by bone in the occipital regions, the otic regions, and the orbitosphenoids. The *basicranial* fenestra (the opening through the brain case) will be seen to be larger on the dorsal surface than on the ventral. It is limited cephalad by the triangular *ethmoid plate,* which is formed by the fusion of the cephalic ends of the prechordal cartilages or bars. The prechordals, laterally beyond the ethmoid plate, form two processes; the anterior (median) one is termed *trabecula* and the lateral one *antorbital process.* Between these processes is the very delicate *nasal capsule.*

Along each side of the basicranial fenestra, helping to

[1] We suggest that, while the chondrocranium is soaking in nitric acid, the cranium be studied in order that the student may have a knowledge of the bones which comprise the cranium and know which are the membrane bones.

form the brain case, lies an *orbitosphenoid* (formed by the prechordals) with an ossified shaft and ends of cartilage. The caudal end expands into a *post-orbital process.* Immediately behind the post-orbital process is the ossified *pro-otic bone,* and caudad of this lies *the otic capsule* bearing upon its lateral face an opening, the *fenestra ovalis.* The fenestra is covered by a small circular disc, the *operculum,* bearing the *columella.* This is easily lost in the preparation of the chondrocranium and may not be present.

The *quadrate cartilages,* usually found connected to the chondrocranium and overlapping the ossified pro-otic regions, are ossified upon the anterior and lateral regions. They are free from the chondrocranium (which condition is evidence that they are migrating from the first visceral arch) and, in life, are held in place by connective tissue. The *basal plate* (formed by a fusion of the parachordals) extends between the exoccipital regions and forms the *basioccipital bone* of the cranium.

Dorsally between the *exoccipital bones* is a narrow band of cartilage and bone termed the *synotic tectum.*

The *optic capsules* form the sclera of the eyeball and, of course, are not connected with the main structure of the chondrocranium; nevertheless, these capsules are a part of the chondrocranium and should be diagrammed in place. The exoccipital, basioccipital, pro-otic, and opercular bones with the columellae are ossified.

> [STUDY III: Draw the dorsal aspect of the chondrocranium, labeling all regions, cartilages, and bones described. In outline superimpose the cranium upon this drawing and study relationships. What portions of the chondrocranium form an exposed part of the cranium? Are these portions cartilaginous or bony?]

Color all cartilaginous portions of the chondrocranium blue, and all ossified regions brown. These brown regions are exposed in the definitive cranium, while the greater portion of the blue region is covered by membrane bones.

THE CRANIUM.—This portion is the brain case proper, with the articulations for the visceral arches and the supports for the sense organs.

(*a*) *Dorsal Aspect.*—All the bones on the dorsal aspect are paired. The open space on each side is the *orbit,* which in life is filled in with a thin membrane upon which the optic capsule rests. The two cavities on the anterior border of the cranium are the nostrils. Between the nostrils lie two small triangular bones with their apices directed caudad. These are the *premaxillary bones.* On the anterior margin of each nostril is a suture which separates the premaxillary from the *maxillary bone.* Each maxillary bone projects latero-caudad and forms the outer anterior margin of the orbit. The posterior floor of each nostril is made of the *vomer,* which in some specimens is seen projecting from the the under side of the cranium into the orbit. Meso-caudad of the nostril and caudad of the premaxillary is the *nasal bone,* which meets its partner on the median line, forming a point. Laterad of the nasal and extending caudad, meeting its partner on the medial line in a ridge, is the *frontal bone.* Laterad of the anterior portion of the frontal and articulating with the maxillary is the *prefrontal,* forming the anterio-mesal border of the orbit.

Caudo-laterad of the frontals are the *parietals,* which form the caudo-dorsal roof of the brain case and border on the *foramen magnum,* the exit for the spinal cord. Forming the lateral boundaries of this foramen are the *exoccipitals,* possessing latero-caudal projections—the *exoccipital condyles.* Laterad of the parietal is a narrow bone, the *orbitosphenoid,* forming the lateral wall of the brain case and serving as a prop to keep the roof and the floor of the braincase separated. Laterad of the orbitosphenoid is an irregularly shaped bone, the *palato-pterygoid,* forming the caudal margin of the orbit. Meso-caudad of the palato-pterygoid is the large *pro-otic foramen* for nerves V and VII. The floor and posterior wall of this foramen is formed by the *pro-otic bone,* which is

very irregularly shaped and does not show well except in a disarticulated skull.[2]

Extending laterad from the parietal bones is a heavy projection ending in a distinct articular process which in life is covered with cartilage. This projection is made of three bones: ventrally and caudally by the palato-pterygoid, dorsally by a thin membrane bone, the *squamosal,* and at the lateral articulation by the quadrate. The quadrate also bears a splinter-like process extending between squamosal and palato-pterygoid, on the anterior margin of the projection. Cartilage fills spaces between these bones. Caudad of the region where this projection joins the brain case is the *otic capsule* with its lateral aperture closed with the *operculum.* Caudad of this and fused with the exoccipital is an *opisthotic* region.

(*b*) *Ventral Aspect.*—All but one of the bones in this aspect are paired. On the anterior margin appear, medially, the *premaxillary* bones, and laterad of these the *maxillaries.* The *premaxillaries* and the maxillaries bear a row of teeth on the areas of attachment. Caudad of this row of teeth is a second row which marks the anterior margin of the *vomers.* Between the vomers on the anterior margin is a triangular space filled in life with cartilage of the *ethmoid plate.* Dorsad of these vomers may be seen *prefrontals* projecting into the orbit. Caudad of the vomers is the single median bone, the *parabasal,* or parasphenoid, forming the floor of the brain case. The posterior end of this bone is roughened and its posterior border is formed of a bone inseparably fused with it. This is the *basioccipital.* On the lateral border of the parabasal is the otic capsule, its anterior wall formed by

2 Disarticulated crania give much instruction, and in this case, where the pro-otic is poorly observed in general aspect, it is well to have the students disarticulate crania for themselves. Place the well-cleaned cranium into a Petri dish and cover with N/10 sodium hydroxide for two days. Pour off the liquid and flood several times with water. Float the cranium onto a paper and gently pull it apart, making careful observations of the relations of the bones. Place these bones upon cotton in as nearly relative positions as possible and allow them to dry. They may now be mounted under glass in a Riker mount, under transparent celluloid or cellophane, and preserved.

the pro-otic and its posterior margin by the opisthotic. Laterally is an opening, the *fenestra ovalis,* which is closed by the *operculum* bearing a small lateral projection, the *columella.* Sometimes the cartilage surrounding the operculum is loosened and the bone is lost. Laterad of the parabasal lies the *palato-pterygoid,* forming a thin broad plate which by its caudal region forms the ventral surface of the lateral projection of the cranium. The terminal bone of the projection is the *quadrate.* On the anterio-mesal border of the palato-pterygoid and articulating with the parabasal, a small triangular piece of the *orbitosphenoid* is visible.

THE FORAMINA OF THE CRANIUM.—The nostrils are only supports to the external nares, and are not true foramina, as neither nerve nor blood vessel passes through them. The internal nares are supported by the lateral projections of the vomer, and the true *nasal foramina* lie between vomer and prefrontal, on the cephalo-mesal margin of the orbit. Upon the lateral margin of orbitosphenoid about midway cephalo-caudad is the *optic foramen* for nerve II and the ophthalmic artery, and caudo-laterad of this upon the palato-pterygoid is the *pterygoid foramen* and groove for nerves III, IV, and VI. Caudad of orbitosphenoid and in front of the pro-otic bone, is the *pro-otic foramen* for nerves V and VII and the internal jugular vein. Caudo-laterad of this foramen, passing under the squamosal bone and visible in cephalic or caudal aspect is the *carotid foramen* for the passage of the internal carotid artery. Upon the lateral face of the exoccipital bone is the *exoccipital foramen* for nerves IX and X. Near the lateral margin in the caudal third of the parabasal bone is the *parabasal foramen* for the cerebral artery. Observe the *otic foramen* in the lateral face of the otic capsule for the exit of a blood vessel. (As you discovered when cleaning the cranium, there are numerous other small foramina for nerves and blood vessels.) The caudal foramen (*foramen magnum*) lies caudad of parietals, mesad and dorsad of exoccipitals, and forms the passageway for the spinal cord into the neural canal.

[STUDY IV: Draw (Figure 1) the dorsal and (Figure 2) the ventral aspects of the cranium, labeling each bone and foramen described. Draw (Figure 3) the lateral and mesal aspects of the rami of the mandible, as described next.]

VISCERAL ARCHES.—Account for seven visceral arches. Arch I, the mandible, although almost all membrane bone, still supports a piece of *Meckel's cartilage,* described in Chapter II. The *quadrate* has become part of the cranium. The mandible[3] is made of left and right rami, articulating with each other at the anterior margin of the jaw, and with the cranium at the quadrate bones, the cushion being a part of Meckel's cartilage. Each ramus is made up of four bones. The most anterior and largest is the *dentary.* Mesad to the dentary on the ental surface of the ramus is the *splenial.* At the caudal end of the ramus is a small bone wedged between splenial and dentary on the ventral surface and receiving dentary in a deep notch on the lateral surface; this is *angular.* On the dorsal surface of angular is the small oval bone *articular,* which is the ossified caudal end of Meckel's cartilage.[4] Anterior to the position of the remnant of Meckel's cartilage (where splenial, angular, and dentary meet on the dorsal surface) is an elevation, the *coronoid process.*

Between the rami of the mandible lie visceral arches II to VI. Visceral arch II, the hyoid, is horseshoe-shaped with the open end caudad. It has an anterior median piece, the *basihyal,* from which a bar of two segments extends on either side, first the *hypohyal* and posterior to that the *ceratohyal.* The hyomandibular of the shark has become the *operculum* and the *columella,* and appears upon the cranium. Within the curve of the hyoid lies a median cartilage on a membrane stretched between the sides of the horseshoe; this median

[3] Although not primitive arch I, the mandible is described here for convenience, as it contains and covers the remnants of Meckel's cartilage.

[4] A macerated mandible reveals a piece of cartilage extending from articular between the membrane bones, dentary and splenial.

piece is the *anterior basibranchial,* to which articulate the *ceratobranchials* of arch III and arch IV. Arch III has lost its posterior or dorsal segments, but arch IV possesses an *epibranchial* extending upon the sides of the gill region of the animal. Mesad of the ceratobranchial of arch IV lie two cartilages: *ceratobranchial* of arch V, which is very small and articulates with the *ceratobranchial* of arch IV, and a longer posterior segment, the *epibranchial* of arch V. Arch VI is represented by the epibranchial which lies mesad of the epibranchial of arch V and articulates with it at the cephalic end. Arch VII is represented by an early stage of a voice box at the head of the trachea, the *arytenoids.* (Refer to "Visceral arches" in Chapter II.)

[STUDY V, Figure 1: Draw the dorsal aspect of the arches II to VII in relation to the dorsal aspect of the mandible showing arch I. Label all structures described.

Figure 2: Diagram the skull in lateral aspect showing, clearly, relations of all parts.]

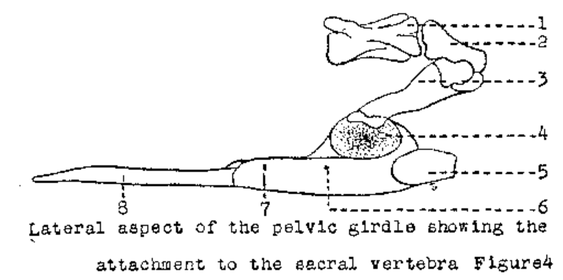
In finishing all aspects of the cranium and the mandible, color cartilage blue, cartilage bones brown, and membrane bones yellow. Color the visceral arches in the following scheme: arch I, or Meckel's (articular), and the quadrate blue; arch II, including the columella brown; arch III yellow; arch IV pink; arch V orange; arch VI green; arch VII gray.]

In the *Cryptobranchus* cranium the cartilage bones are orbitosphenoids, quadrates, exoccipitals, basioccipital, opisthotic regions, operculum, and columella. In the mandible, the articulars are cartilage bones.

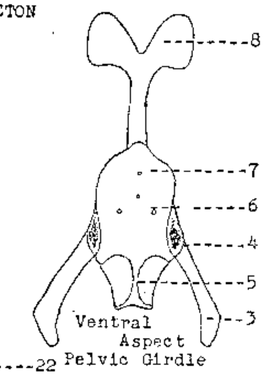
B. APPENDICULAR DIVISION OF THE SKELETON

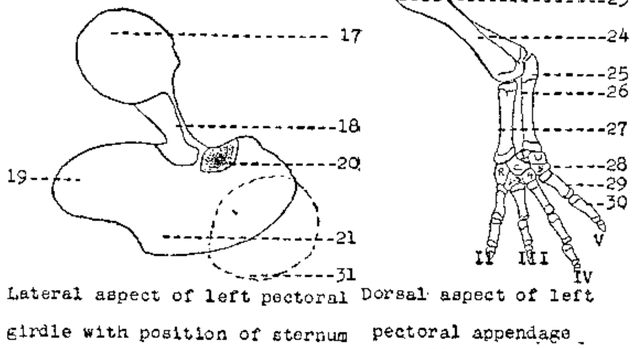
THE PECTORAL REGION: (*a*) *The Girdle.*—Observation shows the pectoral girdle to be of two pices, a left and a right half, lying upon the ventral and lateral surfaces of the region bearing the front legs, and overlapping to some extent upon

PLATE II THE APPENDICULAR SKELETON



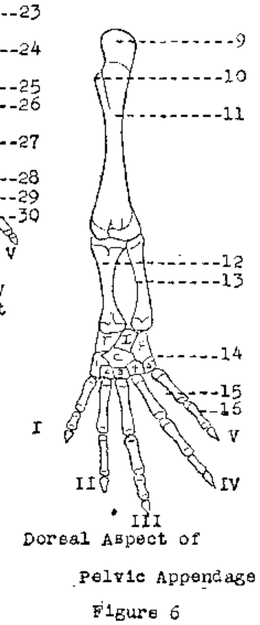
Lateral aspect of the pelvic girdle showing the attachment to the sacral vertebra Figure4





Lateral aspect of left pectoral girdle with position of sternum Figure 7

Dorsal aspect of left pectoral appendage Figure 8



Dorsal Aspect of Pelvic Appendage Figure 6

(Plate II, Figures 4-8)

1—sacral vertebra
2—sacral rib
3—ilium
4—acetabulum
5—ischium
6—obturator foramen
7—pubis
8—ypsiloid process
9—head of femur
10—trochanter
11—shaft of femur
12—tibia
13—fibula
14—tarsus
15—metatarsalia
16—phalanges
17—suprascapula
18—scapula
19—procoracoid
20—glenoid fossa
21—coracoid
22—head of humerus
23—bicipital tuberosity
24—shaft of humerus
25—olecranon process
26—ulna
27—radius
28—carpus
29—metacarpalia
30—phalanges
31—sternum
T —tibialis
F —fibulare
I —intermedium
R —radiale
U —ulnare
C —centrale

the venter between the legs. The structure is almost all cartilaginous and very thin and sheet-like. Observe the portion of the girdle which lies upon the left side of the animal. There are three definite regions of this cartilaginous sheet: a ventral, a cephalic, and a dorsal. The ventral plate is the largest, and is broad with a curved mesal border. It lies in two planes, a ventral and a lateral, and is termed the *coracoid plate.* Extending cephalad from the lateral region of the coracoid plate is the *procoracoid,* and extending dorsad in a projection markedly constricted at its base is the *scapula,* which bears upon its dorsal margin a delicate expanded membrane, the *suprascapula.* In the caudal area of this half of the girdle is a fossa made by these three plates. This is the *glenoid fossa* and forms the socket in which the front leg articulates. Hold the specimen up to the light and note that there is a calcified region around the glenoid fossa and that an ossified region extends well into the scapula. There is a foramen in the coracoid plate, the *coracoid foramen,* through which a branch of the cutaneous artery is seen to pass to feed the supracoracoideus muscle.

[STUDY VI, Figure 1: Draw the latero-ventral aspect of the left half of the pectoral girdle, labeling all regions described. Color the coracoid plate blue, the procoracoid green, the scapula pink, and the suprascapula yellow.]

As we follow the theory that the sternum is cut out of the overlapping pectoral girdles, the description of the *sternum* belongs at this point. It is a delicate plate of cartilage slightly ossified in the central region of the cephalic margin. The plate is slightly heart-shaped with its apex pointing cephalad. In the preparation of the skeleton, this was observed and a sketch made of the sternum in relation to the pectoral girdle. If the skeleton was not prepared, a demonstration will be furnished.

[STUDY VI, Figure 2: Make a diagram of the sternal region showing the manner in which the sternum is overlapped by the halves of the pectoral girdle.]

(*b*) *The Appendage.*—The pectoral appendage is divided into three regions: the upper arm, the forearm, and the hand, the hand being again divided into wrist, palm, and digits. The upper arm is composed of a single element, the *humerus,* the *shaft* of which is ossified and the *epiphyses* cartilaginous. The proximal end of the humerus, which is termed the *head,* articulates in the *glenoid* fossa, and immediately distad of the head is an enlargement, the *deltoid prominence,* for the attachment of the pectoral group of muscles. Upon the distal end of the humerus are two condyles, the *post-axial,* or median, with which the *ulna* articulates, and the *pre-axial,* or lateral, with which the *radius* articulates. Upon the dorsal surface of the distal region lying between the two condyles is the *olecranon fossa* for use in the articulation of the ulna.

Articulating with the lateral condyle of the humerus is the *radius.* Articulating with the median condyle is the ulna. The proximal end of the ulna is prolonged into the *olecranon process,* which articulates in the olecranon fossa of the humerus. The shafts of the ulna and the radius are ossified and the epiphyses are cartilaginous, the distal epiphyses expanding to articulate with the cartilaginous elements of the wrist.

There are seven elements in two rows, four in the proximal and three in the distal rows. Articulating with the radius and the ulna and lying slightly between their distal ends is the *intermedium.* Distad and upon the pre-axial side of the wrist articulating with radius is a five-sided element, the *centrale.* Frequently this element is represented by two small cartilages and at times a line of fusion may be seen upon the single element. Laterad of centrale and again articulating with the radius is another five-sided element, the *radiale.* Mesad of intermedium and articulating with the ulna is *ulnare.* The distal row of elements are the *carpalia.* Carpal 1 has been lost with its digit and carpalia 2 and 3 are fused. Carpalia 4 and 5 lie proximad of the respective digits. The

palm of the hand is formed by four *metacarpals*, the shafts of which are ossified and the epiphyses cartilaginous. Digits 2, 3, and 5 are composed of two phalanges each, and digit 4 possesses three phalanges (formula: 0-2-2-3-2).

[STUDY VI, Figure 3: Draw the dorsal aspect of the pectoral appendage, labeling all cartilages, bones, and regions which appear in this aspect.]

THE PELVIC REGION: (*a*) *The Girdle.*—The pelvic girdle is a single structure lying in median position between the pelvic appendages. Remove the girdle from the formalin jar; observe its ventral aspect. The *pelvic plate* is made chiefly of cartilage and possessed of two lateral foramina one either side of the median line in about the middle of the plate; these are the *obturator foramina*. Cephalad of the obturator foramina and in the median line of the pelvic plate are two small foramina. Fused upon its cephalic median margin is the Y-shaped *ypsiloid process*, the "wings" of which expand laterally. The cephalic region of the pelvic plate is the *pubis*, and the caudal region of the girdle is formed by two ossified semicircles, the *ischia*. Upon either side of the pelvic plate is a fossa which is formed partially by the pubis, partially by the ischium, and partially by a third bone, the *ilium*. This fossa is the *acetabulum* and articulates with the pelvic limb. The ilium is a slender bone which projects dorso-caudally and articulates with the distal end of the sacral rib.

[STUDY VII: Draw the ventral (Figure 1) and the lateral (Figure 2) aspects of the pelvic girdle, showing the relationship to the sacral vertebra and labeling all structures described.]

(*b*) *The Appendage.*—The hind leg is formed of three regions, the upper leg or thigh, the fore leg, and the foot, the foot being again divided into ankle, instep, and digits. The thigh is composed of one single element, the *femur*, the shaft of which is ossified and the epiphyses are cartilaginous.

The proximal epiphysis is the head and articulates in the *acetabulum* of the pelvic girdle. Immediately distad of the head, the femur possesses an expansion of the ventral side. This is the *trochanter* for the attachment of muscles. The distal epiphyses of the femur form two condyles, a *pre-axial condyle* for the articulation of the tibia and a *post-axial* one for the fibula. The *tibia* is heavier than the *fibula*, but both have ossified shafts and cartilaginous epiphyses, the distal ones articulating with the cartilaginous elements of the ankle.

Articulating with the tibia upon the pre-axial margin is the *tibiale* and articulating with the fibula is *fibulare*. Lying between fibulare and tibiale is the rhomboidal *intermedium*. Distad from intermedium is a six-sided element, the *centrale*.[5] The *tarsalia* are five in number. In many specimens tarsale 1 is displaced and takes a position proximad of tarsale 2, giving the impression of a second centrale and a fusion of tarsalia 1 with 2; but as other specimens show the five tarsalia in line with the digits, we prefer the above interpretation. There are five *metatarsals* articulating with the tarsalia and there are five digits. Digits 1, 2 and 5 have two phalanges, while digits 3 and 4 have three each (formula: 2-2-3-3-2).

[STUDY VII, Figure 3: Draw the dorsal aspect of the pelvic appendage, labeling all structures described.]

Questions

What is the nature of the skeleton in *Cryptobranchus?*
Write a synopsis which will show the general divisions and the elements of the vertebrate skeleton as exemplified in *Cryptobranchus.*
Name the regions of the vertebral column.
Diagram the trunk and caudal vertebrae, comparing them with each other and with the similar regions in the shark.
Describe the parts of a rib and its relation to a vertebra.
Upon which vertebrae are ribs situated?

5 *Centrale* is the fusion of the two primitive centralia, which frequently appear.

What forms the connection between sacral vertebra and pelvic girdle?
What is the status of neural and haemal arches in caudal vertebrae?
Name the elements of the primordial chondrocranium, with origin and number of each.
Make a diagram of the chondrocranium including the ossified regions.
Name and locate the cartilage and membrane bones of the cranium, indicating the single and the paired elements.
Name and locate the elements of the lower jaw and compare with the same region in the shark.
Which bones form the following regions: orbital? occipital? otic?
Name the elements of the visceral skeleton and compare with that of the shark.
How does the articulation between mandible and cranium compare with the same condition in the shark?
Name the elements of the pectoral girdle. Is is attached to the vertebral column?
What is the condition in the shark?
How do the appendages agree with the primitive chiropterygial appendage?

Chapter IV

THE MUSCULAR SYSTEM

Skin a specimen according to the directions given in Chapter II, taking care not to cut any blood vessels or tear any muscles. The following additional directions may prove helpful. If the specimen will later be used to study circulation, great care must be exercised in skinning the neck region, as there are blood vessels of great importance upon the ventral side and along the lateral aspect in the gill region and upon the head.[1]

A large heavy vein that runs in the lateral fold must be guarded. Lift the skin upon the back of the head and gently work it loose cephalad to the edges of the maxillae. Cut the skin at the edges of the maxillae and work the piece caudad and laterad, watching for the blood vessels and gently pushing them away from the skin. Free the skin from the ventral side of the pectoral region and, by lifting the skin in the mid-ventral region, work forward and laterad until the gill region is exposed. Cut the skin away from the gill slit but do not injure it.

Much care must be used on the ventral side of the head, as these muscles are thin and frequently stick tightly to the skin. Begin at one corner of the lower jaw and gradually work forward and toward the middle; cut the skin at the margin of the mandible and, if necessary, cut the muscles loose from the skin. Lift the skin toward the middle and

[1] It is well to skin only the left side of the specimen at this time.

cut the skin free from the mid-ventral line, the raphe of the *mylohyoideus* muscle, which will be seen stretched between the rami of the mandible.

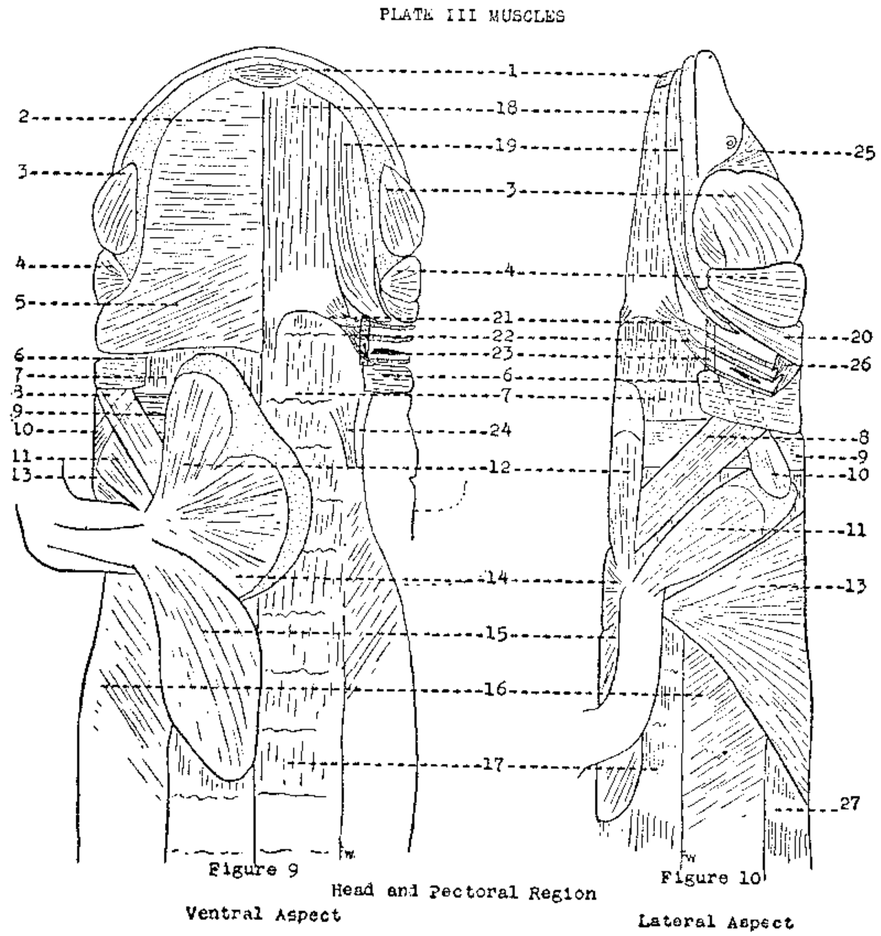
The pelvic region skins easily and quickly and no care is needed except around the cloacal opening, where the skin must be cut away. After the specimen is skinned, remove the slimy membrane which covers the masses of muscles and obscures their margins.

THE HEAD AND GILL REGION

Upon the dorsal side of the specimen five sets of muscles are located. Originating at the median line of the cranium upon the frontal, the parietal, and the cervical vertebra is the *temporalis*. The fibres apparently pass laterad but turn cephalad upon the ventral side of the muscle. The muscle extends as far forward as the caudal margin of the eye, where the fibres form a slender band and pass laterad to insert upon the inner side of mandible, upon splenial.

Caudad of temporalis lie two heavy muscle masses. The more anterior one is *masseter*, which originates on squamosal and inserts upon the dorsal margin of the mandible, on dentary; the posterior one is *digastric*, originating upon the caudad part of parietal and inserting upon angular of the mandible. Just caudad of digastric is a small muscle originating upon the body segments of the "neck" and inserting upon the extreme caudal tip of the mandible; this is *externus ceratohyoideus*. Posterior to externus ceratohyoideus is a muscle which originates upon the body segments and passes ventrally caudad of the gill slit and inserts upon the proximal end of the epibranchial of arch VI, under the side of sternohyoideus (the ventral muscle of this region). This is *dorsalis trachealis*.

Upon the ventral side of the head and gill region are thirteen sets of muscles, four of which have been seen in dorsal aspect. Stretched between the rami of the mandible is *mylohyoideus*, which originates upon the ramus of each side and inserts upon the raphe in the median line. Caudad of this muscle lies a similar one which originates upon the fascia of the side of the gill region and inserts upon the



(Plate III, Figures 9-10)

1—submentalis
2—mylohyoideus
3—masseter
4—digastric
5—mylohyoideus posterior
6—dorsalis trachealis
7—sternohyoideus
8—cucullaris I
9—cucullaris II
10—levator anguli scapulae
11—dorsalis scapularis
12—procoracoideus
13—latissimus dorsi
14—supracoracoideus
15—pectoralis
16—externus obliquus
17—rectus abdominis
18—geniohyoideus
19—internus ceratohyoideus
20—externus ceratohyoideus
21—depressor I
22—depressor II
23—constrictor
24—omohyoideus
25—temporalis
26—levator branchiarum
27—longissimus dorsi

raphe, the fibres running at a slightly different angle from those of mylohyoideus. This is *posterior mylohyoideus.*

At the symphysis of the rami is a small muscle apparently supporting the suture; this is *submentalis.* Frequently this muscle is not exposed until mylohyoideus is removed. Caudad of the mylohyoideus muscles and bordering the median line are two segments of *sternohyoideus,* the insertion of which will be seen later upon the anterior basibranchial of the gill arches. This muscle is continuous with rectus abdominis, the ventral muscle of the trunk. Sternohyoideus passes underneath the coracoid region of the pectoral girdle.

Slit the raphe of the mylohyoideus group and turn the muscles laterad. On either side of the median line is *geniohyoideus,* a thin, flat muscle which originates upon the cephalic end of each ramus and inserts in the following manner: in the caudal region of the muscle is a membrane upon which the fibres of the larger portion of the muscles terminate, but in many specimens a narrow strip of fibres from the lateral border of geniohyoideus inserts upon the ceratobranchial of arch IV (ceratobranchial 2). From the membrane mentioned above, muscle fibres arise in two regions: the median, which inserts upon the sternohyoideus; and the lateral, which inserts upon the epibranchials of the gills. This lateral portion separates into two bundles, a median or slightly ventral bundle and a lateral or slightly dorsal bundle. The median bundle, *depressor I,* inserts upon the epibranchial of arch IV (epibranchial 2) and the lateral bundle, *depressor II,* passes dorsad of depressor I, emerging from its caudal border to insert upon the epibranchial of arch V (epibranchial 3). In many specimens depressor II may send a slender branch to the epibranchial of arch VI (epibranchial 4). All the muscles inserting upon epibranchials of arches IV, V and VI are crossed by a tiny band of muscle, the *constrictor,* which originates upon ceratohyal and inserts upon the caudal margin of the epibranchial element of arch VI. The origin of the constrictor is concealed by a heavy muscle lying laterad to geniohyoideus. This is *internus ceratohyoideus,* which

originates upon the basihyal of the hyoid arch and inserts upon the distal end of the ceratohyal.

Free the geniohyoideus and the internus ceratohyoideus at their origins and reveal the origin of sternohyoideus upon the basibranchial of the gill arches. The masseter, digastric, external ceratohyoideus, and dorsalis trachealis muscles are visible from this aspect.

In lateral aspect many of the muscles of the head and gill region, as described above, appear. A new one is to be observed, *levator branchiarum,* which originates upon the myotomes under externus ceratohyoideus and inserts at three points upon the distal ends of the epibranchials of arches IV, V, and VI.

THE PECTORAL REGION

Turn the specimen to observe the lateral aspect of the shoulder region. It was learned in preparing the skeleton that the pectoral girdle is attached to the body by a series of muscles. The most caudal of these is *latissimus dorsi,* which originates upon the segmented muscles of the back and inserts upon the humerus of the pectoral appendage. Cephalad to this is *dorsalis scapularis,* which covers the scapula and suprascapula of the girdle and likewise inserts upon the humerus. Across the dorsal end of dorsalis scapularis and running perpendicular to it is a narrow muscle, the *levator anguli scapulae,* which inserts upon caudad edge of the suprascapula and, passing beneath dorsalis trachealis and externus ceratohyoideus, originates on the side of the cranium caudad of the otic capsule.

Cephalad of dorsalis scapularis is *cucullaris,* which appears as two muscles. One part, *cucullaris I,* originates upon body myotomes beneath dorsalis trachealis and, passing caudoventrad, inserts upon the procoracoid. The second part, *cucullaris II,*[2] originating upon the body myotomes caudad of

[2] This muscle, which is variable, is not present in all specimens.

dorsalis trachealis, passes underneath cucullaris I and inserts upon the procoracoid cartilage cephalad of the insertion of cucullaris I.

Covering the procoracoid of the girdle and also inserting upon the humerus is the *procoracoideus*. Upon the ventral aspect are two muscles which belong to the pectoral region. Upon the coracoid plate lies *supracoracoideus*, which originates a short distance from the medial curve of the coracoid and inserts upon the humerus. Covering the sternum and originating upon rectus abdominis is *pectoralis*, which also inserts upon the ventral side of the humerus.

Lift up the coracoid plates of the pectoral girdle and expose sternohyoideus lying beneath. Observe that there are seven segments (counting from the caudal margin of posterior mylohyoideus to the origin of pectoralis), and that the muscle is continuous with rectus abdominis of the trunk. There is a ventral slip from this muscle as it passes beneath the coracoid, and this slip is inserted upon the dorsal face of the scapula, marking the change from sternohyoideus to rectus abdominis. This slip is termed *omohyoideus*.

THE PECTORAL APPENDAGE.—Five muscles as described above hold the appendage to the girdle and body; these are known as the "extrinsic muscles" of the appendage. The intrinsic muscles are those which move the appendage upon itself. The dorsal and post-axial aspect is covered by *anconeus*, which presents three heads arising from the scapula, the humerus, and the lateral body wall and inserting in a common tendon which passes over the olecranon process and anchors upon the ulna distad of its articulation with the humerus. The *biceps* is the pre-axial muscle which likewise arises by two heads upon the coracoid and inserts upon the distal end of the radius. The forearm is covered dorsally with small elements, all of which fall into one group by function, *extensor communis*. Upon the ventral aspect three muscles may be seen, two of which have been seen in dorsal aspect. Upon the pre-axial margin lies one portion of biceps. Originating upon the coracoid and inserting upon the radius is *coracobranchialis*. Lying between this and the third portion of anconeus

is a small muscle which originates upon the humerus and joins anconeus distally. This is the fourth slip of anconeus.

THE TRUNK REGION

The dorsal surface of the trunk is covered by a series of myotomes which correspond to the regions between the ribs. These myotomes or segments begin at the caudal margin of temporalis and continue the length of the trunk and the tail. In the gill and head regions these segments appear between the dorsal margins of digastric, externus ceratohyoideus, and dorsalis trachealis. These segments or myotomes make up the *longissimus dorsi* muscle of the trunk.

In lateral aspect the trunk from the gill region to the caudal margin of the pelvic region is covered by the *obliquus muscles*, which are made of three thin sheets. The *externus obliquus* is a surface muscle, and its fibres extend from the dorsal myotomes in a cephalo-ventrad direction. Just beneath externus obliquus is a second sheet with the fibres running cephalo-caudad, *internus obliquus*. Beneath these fibres is another sheet with the fibres running ventro-caudad, *transversus*.

Upon the ventral aspect of the trunk is *rectus abdominis*, which is continuous cephalad with sternohyoideus and extends caudad to the pelvic girdle. The rectus abdominis is divided into right and left halves by a line of membrane, *linea alba*.

[STUDY VIII: Draw the ventral aspect of the head, gill, and pectoral region with enough of the trunk to show the muscles of the pectoral region. Show all the superficial muscles of the right side of the specimen and the deeper muscles of the left side (mylohyoideus and the pectoral group having been removed). Make the outlines of the muscles clear and distinct, and indicate the direction of the fibres in each.]

[STUDY IX: Draw the lateral aspect of the head, gill, and pectoral region with a portion of the trunk. Show

PLATE IV MUSCLES

Pelvic region

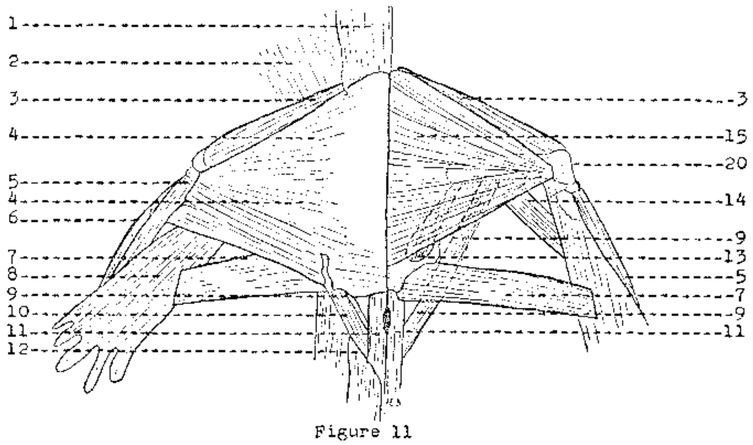


Figure 11

Ventral Aspect

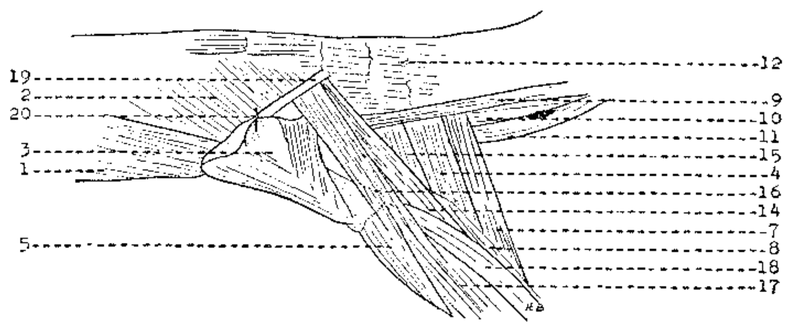


Figure 12

Lateral Aspect

(Plate IV, Figures 11-12)

1—rectus abdominis
2—externus obliquus
3—pubo-ischio-femoralis internus
4—pubo-ischio-tibialis
5—tibialis anticus
6—extensor digitorum communis
7—ischio-flexoris
8—flexor digitorum
9—femoro-caudalis
10—pyriformis
11—ischio-caudalis
12—caudal myotomes
13—ischio-femoralis
14—ilio-fibularis
15—pubo-ischio-femoralis externus
16—ilio-extensoris
17—extensor digitorum communis
18—peroneus
19—ilium
20—femur

all muscles visible in this aspect. Treat the drawing as indicated for Study VIII.]

THE PELVIC REGION

The muscles of the pelvic region may be separated into three main groups: those which hold the girdle to the body, those which hold the appendage to the girdle, and those which are entirely upon the appendage.

In ventral aspect the girdle presents a triangular surface, and the pelvic plate is almost completely covered by a single pair of muscles, the *pubo-ischio-tibialis*. Each member of the pair takes its origin from the median ventral line of the pelvic plate and inserts broadly upon the inner side of the tibia. Upon the cephalic margin of each pubo-ischio-tibialis lies the narrow edge of *pubo-ischio-femoralis internus,* the origin and insertion of which are best observed in lateral aspect. Upon the caudal margin of each pubo-ischio-tibialis lies a narrow bandlike muscle, the *ischio-flexoris,* which originates upon the ischium (underneath the proximal end of pubo-ischio-tibialis and slightly laterad of the ventral median line) and inserts upon the flexor muscle of the ventral side of the appendage. Upon the cephalic border of the girdle, the most caudal segment of *rectus abdominis* inserts and a narrow slip from the lateral border of the segment inserts upon pubo-ischio-tibialis. Caudally three pairs of muscles originate upon the body. Remove the gland around the cloacal opening and reveal the most medial pair, *ischio-caudalis.* Each muscle originates upon the caudal vertebrae and inserts upon the caudal border of the ischium close to the median line. Laterad of each ischio-caudalis lies a narrow band of muscle directed cephalo-laterad. This band originates upon caudal vertebrae and is composed of a ventral and a dorsal bundle. The ventral bundle, *pyriformis,* inserts upon the caudal fibres of ischio-flexoris and pubo-ischio-tibialis; and the dorsal bundle, *femoro-caudalis,* passes dorsad of pubo-ischio-tibialis and ischio-flexoris to insert upon the femur.

Cut the left pubo-ischio-tibialis near its insertion and pull the muscle gently toward the median line. Note the thin membrane by which the muscle originates, and observe that

the fibres do not arise upon the median edge except at the caudal and cephalic borders. Beneath this muscle lie the deeper muscles of the girdle, the larger of which is *pubo-ischio-femoralis externus,* originating upon the median line of the pelvic plate for almost its entire length and inserting upon the shaft of the femur. A small muscle, *ischio-femoralis* originates upon the ischial region (cephalad of the region of ischio-flexoris) and, passing in a cephalo-lateral direction and dorsad of pubo-ischio-femoralis externus, inserts upon the femur. This insertion, as well as that of femoro-caudalis, may be seen by cutting across pubo-ischio-femoralis externus and turning aside the cut edges.

Observe the region in lateral aspect and pull the appendage ventrad to expose its dorsal surface. The ilium is supported by *externus* and *internus obliquus* muscles which insert upon its cephalic border and by the myotomes of the tail, which originate upon its caudal border. Several muscles previously mentioned appear in this aspect. Cephalad of the appendage lie the rectus abdominis and pubo-ischio-femoralis internus. The latter may now be observed as a fan-shaped muscle originating upon the cephalic tip of the pubis and the inner surface of the pelvic plate both cephalad and caudad of the ilium and inserting upon the dorsal and caudal surfaces of the femur. Caudad of the appendage appear ischio-caudalis, pyriformis, and femoro-caudalis as well as ischio-flexoris. Dorsad of the caudal portion of pubo-ischio-femoralis externus lies a broad, thin muscle which originates upon the ilium. This muscle immediately divides into a cephalic portion, *ilio-extensoris,* which passes over the knee by a flat tendon and inserts upon the extensor muscles covering the dorsal surface of the foreleg, and a narrow caudal portion, *ilio-fibularis,* which inserts upon the fibula. Eight muscles, as described above, hold the appendage to the girdle and body and are known as the "extrinsic muscles" of the appendage.

THE PELVIC APPENDAGE.—There are four intrinsic muscles of the leg. Upon the pre-axial border lies *tibialis anticus,* which originates upon the femur and inserts upon the distal end of the tibia. Upon the post-axial margin lies *peroneus,*

which originates upon the femur and inserts upon the fibula. Upon the ventral surface lies a group of flexors, *flexor digitorum,* which originate as a single muscle upon the femur and, after passing over the sole, separate to insert upon the metatarsals and phalanges of the digits. Upon the dorsal surface of the foreleg lie the extensors, which originate in a single muscle *extensor digitorum communis* upon the proximal end of the tibia and, after passing over the tarsals, separate to insert upon the metatarsals and phalanges of each digit.

Recall that in the skeleton of the girdle a cephalic projection of the pelvic plate, the ypsiloid process, appears. This process lies embedded in the rectus abdominis muscle. The tail portion of the process lies in the *linea alba,* which divides the segments of the rectus abdominis in the median line; and the spatulate ends of the process lie in the third myotome from the girdle. Remove the segments of rectus abdominis carefully and expose one side of the ypsiloid process. Extending from the caudal margin of the spatulate end of the process to the pubis is *ypsiloideus posterior,* and from the cephalic margin of the spatulate region of the process to the myoseptum of the third myotome extends *ypsiloideus anterior.*

Upon the lateral aspect of the body, the transition from trunk to tail is shown. Dorsad of the appendage and girdle may be seen the *externus obliquus* and the *longissimus dorsi* muscles. Caudad of the girdle region, the tail is composed laterally of myotomes and ventrally of a pair of cordlike muscles which lie on either side of the haemal arches.

[STUDY X: Draw the ventral aspect of the pelvic girdle and appendage in relation to trunk and tail. Upon the right side of the specimen show the superficial muscles; upon the left side show the deeper muscles with pubo-ischio-tibialis removed.]

[STUDY XI: Draw the lateral aspect of the pelvic region in relation to trunk and tail. Treat the drawings as in Study VIII]

Questions

Where do you find any suggestion of the myotomes and myosepta seen in the shark?
How many myotomes are there in the trunk? in the tail?
How many segments are there in the rectus abdominis and in sternohyoideus?
Where is *linea-alba* in *Cryptobranchus?*
Name the extrinsic muscles of the pectoral appendage.
Name the intrinsic muscles of the pectoral appendage.
Which ones are similar in function to the extrinsic muscles of the pectoral appendage of the shark?
Which muscles aid in the opening of the mouth?
Which muscles aid in the closing of the mouth?
Which muscles are functional in the opening and closing of the gill slit?
Name the extrinsic muscles of the pelvic girdle.
Name the extrinsic muscles of the pelvic appendage.
Name the intrinsic muscles of the pelvic appendage.
Which muscular structures of *Cryptobranchus* recall the musculature of the amphioxus?

Chapter V

THE DIGESTIVE, URINOGENITAL AND RESPIRATORY SYSTEMS

To open the visceral and pericardial cavities, slit the ventral wall of the trunk from pelvis to pectoral girdle about ¼ inch to the left of the median line. Make a transverse incision in the left wall about midway between the girdles. Lift up the right wall and note that it is attached by a membrane to an organ, the liver, for a great length. Upon the ventral margin of this membrane lies a vein, the ventral abdominal. Sever the connection between this vein and the body wall as far as the liver, and make a transverse incision in the right wall as you did in the left. Cut through the median line of the pelvic girdle, observing that here is a ventral membrane which holds a long, narrow sac, the urinary bladder, in place. Sever the girdle from this membrane and lay back the four flaps of the body wall. This will expose the greater part of the visceral cavity.

Lift the coracoid plates of the pectoral girdle slightly and cut through the median line of the sternohyoideus muscle lying beneath. (Be *sure* that only muscle is cut.) Push the muscle gently laterad and free it from the tissue beneath. Under the coracoids will be exposed the cephalic end of the liver and in the procoracoid region a chamber protected by a thin but tough membrane. This is the pericardial cavity, in which lies the heart. Cephalad from this cavity will be seen a bulb filled with a colored mass, if your specimen has been injected, or a dark-brown mass if uninjected. From this bulb

blood vessels proceed left and right; these are the aortic arches, which will be followed later. (Do not remove the membrane which covers the heart until time for the study of this region.) The visceral cavity is now to be exposed.

THE VISCERAL CAVITY

The membrane separating the visceral cavity from the pericardial is the transverse septum and should be located carefully in relation to the pectoral girdle. Locate the position of this septum upon a large outline of the animal including the legs and tail. The organs included in the visceral cavity comprise three systems—digestive, urinogenital, and respiratory—as well as the blood vessels which circulate in the cavity feeding and draining these organs.

THE DIGESTIVE SYSTEM.—In the extreme cephalic region of the cavity is the *liver,* composed of two lobes. The right one is the larger and bears on its mesal side, in the caudal portion, the *gall bladder,* a thin-walled greenish organ about ½ inch in diameter. The liver is held to the ventral body wall by the *mesohepar membrane,* in which will be seen a vein which connects with the ventral abdominal. In the cephalic region of the liver between the lobes will be seen the *hepatic sinus,* which collects blood from the liver and carries it into the heart, passing through the transverse septum.

Lift the left lobe of the liver and expose a long white organ, the *stomach.* At the cephalic end of this organ, lying dorsad of the pericardial cavity and connecting the oral and pharyngeal cavities with the stomach, is the oesophagus. At the level of the cephalic third of the liver is a constriction where the stomach begins. Slit the ventral wall of this region and note the change in the folds of the lining as the change is made. The stomach is about 4 inches long.[1] At its caudal end it turns abruptly cephalad and narrows immediately. This caudal region is the *pyloric stomach,* and the cephalic end is the

[1] The specimen used in this description was 17 inches from tip of head to tip of tail.

cardiac stomach. The constriction at the end of the pyloric stomach, the *pylorus,* marks the change of the tract from stomach to *intestine.* A window in the ventral will will show the change in folds. The stomach and oesophagus are held to the median dorsal wall by a membrane, the *mesogaster,* and to the liver by the *gastrohepatic omentum.*

The intestine is about 21 inches in length (17 inches the small intestine and 4 inches the large) and is held to the dorsal wall by the *mesentery proper,* which likewise extends into the folds of the intestine and binds all the folds into a compact mass. From the pylorus, the intestine passes cephalad, turning to the right at the caudal edge of the liver, to which it is attached by the *hepato-duodenal omentum.*

Along the dorsal border of this duodenal portion of the intestine and the caudal end of the left lobe of the liver lies the *dorsal pancreas,* and along the ventral border of the stomach in the gastrohepatic omentum lies the *ventral pancreas.* From the gall bladder runs a short *bile duct,* which empties into the duodenum, and dorsad of this duct may be found the *pancreatic duct,* passing from dorsal pancreas directly into duodenum, or more frequently into the bile duct. Cut a window in the ventral wall of the intestine at this level and probe for the entrances of these ducts. After receiving the bile and pancreatic ducts, the intestine turns sharply caudad and for about a foot of its length is coiled upon the right side of the body cavity. The *large intestine,* or *colon,* is seen to issue from the dorsal side of this mass, where it enlarges suddenly, becoming the *rectum* and proceeds caudally, being held to the median body wall by the *mesorectum,* to open into the common chamber, the *cloaca.*

Upon the dorsal side of the stomach is the *spleen,* a small gray body attached to the stomach by the *gastro-splenic omentum.* This organ has no duct leading into the digestive cavity, as it belongs to the ductless glands; it is described here for convenience rather than function.

[STUDY XII: Diagram the digestive system in ventral

aspect, labeling all structures described. Demonstrate the specimen to an instructor.]

THE URINOGENITAL SYSTEM.—*Cryptobranchus* is dioecious and fertilization is external. The males eject sperms over the freshly laid eggs of the female. From 300 to 400 eggs are deposited in festoons of gelatine.[2]

(*a*) *The Female System.*[3]—Lift up the caudal end of the stomach and hold the intestines in median position. Lying in the median line of the body is the postcaval vein and, spreading either side of this is a membrane, the *mesovarium*. Upon the lateral margin is an elongate body about ½ inch wide, composed of yellow globules or eggs. This elongate organ is the *ovary*. In immature specimens this organ is much smaller and consists of a gray pulpy mass. Lift the mesovarium and observe along either side of the median line a brownish elongate mass extending caudad to the limit of the body cavity, cephalad to the level of the spleen, becoming gradually narrower as it proceeds cephalad. The cephalic region of this organ is the *pronephros* and is nonfunctional; the caudal region is the functional region, the *mesonephros*. Laterad of each mesonephros is a membrane, *mesotubarium*, upon the lateral margin of which is a large coiled tubule. This tubule, the *oviduct*, begins in the cephalic region of the visceral cavity on a level with the cephalic end of the liver and lies upon the lateral wall of the cavity. In the cephalic region of the cavity it is attached to a membrane from the cephalic margin of the cavity and the transverse septum, and it is expanded into a funnel-shaped mouth, the *ostium*. Proceeding caudad, this tubule is supported by a membrane which lies laterad of the dorsal aorta and later joins the membrane from the mesonephros. At about the level of the mesonephros, these oviducts expand to about four times their former diameter and form the *uteri*, lying on either side

[2] Horatio H. Newman, *Vertebrate Zoology*.

[3] To observe the systems of both sexes, trade specimens with another member of the class.

of the mesonephroi. Each uterus joins the cloaca laterad of the opening of the rectum. The eggs are freed from the ovaries into the body cavity, from which they find their way into the ostia and are carried down through the cloaca and to the outside world.

Lying in the mesal border of each membrane which supports the oviduct in the mesonephric region is a white tubule, the *mesonephric duct*. This duct is connected to the mesonephros by tiny tubules, which bring the excretory material to the duct. The mesonephric duct is sometimes coiled upon the lateral margin of the mesonephros and the connecting ducts are not visible. Under either condition, the mesonephric ducts pass caudad and enter the cloaca mesad of each uterus. Upon the ventral wall of the cloaca opens the thin-walled sac, the *urinary bladder*, which stores the excretory material from the mesonephroi.

[STUDY XIII: Draw the urinogenital system of the female, showing ovary and mesovarium removed from one side to expose the mesonephros, the oviduct, and the uterus of that side.]

(*b*) *The Male System.*—Lift up the caudal end of the stomach and hold the intestines in a median position. This will expose the postcaval vein lying in the median body line, on either side of which extends a membrane, the *mesorchium*, upon the lateral margin of which is an elongate yellow body, the *testis*. Upon its mesal border, this testis possesses a deep indentation into which the membrane passes. In the membrane pass three veins, fourteen or fifteen arteries, and seven to ten delicate white tubules, the *epididymal tubules*, the function of which is to carry the spermatic material from the testis into the *mesonephros*. Lift the mesorchium and expose the mesonephros, extending as in the female. Along the side of each mesonephros is a membrane in the lateral margin of which runs a convoluted tube, the *mesonephric duct*. This tubule enlarges slightly as it proceeds caudad and, beginning at a level with the cephalic end of the testis, receives delicate

tubules from the lateral margin of mesonephros. These tubules carry sperms and excretory matter to the mesonephric duct, which serves a double function. The mesonephric ducts enter the cloaca laterad of the rectum. A *urinary bladder* opens into the ventral side of the cloaca. The *cloaca* opens by means of the cloacal opening and serves a triple function.

[STUDY XIV: Draw the urinogenital system of the male, showing testis and mesorchium as though removed from one side to expose the mesonephros and its ducts.]

THE RESPIRATORY SYSTEM.—The visceral cavity is likewise the pleural cavity, and is frequently termed the *pleuro-peritoneal cavity*. Upon the dorsal side of the right lobe of the liver and connected to it by a *pleural membrane* is the *right,* and larger, *lung*. Upon the left side of the stomach and oesophagus and held to them by a membrane is the *left lung*. In the demonstration specimen (or your own *after* the circulatory system has been explored) trace the lungs cephalad. From the transverse septum, a membrane holds these lungs to the body wall. The lungs pass dorsad of the transverse septum and, dorsad of pericardial cavity, fuse to form the *trachea,* which connects with the *oral-pharyngeal cavity*. The opening of this trachea is guarded by two small cartilages, the *arytenoids*.

As the oral-pharyngeal cavity is a part of both the digestive and respiratory systems, it is included here.

THE ORAL-PHARYNGEAL CAVITY

Cut the muscles which close the lower jaw; now open the mouth. Upon the roof of the mouth on the upper jaw, or premaxillary and maxillary bones, will be found a row of teeth, the maxillary teeth, and just behind these teeth a *marginal sulcus*. Caudad of this sulcus is a short row of teeth, the *vomerine teeth*. At the lateral margins of this row of teeth will be found the *internal nares*. At the back of the cavity is the opening into the oesophagus. In the floor of the

cavity will be found the *mandibular* row of *teeth,* caudad of which is the *sulcus*. The *tongue,* which occupies the greater portion of the floor, is a roughened elevation resting upon the hyoid elements and anterior basibranchial of the gill arches. Caudad of the tongue is the *glottis,* or opening into the trachea. Place a blow pipe into this opening and inflate the lungs. Caudad of the glottis is the opening of the oesophagus, which causes the caudal portion of this cavity to be termed the *pharyngeal cavity*.

[STUDY XV: Diagram the mouth, open to show all structures described, and add a diagram of the lungs.]

Questions

Compare the shape of each organ in the visceral cavity with the corresponding organ in the shark.
What organ has replaced the spiral valve of the shark?
What new organs are found in the pleuro-peritoneal cavity of *Cryptobranchus?*
What organs lie in the dorsal region of the pleuro-peritoneal cavity?
How do these organs compare with similarly functioning organs in the shark?
Compare the position of ovaries and testes in the shark and in *Cryptobranchus.*
How does fertilization differ in the dogfish shark and in *Cryptobranchus?*
Is the dogfish shark oviparous or viviparous? Which term applies to *Cryptobranchus?*
What effect does this have upon the structure of the oviducts in a mature female?

Chapter VI

THE VASCULAR SYSTEM

PERICARDIAL CAVITY AND HEART—The pericardial cavity lies just cephalad of the coracoid plates and between the procoracoid plates of the pectoral girdle, under the sternohyoideus muscle. This cavity was exposed when the animal was opened (Chapter V). Note the tough membrane which forms the ventral wall of the cavity; remove it to expose the heart. This membrane is the *pericardium,* which lines the cavity and is continuous with the covering upon the heart, the *epicardium*. The caudal margin of the pericardial cavity is formed by a heavy membrane, the *septum transversum*.

The most prominent portion of the heart is the *ventricle,* which lies in the right side of the cavity. This chamber is triangular, and from the cephalic end rises the *conus arteriosus,* a heavy artery which expands to form the *bulbus arteriosus* as the artery leaves the pericardial cavity. Projecting from the left side of the ventricle is a large flaccid lobe, the *atrium*. (*Cryptobranchus* appears to have a single atrium, although Reese[1] describes two.) Press the ventricle gently upon the left side and note that it is attached to the atrial region. Gently raise the caudal margins of the ventricle and the atrium and expose a thin-walled triangular chamber, the base of which rests upon the septum transversum and the apex attached to the atrium. This is the *sinus venosus*. Just caudad of the septum transversum and at the head of the liver lies the *hepatic sinus,* which is connected to the sinus venosus by a

[1] Albert M. Reese, "Anatomy of *Cryptobranchus allegheniensis*."

PLATE V CIRCULATORY SYSTEM

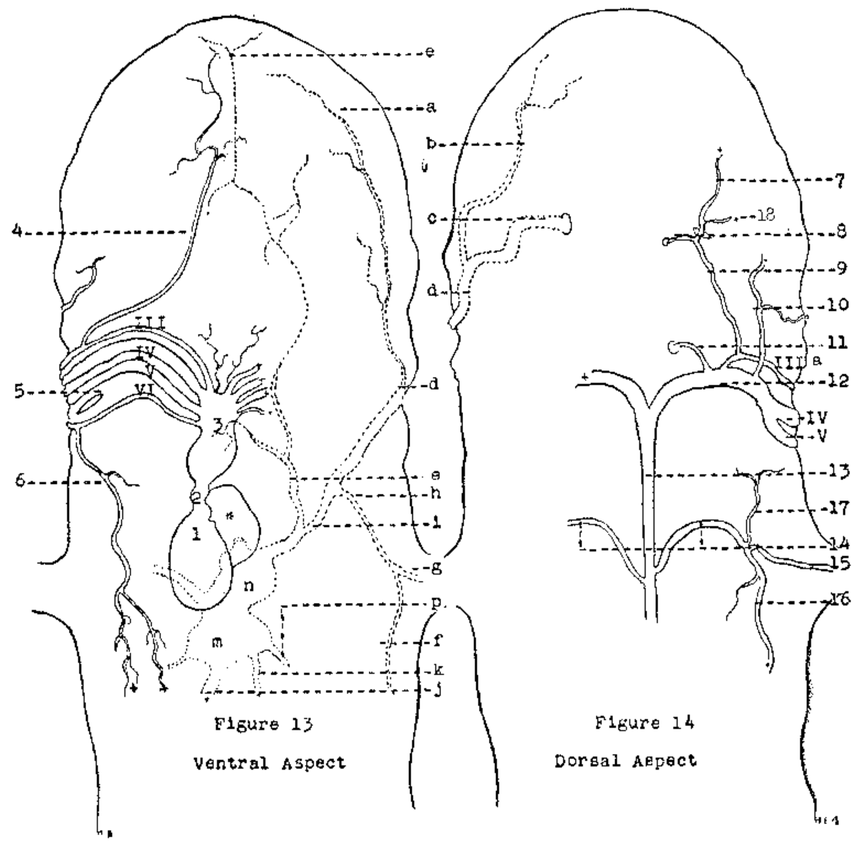


Figure 13
Ventral Aspect

Figure 14
Dorsal Aspect

(Plate V, Figures 13-14)

1—ventricle
2—conus arteriosus
3—bulbus arteriosus
4—lingual (external carotid)
5—gill slit
6—pulmonary artery
7—supratemporal
8—cerebral
9—internal carotid
10—digastricus
11—vertebral
12—right radix aorta
13—dorsal aorta
14—subclavian artery
15—brachial artery
16—cutaneous artery
17—pectoral artery
18—to pro-otic foramen
III—common carotid (Arch III)
IV, V, VI—respective aortic arches
III a—internal carotid
a—mandibular vein
b—external jugular
c—internal jugular
d—common jugular
e—lingual vein
f—cutaneous vein
g—brachial vein
h—subclarian vein
i—left common cardinal
j—post caval vein
k—left hepatic vein
m—hepatic sinus
n—sinus venosus
p—left pulmonary vein
*—atrium

short, broad hepatic connection that pierces the septum transversum.

[STUDY XVI: Draw the pericardial cavity with the heart and hepatic sinus in place, showing and labeling all structures.]

The study of the heart will be continued after the venous and arterial studies are completed.

THE VENOUS SYSTEM

HEAD AND PECTORAL VEINS.—These veins lie just underneath the skin, and if care was used in skinning they will be prominent. The *common jugular* crosses the lateral region of the gill arches, and the *cutaneous vein* lies along the lateral edge of the segmented muscles of the dorsum upon the dorsal border of externus obliquus. Lift up the heart *carefully* and upon the dorsal wall of the pericardial chamber observe two large veins coming in from a cephalo-lateral direction. These are the *right* and *left common cardinal veins* which collect blood from the head and pectoral region as well as from the external body wall and skin. The left common cardinal enters only the sinus venosus, but the right common cardinal may send caudad a short, heavy branch which passes through the septum transversum opening into the hepatic sinus. Follow the left common cardinal away from the heart and observe that it receives a slender vein from the ventral side of the lower jaw. This vein, the *lingual,* arises medially at the tips of the mandibular rami in conjunction with its mate and separates at the level of the basibranchial. It receives a branch from the lingual gland and crossing the geniohyoideus caudolaterally joins the common cardinal as described above.

Continue to follow the common cardinal away from the heart and observe that it is made up of the *common jugular,* which brings blood from the head region, and the *subclavian,* bringing blood from the arm, the pectoral girdle, and the external body wall. The common jugular crosses the aortic

arches along the side of the "neck" and cephalad of the arches receives the *mandibular vein,* which drains the mandibular region. By careful dissection the common jugular may be seen to be made up of a heavy *internal jugular,* which issues from the brain case at the pro-otic foramen (turning sharply caudad to pass through the carotid foramen) and the *external jugular,* which drains the dorsal and lateral regions of the head, arising around the eye, and, passing across the masseter muscle and along the lower portion of the digastric, joins the internal jugular. The *subclavian vein,* which with the common jugular forms the common cardinal, is made up of two branches, the *brachial* from the arm and the *cutaneous,* which drains the external body wall, receiving branches dorsally from each myoseptum of the segmented muscles of the back and ventrally from the myosepta of the rectus abdominis, these latter passing beneath externus obliquus.

[STUDY XVII: Draw the venous system of the head and pectoral regions, including the cutaneous branches, in an outline of the form of the body, labeling all veins described.]

VENOUS CIRCULATION OF THE TRUNK.—The cephalic margin of the pleuroperitoneal cavity is formed by the septum transversum. Just caudad of this septum at the head of the liver lies the hepatic sinus (described above in connection with the heart). Find the *pulmonary veins* as they course along the mesal side of each lung; these enter the hepatic sinus upon its lateral borders. Along the left lobe of the liver will be seen the *left hepatic vein,* which arises in capillaries in the liver tissue. Along the lateral margin of the right lobe of the liver is a vein which should be traced through the liver tissues. Begin at the hepatic sinus and carefully pick away the tissue along the path of the vein. Within the deeper tissue this vein receives several *right hepatic veins.* This main vein will be seen to pass through the length of the right lobe, reappearing in the coelom at the tip of the liver; this is the *postcaval vein.* At the tip of the liver the vein turns sharply

and takes up a median position. The postcava drains the mesonephroi in segmental fashion with thirteen to fourteen pairs of *efferent renal veins,* the mesovaria and ovaries (or mesorchia and testes) with six pairs of *ovarian* (or four pairs of *spermatic*) *veins,* and the back with five medially placed *parietals.* The postcava arises between the caudal extremities of the mesonephroi, dorsad of the cloaca.

THE RENAL PORTAL SYSTEM.—The tail region is drained by the *caudal vein,* which lies in the haemal canal ventrad to the caudal artery. At the level of the first caudal vertebra the caudal vein emerges and forms two veins, the *renal portals,* which pass upon the lateral edges of each mesonephros, giving off many *afferent renals* and nine *parietals.* At the level of the acetabulum of the pelvic girdle each renal portal receives a vein from the pelvic appendages, the *femoral.* The femoral receives, as it enters the body cavity, the *epigastric vein,* which drains the ventral body wall of the cavity. At the level of the cephalic point of the mesonephroi the renal portals pass over into the *post-cardinals,* passing up the side of the dorsal aorta. Each receives four *parietals,* and the left vein may continue along the side of left subclavian artery, possibly anastomosing with the left subclavian vein. At the cephalic end of the mesonephroi each post-cardinal is seen to be connected with the postcava by a short transverse vein, the *azygos.* Frequently the postcava is connected to the renal portal on one or both sides by a heavy transverse vein upon the ventral face of the mesonephroi in the pelvic region.

[STUDY XVIII: Draw the postcaval and renal portal system, showing the mesonephroi and the sex organs of one side in place. Label all structures as described.]

THE VENTRAL ABDOMINAL VEIN.—The *ventral abdominal* vein, which is seen along the internal ventral body wall beneath the *linea alba* of the rectus abdominis, arises in the pelvic region in a pair of *pelvics* from the femoral veins of the legs and a slender median *external caudal vein.* The ventral abdominal vein receives branches, the *cystic,* from

the urinary bladder and the ventral body wall. At the level of the liver it receives the *cephalic vein,* which drains the ventral body wall of the pectoral region. The ventral abdominal, after receiving the cephalic vein, turns sharply dorsad and joins a heavy vein, the *hepatic portal vein,* which enters the liver just above the gall bladder.

THE HEPATIC PORTAL SYSTEM.—If this specimen has been triply injected, this system will be filled with a colored mass that differs from either the veins or the arteries, but if the specimen was only doubly injected, the hepatic portal system will be pale and slightly filled with old blood. In case the specimen was injected only for the arteries, you must guard against confusion of vessels at the caudal end of the liver. The hepatic portal system begins with a *posterior mesenteric vein,* which drains the wall of the colon. This receives many large branches, the *posterior intestinals,* from the caudal region of the small intestine, and proceeds cephalad to the region of the gall bladder, where it turns mesad and receives the *gastro-splenic,* a large vein which drains the dorsal side of the stomach and the spleen. The main vein now receives two veins: (1) the *anterior mesenteric* (frequently entering as many small veins), which drains the cephalic region of the small intestines and the dorsal pancreas, and (2) a *gastro-pancreatic,* which drains the caudal and ventral area of the stomach and the ventral pancreas. The vein now termed the *hepatic portal vein* passes for a short distance along the mesal face of the left lobe of the liver, along the side of the gall bladder between the lobes of the liver. The vein receives the *ventral abdominal vein* and the *gastro-hepatic vein,* which drains the cephalic and ventral area of the stomach and the liver, and passes into the liver, where it breaks up into capillaries. The blood thus distributed is picked up by the capillaries of the left hepatic vein (which appears upon the surface of the left lobe of the liver) and by the postcava as it passes through the right lobe of the liver, and is carried to the *hepatic sinus* and into the *sinus venosus.*

[STUDY XIX: Draw the hepatic portal system upon a

diagram of the organs; include the pulmonary circulation and the ventral abdominal vein.]

ARTERIAL CIRCULATION

THE HEAD AND NECK REGION (the aortic arches).—When the heart was examined, it was discovered that the blood leaves the ventricle by way of the *conus arteriosus,* which proceeds cephalad from the ventricle and within a distance of ½ inch expands into the *bulbus arteriosus.* This bulb gives rise to paired aortic arches spreading right and left upon the ventral side of the "neck" and the head; there are three and sometimes four pairs of these arches. (The number of arches vary, three being common, although four is not unusual. Two specimens with only two aortic arches have come within our observation.) They are numbered III, IV, V, and VI from the cephalic border caudad.

Arch III (the *common carotid*) is more slender than arches IV and V, and upon the lateral face of the neck region sends, meso-cephalad, a slender artery, the *lingual* or *external carotid,* which runs between the sternohyoideus and internal-ceratohyoideus muscles. Slightly cephalad of the caudal level of the mandible, the lingual sends a small branch to the lingual gland, and the main artery appears upon the ventral surface of the geniohyoideus, spreading into capillaries upon this muscle. After giving off the lingual, arch III proceeds around the side of the neck as the *internal carotid.* It connects with arch IV and also sends a branch which proceeds underneath digastricus.

Arch IV is a heavy vessel which, after receiving Arch V, proceeds around the neck to become the *radix aorta,* which gives off a branch, *digastricus,* to the digastric muscle and receives Arch III just mesad of the forward turn of the internal carotid. The internal carotid now proceeds cephalad and courses laterad of the otic capsule. At the carotid foramen (underneath the squamosal) the internal carotid branches into the *supratemporal,* which feeds the muscles of the head, and the *cerebral,* which turns sharply mesad and enters the

brain case at the parabasal foramen. The supratemporal gives off a ventral branch to the mandible and the floor of the mouth and, passing through the carotid foramen, sends a small vessel into the pro-otic foramen and extends cephalad to feed masseter and temporalis.

Arch V is heavy but has no branches, unless arch VI be absent. Arch VI is the most caudal of the arches and does one of three things: (1) it may proceed from the bulbus arteriosis laterad and, upon the face of the neck, send a connection to arch V and a branch caudad to form the *pulmocutaneous;* or (2) there may be no connection to arch V, and arch VI turns sharply caudad to become the pulmocutaneous; or (3) arch VI may be absent. In the last case, the pulmocutaneous is a branch of arch V, the connection having been retained as the ventral side of arch VI was obliterated. (The position of arch VI is caudad of the gill slit, the only arch in this position.) The pulmocutaneous artery arises laterad of the gill slit, passing under the cucullaris muscle, gives off a small *cutaneous* to procoracoideus, and enters the body as the *pulmonary.* After reaching the lung, the pulmonary artery branches into two arteries and courses through the length of the lung.

To follow the radix aorta the visceral arches must be cut through from the caudal edge of the mandible to the caudal margin of the gill slit. The radix aorta upon either side of the animal turns sharply mesad and enters the body between the epaxial and hypaxial muscle masses. The radices aortae meet on a dorsal side of the pharyngeal cavity under the membrane lining the cavity and form the *dorsal aorta.* Just before the radices fuse, each gives off cephalad an artery which runs upon the ventral face of the epaxial muscles mass for a short distance and then disappears into the vertebral column. This is the *vertebral artery,* which proceeds cephalad for a short distance, then turns sharply mesad between the exoccipital condyles and the atlas, then, turning sharply caudad, enters the vertebrarterial canal, through which the artery continues to pass caudad, giving off a branch at about the middle of each vertebra to feed the spinal cord.

[STUDY XX: Draw the ventral, lateral, and dorsal aspects of the aortic arches, showing relationships and branches. Show the actual condition of your specimen and figure wherein it differs from the above description. (The variations of this region are numerous, and a single description cannot cover all conditions.)]

THE DORSAL AORTA.—This trunk artery passes down the median dorsal line of the body cavity, giving off branches to the organs of the cavity and the appendages. There are no branches from the dorsal aorta until the level of the front legs (or forearms); then a pair of *subclavian arteries* arise at slightly different levels and pass right and left. Each subclavian arches cephalad and then caudo-laterad, giving off cephalad an artery, *the pectoral,* which soon branches and supplies the muscles of the pectoral girdle. Caudad of the pectoral is a branch leading to the lateral body wall, the *cutaneous.* The cutaneous runs in the muscle of the ventral body wall as far as myotome eleven. It gives off four *segmental branches.* Between pectoral and cutaneous lies the artery to the arm, the *brachial.*

At about the level of the cephalic fourth of the stomach, the dorsal aorta gives off medially the *gastric artery,*[2] which immediately sends off cephalad along the ventral surface of the dorsal aorta a small artery to the tip of the left oviduct and ostium (if specimen is female). The gastric branches upon mesal and ventral walls of stomach, ventral pancreas, and oesophagus. The dorsal aorta give off many fine branches right and left to the reproductive organs but does not give off a large branch until the caudal end of the liver is reached, where the *coeliaco-mesenteric* arises. Sometimes this arises as a short trunk which immediately branches; again, two arteries may arise, one caudad of the other. The more cephalic branch passes left as the *gastrosplenic* and branches into two arteries, the more cephalic of which sends branches to the ventral side of the spleen and the dorsal wall of the

[2] This may frequently arise as two arteries.

cardiac stomach, while the caudal branch feeds the caudal dorsal wall of the pyloric stomach. The caudal branch, the *anterior mesenteric,* of the coeliaco-mesenteric branches into two: (1) The cephalic portion passes ventrad between the caudal tips of the lobes of the liver to form two arteries, one, the *pancreatic,* feeding the dorsal pancreas and the other branch, the *hepatic,* passing to the left of the gall bladder and into the liver, being visible in places upon the dorsal wall of the left lobe. (2) The caudal portion, the *anterior intestinal,* goes to the intestines just caudad of the liver and there branches into two, and the lower of these again into two, and these three branches pass to the wall of the intestine.

Caudad of the coeliaco-mesenteric, the dorsal aorta gives off four arteries, the *accessory mesenterics,* which branch to the intestines; and the most caudal of the four sends arteries to the colon. For considerable space the dorsal aorta gives off arteries, *urinogenitals,* segmentally arranged, to the mesonephroi, oviducts, and ovaries (testes). About midway the length of the colon two or three arteries, the *inferior mesenterics,* arise ventrally from the dorsal aorta and feed the colon. In the trunk region the dorsal aorta gives off dorsad, in the medial line of the body, three to six paired *parietals.* Caudad of these the dorsal aorta may give off a pair of *lumbars* which arise just cephalad of the pelvic branches.

From the origin of the lumbars, the dorsal aorta proceeds caudad, and at a level of the pelvic appendages gives off a pair of *external iliac arteries.* Immediately caudad of the external iliacs arise the *internal iliacs,* which go to the pelvic girdle. The external iliac artery sends a cutaneous branch, the *epigastric,* to the lateral body wall, then proceeds upon the pelvic appendage as the *femoral.* Medially beyond the internal iliacs, the dorsal aorta gives off an artery, the *cystic,* which branches upon the urinary bladder and the caudal end of the cloaca and the colon or rectum. The dorsal aorta gives off two *pelvic parietals* and passes into the haemal canal to extend the length of the tail as the *caudal artery.*

[STUDY XXI: Draw the dorsal aorta and its branches

upon an outline of the visceral cavity and organs. Label all branches described. If your specimen varies from the description, draw the variations and ask for assistance in labeling.]

THE HEART

In order to study the heart, it must be removed from the body. Lift up the ventricle and observe how the *common cardinals* enter the *sinus venosus*. The sinus venosus is bi-lobed and receives upon its caudal margin a short, heavy vein from the hepatic sinus. Do both common cardinals enter the sinus venosus? The left one usually enters the sinus venosus normally; the right one may have a secondary connection with the hepatic sinus. Cut through the conus arteriosus, the common cardinals, and the hepatic sinus as near the outer edges of the pericardial cavity as is possible.

Lift the heart from the cavity, using much care, as the injection makes the organ very brittle. Observe the dorsal aspect of the heart. The atrial region may have a small lobe, in the caudal region, which can be interpreted as a rudimentary left atrium. Remove the dorsal wall of the heart chamber and note the sino-atrial valve from sinus venosus into the atrium and the atrio-ventricular valve at the union of atrium and ventricle.

[STUDY XXII, Figure 1: Draw the dorsal aspect of the heart, showing the chambers and all vessels leading into or from the heart. Label the drawing to the best of your knowledge.

Figure 2: Draw the dorsal aspect of the heart with the dorsal walls of atrium and sinus venosus removed. Show the sino-atrial valve and the atrio-ventricular valve as well as the connection of the sinus venosus with the common cardinals and the hepatic sinus.]

Questions

Name the chambers of the heart of *Cryptobranchus*.
Name the blood vessels which enter the heart and those which leave the heart.

How do the chambers and blood vessels of the heart of the *Cryptobranchus* compare with those of the shark?
Trace the blood from conus arteriosus to the brain and back to conus arteriosus.
How does this tracing differ from one to the same destination in the shark?
Trace the blood from the ventricle to the arm and back to ventricle.
Trace the blood to the digestive system from ventricle back to ventricle.
How does this compare with the same type of tracing in the shark?
Trace the blood from the ventricle to the lungs and back to the ventricle.
Is there a change here from the condition in the shark? What is it?
Trace the blood from the ventricle to the leg and back to the ventricle.
Can such a tracing be made in more than one way? How?
How is the supply and drainage of the tail accomplished?
How many aortic arches occur in your specimen? Which ones are present?
Of what is the radix aorta formed?
Is there such a structure in the shark? Why?
How is the supply and drainage of the mesonephroi accomplished?
Compare this condition with that in the shark.
What is a portal system? Where are such conditions found in *Cryptobranchus* and in the shark? Compare the two animals.
Be prepared to trace the blood to any region from any region and back to the starting place.
Be prepared to trace the blood from the ventricle to the tail, naming all vessels passed and the distribution of all vessels.
Be prepared to return the blood from the tail to the ventricle and name all veins picked up and the regions drained by each.

Chapter VII

THE NERVOUS SYSTEM

The specimen may now be placed in a solution of 5% nitric acid in water for two or three days or until tests show that the bone is pliable. Clean away the temporalis muscle and remove the parietal, frontal, and nasal bones, taking care not to disturb any organs.

THE BRAIN AND THE CRANIAL NERVES

THE BRAIN (dorsal).—This dissection will reveal the dorsal surface of the brain and the bases of the cranial nerves. (If the specimen is placed in water, the lobes and nerves will be more clearly differentiated.) The structure of the brain is simple and linear.

The two elongate lobes of the cephalic portion are the *cerebral hemispheres* (*telencephalon*), upon the cephalic region of which are the *olfactory lobes* (*rhinencephalon*), usually not well differentiated from the cerebral hemispheres. Between the caudal tips of the cerebral hemispheres lies the *diencephalon,* the dorsal wall of which is formed partially by the *first choroid plexus.* Remove this wall and observe in the caudal portion of the diencephalon the *epiphysis,* or pineal body.

Caudad of the diencephalon lie the *optic lobes* (*mesencephalon*), about two thirds as long as the cerebral hemispheres and slightly narrower. The meninges are heavy over this region, and it may be necessary to remove the membranes before the paired condition of the mesencephalon appears.

If the dorsal walls of the cranium were removed carefully, a dark triangular body will be observed caudad of the optic lobes. This is the *second choroid plexus,* which forms the roof of the fourth ventricle and is the dorsal wall of the *medulla oblongata* (*myelencephalon*). Remove this plexus and observe the narrow bandlike structure lying between mesencephalon and myelencephalon. This is the *cerebellum* (*metencephalon*). Note that it projects laterad beyond the optic lobes.

The *medulla* passes gradually into a spinal cord, which makes its exit from the cranium through the *foramen magnum* into the neural canal.

THE CRANIAL NERVES.—Nerve I is the olfactory nerve, *olfactorius,* which proceeds cephalo-laterad as part of the rhinencephalon and spreads out into innumerable small branches upon the olfactory bulb. This olfactory bulb is the dark flat, expanded body lying in the cephalo-lateral region of the skull. Note that the lateral portion of this bulb lies in the optic orbit, as the olfactory canal lies in a caudo-lateral direction, with the posterior naris more laterad than the anterior naris. This bulb is covered with the thin cartilage of the olfactory capsule of the chondrocranium; the nerves may be observed through this or the cartilage may be removed. Nerve I appears to consist of two large bundles of fibres. Is there any difference in the region of external origin for these bundles?

Nerve II, the optic nerve, or *opticus,* may be seen projecting from beneath the lateral face of the caudal region of the cerebral hemispheres, and its exit from the brain will be seen when the ventral side of the brain is examined. The nerve passes out the optic foramen, lying between the orbitosphenoid and palato-pterygoid bones, and proceeds cephalo-laterad, entering the eyeball.

Nerve II, *oculomotor,* appears at the lateral margin of the optic lobe. It is very slender and leaves the brain case by the pterygoid foramen, laterad of the optic foramen, and

passes to four muscles of the eye (superior rectus, inferior rectus, internus rectus, and inferior oblique). This distribution is difficult to observe, as the muscles are degenerate and the branches very delicate. Demonstrate your dissection.

Nerves IV and VI are very delicate and seldom seen. However, a careful dissection under water may reveal them. Nerve IV, *trochlearis,* arises on the caudo-lateral margin of the optic lobes and passes out (with nerve III) to the superior oblique muscle. Nerve VI, *abducens,* arises from the anterior margin of the ventral wall of the medulla just caudad of nerve IV, in dorsal aspect, and passes out (with III and IV) to the external rectus muscle.

From the lateral margin of the medulla projects a network of nerve bundles. Nerve V, *trigeminalis,* arises in two bundles, the caudal one of which anastomoses with the base of the nerve caudad to it. There is a large ganglion upon the base of nerve V just before it passes through the pro-otic foramen. As it leaves this foramen the branching mentioned above occurs; the cephalic portion, or *opthalmicus profundus,* passing along a groove in the palato-pterygoid bone, comes to the surface in the optic orbit and branches to tissues in the maxillary region. This ophthalmicus profundus has a short connection with the caudal branch of nerve V after the foramen is passed. The caudal portion of the nerve as it leaves the foramen lies upon the base of VII-VIII but soon separates and, after receiving a branch from ophthalmicus profundus, proceeds laterad and branches into two portions: one, *buccalis,* which passes cephalad to the mouth, and a second heavy branch, which passes almost to the margin of palato-pterygoid and bifurcates. One branch, *superior maxillaris,* passes cephalo-laterad and innervates the maxillary region, and the other branch, *mandibularis,* innervates the region of the mandible.

Just caudad of nerve V is compound nerve VII-VIII, which passes cephalad of the otic capsule. Nerve VII, *facial,* soon leaves nerve VIII and, passing out the pro-otic foramen, bifurcates laterad and caudad to innervate the muscles of the jaw and the gill arches. Nerve VIII, *auditory* or *acousticus,* remains near the capsule and sends branches into the capsule to the semicircular canals of the internal ear. Where nerves VII and VIII separate, a small nerve arises and passes cephalad, under the caudal branch of nerve V, and into the floor of the mouth. This is probably *buccalis of VII.*

Nerve IX-X arises in a network of exits from the lateral margin of the medulla. These bases fuse, then separate into two nerves within the brain case. The more cephalic branch, nerve IX, or *glossopharyngeal,* passes out the exoccipital foramen and innervates the muscles of the gill region. The more caudal branch is nerve X or *vagus,* which passes out through the *foramen magnum* between the cranium and the cervical vertebra into the visceral cavity after giving off branches to the gill region.

[STUDY XXIII: Draw the dorsal aspect of the brain and the cranial nerves, showing the eye, the olfactory capsule, and the otic capsule, with the semicircular canals in place, and the distribution of the nerves.]

THE BRAIN (ventral and mesal).—Cut the spinal cord as it joins the medulla and sever all nerves where they pass through foramina. Lift the brain by the caudal extremity and pull it gently upward and forward. Note that a portion is embedded in the ventral wall of the brain case and will need to be carefully loosened. This is the pituitary body. It is very possible to remove the brain from the cranium intact and with the bases of all nerves present, but the dissection takes time and patience. Do not hurry.

Turn the brain ventral side up and observe under water. Nerve I will be seen to arise slightly caudad of the cephalic margin of the cerebral hemispheres. Do you find one or two points of exit? Caudad of the cerebral hemisphers will be seen the *infundibulum,* which is an outpocketing of the ventral wall of the diencephalon. It projects ventro-caudad and lies ventrad of the optic lobes. From the cephalic portion of the infundibulum arise optic nerves, or nerve II, which pass cephalo-laterad along the venter of the caudal portion of the

cerebral hemispheres. Where these nerves are joined upon the infundibulum is the *optic chiasma.*

Upon the caudal region of the infundibulum arises a delicate reddish body usually with a left and a right lobe. This is the *hypophysis,* which with the infundibulum comprises the *pituitary body.* The hypophysis covers the ventral surface of the cerebellum, which may be seen projecting laterad beyond the hypophysis. The medulla is the triangular portion just caudad of this region, and it passes over gradually into the spinal cord. The network of exits of nerves V, VII-VIII, and IX-X are easily observed from this aspect. Demonstrate your specimen. Can you find the exit of nerve VI?

> [STUDY XXIV: Draw the ventral aspect of the brain with all the nerves, with the possible exception of IV and VI. If these are located, show them also. Label your drawing in as detailed a manner as possible.]

With a sharp razor blade, bisect the brain along the exact median line. Two ventricles will be very evident: one in the diencephalon, the *third,* and one in the medulla, the *fourth.* Remove the mesal wall of the optic lobe and observe that there is a ventricle here; this is half of *ventricle five.* Between the third and fourth ventricles in the exact median line is a slender canal, the *aqueduct of Sylvius,* extending through the ventral floor of the brain cephalo-caudad and is joined by the fifth ventricle. Remove the mesal walls of the cerebral hemispheres and observe that these hemispheres are hollow. These cavities are the *lateral ventricles, ventricles one* and *two.* Note that each of the lateral ventricles opens into ventricle three by a small aperture, the *foramen of Munro.* Can you locate the outpocketings for the infundibulum and epiphysis?

> [STUDY XXV: Draw the mesal aspect of the brain showing and labeling all regions and ventricles.]

THE SPINAL CORD AND THE SPINAL NERVES

Slice off the ventral surface of the vertebrae of the trunk region until the cord with its nerves is exposed. Note the dorsal and ventral origin of each nerve. Do these origins fuse to form the trunk within or outside of the neural canal? How many nerves do you find? Where is the brachial plexus? What nerves form it? Trace the brachial nerve out into the arm. Where is the sciatic plexus in the caudal region of the trunk? What nerves form it? Trace the sciatic nerve out into the leg.

> [STUDY XXVI: Draw the ventral aspect of the spinal cord and the nerves of the trunk, showing the plexuses.]

Remove a portion of the cord, after hardening it in alcohol for twenty-four hours make a freehand cross-section of it; mount it in water or glycerin and observe with a compound microscope. Observe the hole in the central region. This is the *neurocoele,* which is continuous with the fourth ventricle in the medulla. A four-pointed region of *gray matter* will appear around this neurocoele; the remainder of the material is white matter. Do you find *dorsal* and *ventral fissures* dividing the cord into right and left portions?

> [STUDY XXVII, Figure 1: Draw the cross-sections of the cord showing all regions and areas visible.
>
> Figure 2: Take another bit of the nerve trunk and observe it from the lateral aspect. Draw the cord in lateral aspect, showing the levels of the dorsal and ventral roots of a trunk nerve.]

Questions

Compare the regions of the brain of *Cryptobranchus* with those of the shark.

List the regions innervated by each cranial nerve in the shark and in *Cryptobranchus.*

What changes can be noted in the amphibian brain as compared with the elasmobranchian?

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