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**THE SPINY DOGFISH**  
**A LABORATORY GUIDE**



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# THE SPINY DOGFISH

## A LABORATORY GUIDE

BY

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“As the outcome of 40 years of experience and reflection, I submit the following proposition: For the study of the structure, development, succession and relationships of vertebrates, the best group to begin with is the selachians, the sharks and rays; if several forms can be studied, the former should be; if but one, that one should be the acanth, or ‘horny dogfish,’ *Squalus acanthias*.”

BURT G. WILDER, 1907.



## PREFACE

The following pages constitute an outline intended for use in beginning classes in vertebrate or comparative vertebrate anatomy. For many years the dogfish *Squalus acanthias* and its near relatives have been a standard for laboratory dissection because of the importance of a fundamental knowledge of the simple, yet typical vertebrate structure which is acquired by a careful study of the anatomy of elasmobranchs. Certainly no form is better suited for the beginning student than is the dogfish; besides its importance from a pedagogical viewpoint, it is easily obtained, easily kept, and relatively easy to dissect.

This outline differs in some respect from other manuals in that an attempt has been made to correlate the various systems in such a manner as to afford the student an opportunity to understand and to interpret the interrelations of these systems. An animal is not made up of an isolated digestive, circulatory, and nervous system. It is the resultant of the coöperation and interaction of all of its component systems, and these should be studied together as far as is practicable. Unless a number of specimens are available for each student, this idea can not always be carried out to its logical conclusion; nor is it always wise that it should be. If, in using the outline, the student will bear in mind this interrelationship and attempt to interpret what he sees in this light, it is believed that he will acquire a broader understanding of the actual anatomy of the form he is dissecting. No attempt has been made to follow out each system into its finest details or ramifications; such is

not the intent of a beginning laboratory course for which the manual is intended.

The material required for the completion of the work here outlined is as follows: Each student should supply himself with a dissecting set of good quality, containing: 1 strong scissors, 1 fine pointed scissors, 1 all steel scalpel, 1 cutting probe, 1 tracer or non-cutting probe, 1 forceps, 2 dissecting needles, and a small ruler; 1 4H drawing pencil; 24 sheets of good grade 8½ by 11 drawing paper; a manila folder; an eraser. The laboratory supply for each student requires: 1 doubly injected dogfish; 1 extra head (if the muscular system is to be worked out a second, uninjected specimen will be required instead of the head); and at least 1 well-prepared demonstration dogfish skeleton for each two students in a section. In ordering the injected specimens it is well to get approximately equal numbers of both sexes. The fish can be cared for in the laboratory in copper boilers or other containers, preserved either in 5% formalin or in paraffin oil in case the odor of formalin is found objectionable. The time required to complete the work is approximately sixty hours.

The outline calls for a minimum number of drawings, and no notes. The writer has found that too often the student has the idea that the object of the course is the making of a "pretty" note-book rather than the acquiring of a knowledge of anatomy. Furthermore, very few students are artists, and much valuable time is wasted in futile artistic efforts. For this reason it is hoped that the instructor using the manual will substitute for a multitude of drawings frequent actual *demonstrations by the student* of the parts or organs upon which he is working. This is the only way in which a student will actually *learn* anatomy, and the only satisfactory way in which an instructor can find out just what the student is doing in the way of careful dissec-

tion upon his own specimen, just how complete his knowledge is of the structures he is handling, and, equally important at least, where the student has gone astray or misinterpreted the facts at hand. In anatomy, *dissection* rather than art should be fostered.

The dogfish and prepared skeletons may be obtained at any of the biological supply houses.

A. R. C.



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**THE SPINY DOGFISH**  
**A LABORATORY GUIDE**



# THE SPINY DOGFISH

## A LABORATORY GUIDE

### INTRODUCTION

#### CLASS PISCES

#### SUBCLASS ELASMOBRANCHII

The elasmobranchs are the most primitive of the true fishes. They comprise a group which has a very ancient origin, and which has come down through the ages to the present time, yielding us the various species of sharks and rays which inhabit the oceans. We find them first represented as fossils in the rocks of the early Devonian period. It is probable that the group had its origin in fresh water, as we find fossils of many species and a host of individuals among the remains of fresh-water lake life. During the late Devonian and Mississippian periods the elasmobranchs first reached the sea. Thereafter for a time their history is uncertain and obscure, as the marine forms seem to have been wiped out: the marine genera of these periods disappear. Again the seaward movement took place from the lakes and rivers and from late Jurassic times at least many of the ancestral lines of descent of our present species may be traced. In their development during this great lapse of time they have been a very conservative group, showing very little change since Tertiary times.

Less highly developed than the boney fishes (Teleostei), they differ from the lower, pre-fish hags and lampreys (class Marsipobranchii) in the possession of jaws, girdles, and paired fins. The body is covered by a tough, leathery skin which carried imbedded in it a vast multitude of minute scales, very different in type from the scales of the higher fishes. Five or more pairs of gill openings appear on the neck region, instead of the single opening found among the teleosts, and these have no outer covering. Water is admitted to the pharynx through a spiracle in the posterior dorsal surface of the cranium, and passes from this region through the gill openings. The skeleton is, for the most part, cartilaginous. The mouth is always on the ventral surface of the head, and is armed with exceedingly well developed teeth. These are, however, imbedded in the gums instead of in the skeleton of the jaws. Elasmobranchs may be either ovoviparous, oviparous or viviparous; in all cases impregnation is internal. Most of the species are relatively sluggish in their actions, although they may become very active and do an immense amount of damage to valuable sea life.

### *Squalus acanthias* Linnæus

The spiny dogfish is a small shark, averaging about two feet in length, with a weight of three or four pounds. Mature females occasionally reach a length of three and a half feet and a weight of eight pounds. The species has a wide distribution in the north Atlantic, occurring abundantly on both the American and European shores, as well as in the Mediterranean. On the American side it ranges from the Gulf of St. Lawrence southward to Cuba. The fish are very gregarious, swimming in enormous schools or packs which are constantly in motion: here to-day, gone to-morrow.

These schools do great damage to the fishing industry along the coast, where they are abundant from May to October.

Their appearance along the entire Atlantic seaboard is almost simultaneous. Where they come from, where they go, is unknown, but it is inferred because of this almost spontaneous appearance along such a great coast line that theirs is not a southern and northern migration, but rather an off-and-on shore movement. Once they arrive, the dogfish move about following schools of fish upon which they prey. In spite of their small size, they are remarkably voracious and fully deserve the bad reputation in which they are held by fishermen. Not only do they completely destroy fishing grounds by disbursing the great schools of mackerel and other valuable food fishes, but they monopolize set lines, and they often attack the fish within the seines if they chance to be caught inside (and there is a record of a seine bringing up twenty thousand dogfish!). They bite their way through the nets, making great gaps through which valuable species of fish escape. In spite of their voraciousness, there is no record of the spiny dogfish having injured a human being.

The dogfish is a viviparous shark, giving birth to from one to eleven "pups", with three or four being a normal litter. The eggs are large and contain considerable yolk material. During their early development within the uterus they are encased in a pliable, horny egg capsule which, however, breaks down, leaving the pups entirely free within the uterus; there is no placental attachment. Recent studies indicate that the young are carried for about ten months. At the time of birth they are from nine to twelve inches long. While these large pups are developing within the uterus, another set of eggs is developing in the ovary. It is not infrequently that a female is found carrying young of two very different sizes. The young are born in June,

and there is some evidence to indicate that there are two breeding seasons, and that a second litter is born late in the fall or early winter.

As to the economic importance of the dogfish, it must be ranked as a pest. The damage these sharks cause to the fishing industry is very great, and there is practically nothing beyond their value as a form for laboratory dissection that can be said in their favor. While shark skin tans into a very excellent leather from which all sorts of articles, including shoes, may be made, the species in question is too small to be of much value in this respect.

## SECTION I. EXTERNAL FEATURES.

### 1. FORM.

In form the dogfish is distinctly elongated, its maximum depth, just anterior to the first pair of fins, being approximately one sixth of its total length. The maximum width, the posterior end of the head, is about two thirds of the greatest depth. The **head** is **depressed** and triangular, terminating at the anterior end in a pointed **snout**. At the posterior end, the **tail** is **compressed**, while cross-sections of the **body** would show varying intermediate forms at different points.

The general **color** of the shark is gray, shading to a much lighter tone on the ventral surface, and exhibiting in some specimens spots of a lighter color on the lateral surfaces. The abundance of these spots varies somewhat with the sex of the individual, being larger and fewer in the female than in the male. The entire surface is covered with minute **scales** (par. 15), which may be felt by rubbing the hand from the tail toward the head.

### 2. FINS.

The **fins** are flattened outgrowths of the body and are covered with scales. They are supported by internal cartilaginous rods, the **dermal fin rays**, visible on external examination. The fins are of two types: **azygos** or median, and **paired**. The paired fins are homologous with the paired

limbs of the higher vertebrates, though they lack the characteristic skeletal elements of those appendages. There are two sets of paired fins.

*Identify the following fins:*

- (1) The **dorsal fins** are azygos and are two in number, located on the mid dorsal line of the body. The first is placed at about the middle of the body, the second a short distance anterior to the base of the tail. Note the strong **spine** (par. 17) at the anterior margin of each of these fins. The dorsal fins function in keeping the body vertical in the water.
- (2) The **caudal fin** is azygos and composes the tail fin. Note that it is two-lobed, the lobes being of unequal size, with the axis of the tail bending upward in it, to enter the dorsal lobe. Such a tail is of the **heterocercal** type. The caudal fin is an organ of propulsion.
- (3) The **pectoral fins** are paired. They are large and triangular in shape and are attached to the sides of the ventral surface of the body just posterior to the head. Note that their position is horizontal, that of the azygos fins vertical. The pectoral fins function in controlling the horizontal position of the body in the water.
- (4) The **pelvic fins**, also triangular in shape, are attached to the ventral surface of the body about two thirds of the length back. They are attached horizontally but point backward, their median margins touching. In function they are accessory to and act with the pectorals. In the female the pelvic fins are simple; in the male the median margin of each pelvic fin is specialized into an elongated rod-like **clasper**, an organ of copulation. Note the **groove** on the median

dorsal surface of the clasper; trace it forward and note that it terminates in a blind sac, the **glandula pterygopodia**, within the base of the fin.

### 3. APERTURES.

There are numerous external openings into the body.

*On the ventral surface identify the following openings:*

- (5) The **mouth** is located on the ventral side of the head. It is a transverse crescentric structure. Note the **oronasal groove** just anterior to the lateral angles of the jaw. In some sharks this passage extends forward to communicate with the nasal passage, but in the spiny dogfish it ends blindly at a point anterior and lateral to the mouth.
- (6) The **nostrils** are paired apertures on the ventro-lateral surface of the head, anterior to the mouth. Note that each is the entrance to a rounded cavity (par. 164). Each nostril is divided by a flap of skin into an incurrent and excurrent aperture. Probe the nasal cavity and determine that it is a blind sac. In some species of sharks the cavity communicates with the mouth.
- (7) The **cloacal aperture** lies beneath, between and nearly concealed by the pelvic fins. Through it the products of the genital and renal organs are discharged (par. 33) to the outside, as well as the waste matter from the intestines. Locate and probe the **abdominal pores**, a pair of minute openings, one on each side of the inner wall of the cloaca. The finger-like projection is the **papilla** (par. 81).
- (8) The **mucous pores** are minute scattered openings

arranged in symmetrical pattern over certain regions of the head. They communicate with the lateral line organs (par. 167) and with the ampullæ of Lorenzini (par. 176), a special type of sense organ. Note the distribution of these pores on the ventral surface of the head. A jelly-like substance can be squeezed out of them.

*On the lateral surface identify the following features:*

- (9) The **eye** occupies a position on the side of the head, midway between the nostril and the mouth. Note its elliptical shape. Two **eyelids** are present, a dorsal and a ventral, but they are immovable. In some sharks (e. g. the smooth dogfish *Mustelus canis*) a third lid, the nictitating membrane, is present, but this is absent in *S. acanthias*.
- (10) The **spiracles** are paired apertures on the dorsal lateral margin of the head, just posterior to the eyes. They communicate internally with the back part of the pharynx and are modified gill clefts (par. 131). Note carefully, but without cutting, their structure.
- (11) The **gill clefts** are seen as five slit-like openings on each side of the body just anterior to the pectoral fins. They open into the pharynx and afford a passage for the escape of water taken in through the mouth, after the water has passed over the gills in the process of respiration.
- (12) The **lateral line** appears as a series of very small apertures extending in a linear series along each side of the body. Follow it as far forward as possible. It is an organ of special sense which will be studied in detail later (par. 167).

*On the dorsal surface identify the following features:*

- (13) The openings of the **endolymphatic ducts** appear as a pair of minute pores on the top of the head almost exactly on a line drawn between the spiracles. Each communicates internally with the inner ear (par. 177) located within its respective side of the posterior neurocranium.
- (14) Identify the mucous pores on the dorsal surface of the head, and note their distribution.

#### 4. SCALES.

*Remove a small, thin particle of skin and place it in glycerine for twenty-four hours. Place it on a slide and examine under the low power of the microscope.*

- (15) Identify the **scales** imbedded in the skin. Note that each scale is composed of a broad, shield-shaped **base** and a vertical, posterior-curving **spine**. This is the **placoid** type of scale. On your specimen follow the scales over the edge of the jaws and note the transition into:
  - (16) the **teeth**. These teeth have no roots and, except for their varying size, they are alike (**homodont**). Notice that each functional tooth has behind it a row of non-functional teeth. These latter become functional if the functional tooth is lost. Since this replacement may occur many times the condition is said to be **polyphodont**. These teeth are in reality enlarged placoid scales, modified to perform a new function.
  - (17) The dorsal spine (par. 1) occurring at the anterior margin of each dorsal fin, is a modified scale. Note that it is buried nearly one half its length

in the skin. The buried part is sometimes referred to as the **root**, the projecting portion as the **crown** or spine proper.

**DRAWING 1.** In the middle of a sheet of paper make a drawing nine inches long of the lateral view of the shark. To the left of this drawing project the head as seen from the ventral surface; to the right project the head as seen from the dorsal surface. Be careful to get the proper proportions. Label all drawings fully.

## SECTION II. THE ABDOMINAL CAVITY

*Lay the dogfish on its back and pin it down through its pectoral fins. Locate the pectoral and pelvic girdles by feeling. Make a median ventral incision extending from the pectoral girdle to the pelvic girdle, cutting through the latter and then curving to the right around the cloacal aperture. Make a right and left transverse incision through the body wall just posterior to the pectoral girdle and pin down the flaps. Do not make the transverse incisions longer than is necessary to expose the body cavity. Do not cut through the pectoral girdle, and cut no internal structures unless directed to do so.*

*Identify:*

### 1. THE CÆLOM. ✓

(18) The **cœlom**, or body cavity, is that large space in which lie the viscera of the body. In the dogfish the cœlom is divided into two parts: (a) the pericardial cavity, containing the heart, which lies anterior to the pectoral girdle and which will be exposed and studied later (par. 95); and (b) the **abdominal (pleuroperitoneal) cavity**. The abdominal cavity has been exposed by the incision you have made. Its anterior boundary is the **septum transversum** which separates it from the pericardial cavity, from which it extends to a point just posterior to the cloacal opening.

(19) The abdominal cavity is lined throughout by a delicate membrane, the **parietal peritoneum**, which

forms the smooth wall of the cavity, adhering very closely to the muscles of the body wall.

## 2. THE VISCERA. ✓

(20) The large, yellow-brown organ, conspicuous in the anterior region of the cœlom is the **liver**.

(21) Note that it is composed of a long **right** and **left lobe**, and a short **median lobe**.

(22) On the margin of the median lobe locate the **gall bladder**, a thin-walled sac extending nearly the length of the lobe itself.

*Separate the right and left lobes of the liver carefully without rupturing any structures.*

*Identify the following structures:*

(23) The **stomach** is a large J-shaped organ lying dorsal to the liver. Note its length in relation to that of the liver. It extends forward to the septum transversum where it unites with the **œsophagus** from which it can not be differentiated externally (par. 64). Beyond the base of the J, where the stomach turns forward and to the right, the diameter decreases rapidly, to terminate in the **pylorus**, a muscular constriction. The large left arm of the stomach is the **cardiac** portion; the right arm is the **pyloric** portion. The transition between the two will be more easily seen by an examination at a later period of the internal structure of the stomach (par. 65).

(24) Note the numerous parallel white lines extending over the surface of the cardiac stomach. These are branches of the **vagus nerve** (par. 210).

(25) Immediately posterior to the bend of the stomach

- identify the reddish-brown, triangular **spleen**. Note its position a trifle to the left of the stomach.
- (26) The **intestine** extends from the pylorus to the cloacal aperture. It is rather short and relatively little coiled. The slender portion of the intestine immediately posterior to the pylorus is the **duodenum**.
- (27) Locate the **ductus choledochus**, or **bile duct**, a long, slender tube arising at the anterior end of the gall bladder and leading to the dorsal surface of the duodenum, which it enters near the pyloric end of the stomach.
- (28) The **pancreas** is a flattened, whitish, two-lobed (but apparently tripartite) organ. The **ventral lobe** lies in close contact with the ventral surface of the proximal end of the duodenum. This lobe is joined near its center by the **dorsal lobe**, the free end of which lies dorsal to the distal end of the cardiac stomach, and curves around the pylorus to join the ventral lobe.
- (29) Posteriorly the duodenum widens rapidly into the **ileum**, or **valvular intestine**. Note that its walls appear to be thin and that they are marked by a series of rings. These rings indicate the internal attachment of the spiral valve (par. 70).
- (30) The valvular intestine narrows again posteriorly into the **colon**.
- (31) The **rectal (digitiform) gland** is a cylindrical body lying dorsal to the colon, and is attached to the intestine by a short duct. This duct marks the posterior limit of the colon and the anterior limit of
- (32) the **rectum**. The rectum is very short and slender, opening almost at once into
- (33) the **cloaca**. This is a somewhat expanded region

and is the chamber into which digestive and urogenital systems discharge. The cloaca empties to the exterior through the cloacal aperture or **vent**.

**DRAWING 2.** Make a full page drawing of the viscera, the lobes of the liver laid to each side so as to expose the more dorsal organs.

### 3. THE MESENTERIES.

The viscera are held in place by a number of delicate membranes or **mesenteries**.

*Identify the following membranes, but do not rupture them unless so instructed.*

- (34) The **dorsal mesentery** extends from the median dorsal wall of the abdominal cavity to the digestive tract. Note that it is not complete over the entire length of the alimentary tract.
- (35) That portion of the dorsal mesentery which supports the stomach is the **mesogaster**. It is attached to the stomach, spleen, pancreas and duodenum.
- (36) The membrane which connects the spleen to the stomach is the **gastrosplenic omentum**.
- (37) The liver is connected to the loop of the stomach by the **gastrohepatic omentum**.
- (38) This is joined near the stomach by the **hepatoduodenal omentum** extending from the liver to the duodenum. This omentum also unites with the mesogaster. The ductus choledochus extends along the edge of the gastrohepatic and hepatoduodenal omenta.
- (39) The portion of the dorsal mesentery supporting the valvular intestine is the **mesentery proper**. This fuses anteriorly with the mesogaster to form a

pocket at the bend of the stomach, in which pocket most of the pancreas lies.

- (40) At the posterior end of the abdominal cavity the **mesorectum** supports the rectum and the rectal gland.
- (41) At the anterior end of the liver find the **suspensory ligament**. This is a remnant of a **ventral mesentery**, extending from the mid-ventral wall of the cœlom to the mid-ventral surface of the liver.

#### 4. THE VISCERAL ARTERIES. ✓

*Lay the viscera carefully to your left side, being careful not to destroy the mesenteries, and identify the following arteries. As all blood vessels are identified, make a series of sketches showing their origin and distribution, which will enable you to make the final drawings of the arterial and venous system which will be called for later (page 43).*

- (42) The **dorsal aorta** lies on the median wall of the roof of the cœlom. It is visible through the peritoneal lining. Trace it backward along the length of the body cavity, just ventral to the vertebral column. At a point anterior to the tip of the rectal gland the dorsal aorta descends deeper into the trunk and is obscured. Its course in this region can best be traced later (par. 139). It is prolonged beyond the cœlom into the tail, where it becomes the **caudal artery (aorta)**. Identify the caudal artery in a cross-section of the tail.
- (43) The **cœliac axis (artery)** arises from the dorsal aorta immediately posterior to the septum transversum; the point of its origin will be seen later (par. 138). It extends along the dorsal surface of the stomach and gives off the following branches:

- (44) Near its point of origin it gives off a series of small **genital arteries** which pass to the gonads. At the same point a few small branches (often uninjected) pass to the cardiac end of the stomach and to the oesophagus. From this point the **coeliac axis** extends posteriorly without branches, to enter the **gastrohepatic omentum** where it branches into two large vessels:
- (45) The **gastrohepatic artery** is a vessel which divides at once into:
- (46) the **hepatic artery** which turns forward and extends the **ductus choledochus**, which it supplies, and enters the liver; and
- (47) the **gastric artery**, which supplies the stomach. This vessel divides into a **dorsal** and **ventral** gastric vessel which penetrate the walls of the stomach after branching over its surface.
- (48) The **anterior intestinal (pancreatico-duodenal) artery** passes from the point of origin of the **gastrohepatic artery** backward to the region of the stomach, where it sends off small branches to the pylorus and to the ventral lobe of the pancreas.
- (49) A larger **duodenal artery** arises from the anterior intestinal and supplies the duodenum.
- (50) Beyond the duodenal artery the vessel continues as the **anterior intestinal artery**, which reaches the valvular intestine, to extend along the right side of this organ, giving off branches to the right and left which coincide with the points of attachment of the spiral valve within the ileum.

- (51) At the posterior edge of the dorsal mesentery, near the point where the dorsal aorta disappears, arises from the dorsal aorta the **anterior mesenteric artery**. It is very short, and is often entirely absent. If present, it divides at once into two vessels; if absent, these vessels arise directly from the dorsal aorta.
- (52) The **anterior gastropancreaticosplenic artery** passes to the distal end of the cardiac stomach, and spleen.
- (53) The **posterior intestinal artery** passes to the dorsal wall of the valvular intestine where it gives off branches to the right and left, these coinciding with the points of attachment of the spiral valve in the posterior region of the ileum. A considerable amount of variation occurs in the region of the anterior mesenteric artery. It may be present or absent; it may be a quarter of an inch long or extremely short. When absent, in some cases the posterior intestinal artery arises anterior to the anterior gastropancreaticosplenic.
- (54) Beyond the posterior border of the dorsal mesentery the dorsal aorta gives off the **posterior mesenteric (hypogastric) artery** which passes along the anterior border of the mesorectum, to break into many small branching vessels on the rectal gland. It is usually single, but in an occasional specimen is found to be double.

##### 5. THE VISCERAL VEINS. ✓

The series of veins in evidence over the alimentary tract constitute the **hepatic portal system**, returning the blood which is brought to the viscera by the coeliac artery and the two mesenteric arteries to the heart via the liver.

*Starting at the posterior end of the digestive tract, identify the following veins, sketching the vessels as you proceed.*

- (55) The **dorsal intestinal vein** arises on the dorsal surface of the rectal gland, passing from the gland to the intestine on the duct of the gland. This vein is continued over the valvular intestine as
- (56) the **posterior intestinal vein**. This extends forward along the dorsal side of the valvular intestine, receiving branches from right and left. When opposite the spleen, it leaves the ileum and passes through the mesentery, to run past the spleen.
- (57) As it passes the spleen it receives the **anterior gastrosplenic vein** which is composed of small branches from the spleen and the bend of the stomach. The posterior intestinal then extends forward to be joined by:
- (58) The **anterior intestinal vein**. This vessel lies on the ventral surface of the ileum opposite to the posterior intestinal vein and, like it, receives annular branches. At the anterior end of the ileum it receives small vessels from the pancreas and
- (59) the **posterior gastropancreaticosplenic vein** from the anterior end of the spleen and the pyloric end of the stomach.
- (60) At the point where the anterior and posterior intestinals unite, a third vessel, the **gastric vein**, comes from the cardiac portion of the stomach where it is formed by the accumulation of a number of smaller vessels, and joins with the other two.
- (61) At almost the exact point where these three vessels unite, a fourth vein, the **duodenal**, joins the others, coming from the duodenum.
- (62) The fusion of these four vessels forms the **hepatic**

**portal vein** which extends to the liver and enters it dorsal to the median lobe. Within the liver the hepatic portal breaks into a fine network of small vessels.

*Cut off the liver at a point about one inch from its anterior margin.*

- (63) These fine vessels are brought together within the liver by the **hepatic veins** which unite into two **hepatic sinuses** which can be seen in the cut ends of the liver. These sinuses pass through the septum transversum and deliver the blood to the heart, as will be seen later (par. 104).

*In the portion of the liver cut off, trace the hepatic sinuses and note the incoming hepatic veins.*

## 6. THE VISCERA: INTERNAL STRUCTURE. ✓

*Cut off the stomach just dorsal to the cut made in removing the liver, cutting through the mesentery and the cœliac artery. Cut all dorsal mesenteries close to the body wall, as well as the anterior gastropancreaticosplenic, posterior intestinal and posterior mesenteric arteries, leaving, however, half an inch of each artery in place. Cut through the rectum just posterior to the rectal gland, and remove the alimentary canal. With the scissors cut open the alimentary canal from end to end, being careful when opening the valvular intestine not to cut deep. Wash out the digestive tract thoroughly.*

- (64) The œsophagus. Note that the walls of this region are thrown into strong, compound, finger-like **papillæ**. These are prolongations of the mucous layer

which lines the region. Posteriorly they cease abruptly and this marks the posterior limit of the œsophagus.

- (65) The stomach. Note the abrupt transition in the character of the mucous lining which in the stomach is thrown into strong longitudinal folds or **rugæ**. They are somewhat irregular and branched. They contain microscopic flask-shaped glands which secrete the digestive fluids of the stomach. As these **rugæ** approach the bend of the stomach they tend to become weaker, but strengthen again in the pyloric stomach.
- (66) Note the thickening of the wall at the distal end of the pyloric stomach. This is the **pyloric valve**, a muscular constriction. The swollen wall is the **pyloric sphincter**, a band of circular muscles which closes the pylorus.
- (67) The duodenum is seen to be short, and its walls relatively smooth.

*Make an incision into the ductus choledochus; insert a bristle and discover the point of entrance into the intestine.*

- (68) Note that the ductus choledochus passes obliquely through the walls of the intestine, the internal opening of the ductus being posterior to the point of entrance.
- (69) The **duct** of the pancreas is difficult to locate. It is imbedded near the posterior margin of the ventral lobe, and can be discovered by picking away the tissue of the pancreas in this region. Note its entrance into the intestine in relation to the first fold of the valvular intestine.
- (70) The valvular intestine is so called because of the

presence within it of the **spiral valve**. This consists of a spirally coiled fold of the intestinal wall, giving the structure the appearance of a series of overlapping cones. The function of the valve is to greatly increase the absorptive surface of the intestine. Discover whether the spiral is "clockwise" or "counter-clockwise". Cut the attached edges of the valve at its posterior end and note the relation of the fold composing the valve to the intestinal wall.

(71) The walls of the colon are smooth.

(72) Cut across the rectal gland and note its **lumen** or cavity. Trace the lumen toward the intestine and note the entrance of the rectal duct into the dorsal surface of the intestine. Probe it with a bristle.

(73) The walls of the rectum and cloaca are smooth.

**DRAWING 3.** Duplicate the drawing already made of the alimentary canal. Show each organ just discussed as having a window cut into it. Within the windows make a detailed drawing to show the character of the inner surface of the organ.

## 7. THE UROGENITAL SYSTEM.

The urogenital system comprises the organs of excretion and of reproduction. So closely associated are they both in position and in function that a combined dissection of the two systems is necessary.

(74) Identify the **kidneys (mesonephroi, or Wolffian bodies)**. They occupy a position of the dorsal wall of the cœlom on either side of the vertebral column, and are clearly seen through the peritoneum. They are greatly elongated, flattened organs, extending

almost the entire length of the abdominal cavity. Note, however, that they are extra-cœlomic (**retroperitoneal**) in location. The kidney is narrower in its anterior portion, which is apparently functionless as an organ of excretion, and is the **cranial mesonephros** or **epididymis**; the wider posterior portion is the **caudal mesonephros** or functional kidney.

*If the specimen is a male, identify the following structures:*

- (75) On the ventral surface of the kidney lies the convoluted **Wolffian** or **mesonephric duct**. Because of its function in the male, that of carrying the products of both excretory and genital organs, it is known as the **ductus deferens** to distinguish it from the duct in the female which occupies the same position but is different in function (par. 87). At the anterior end of the kidney the tube is small and finely coiled, becoming straight in the posterior region. The younger the dogfish, the less convoluted is the ductus deferens.

*Carefully dissect the peritoneum from the last two inches of the right kidney so as to expose the ductus deferens. Cut off the tip of the papilla within the cloacal aperture; slit it open to discover the openings of the two ducts. Slip the point of the scissors into the right aperture and open the sac into which it leads.*

- (76) The ductus deferens, having left the posterior end of the kidney, expands suddenly into a sac, the **seminal vesicle**, which extends forward and ventral to the aperture of the ductus deferens located on its dorsal surface.

- (77) The anterior projection of the seminal vesicle just noted is the **sperm sac**.
- (78) The sperm sacs unite posteriorly into a common chamber, the **urogenital sinus**, which is the cavity of the papilla. The sinus discharges into the cloaca through the tip of the papilla.
- (79) The **testes** are a pair of whitish bodies lying at the anterior end of the abdominal cavity, dorsal to the liver and the digestive tract. They are flattened, ovoid organs.
- (80) The testis is suspended from the dorsal wall of the abdominal cavity by the **mesorchium**, a delicate mesenteric fold of the peritoneum.
- (81) Extending through the mesorchium from the testis to the epididymis is a series of very fine (uninjected) ducts, the **vasa efferentia**. In young individuals they are difficult to see and can best be located by holding the mesorchium to the light. These vasa efferentia connect with the nephric tubules within the tissue of the kidney, and these in turn discharge into the ductus deferens. The ductus deferens, therefore, receives the products of both the testes and the kidneys. Since the papilla receives the contents of the ductus deferens, it is known as the **urogenital papilla** in the male.

DRAWING 4. Make a drawing eight inches long of the urogenital system of the male. Show the papilla as being cut open in order to show the relation of the contained ducts.

*If the specimen is a female, identify the following structures:*

- (82) In the mature female the **oviducts (Müllerian ducts)** are large tubes, ventral to the kidneys.

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They are connected to the kidneys by a fold of the peritoneum, the **mesotubaria**.

- (83) On the ventral surface of the liver identify the **ostium tubæ abdominale**. This is a wide, funnel-shaped common opening to the two oviducts and lies in the suspensory ligament. Its opening is directed backward.
- (84) From the ostium trace one of the oviducts. It curves up over the liver and then runs backward toward the tail. It swells, after leaving the ostium, into a **shell gland**, which is conspicuous in the mature female, but inconspicuous in the immature individual.
- (85) The **uterus** is the greatly swollen region of the oviduct in which the development of the young takes place, for *Acanthias* is a viviparous shark. Young "pups" of various sizes are often found within the uterus.
- (86) Trace the uteri backward and note that they open into the anterior end of the cloaca at the base of and dorsal to the papilla, not into it. In the female, therefore, the papilla does not receive the products of the gonads.

In the immature female the oviducts are small, straight tubes, lying closely adhered to the median ventral wall of the kidneys; there are no mesotubaria. There is no specialization into shell gland or uterus, though the oviducts enlarge slightly toward the posterior end of the kidneys. The openings into the cloaca are very small.

*To locate the openings into the cloaca, slit the oviduct at a point anterior to the cloaca and probe it with a bristle.*

- (87) The **Wolfian (mesonephric or urinary) duct** is located on the ventral surface of the kidney im-

mediately dorsal to the oviduct in the immature female, or at the line of attachment of the mesotubarria in the mature individual. It is more conspicuous at the posterior end of the kidney where the duct extends toward the cloaca and the contained papilla.

*Cut off the tip of the papilla; insert the point of the scissors and slit it open.*

- (88) The single cavity of the papilla is the **urinary sinus**.
- (89) At its anterior end the urinary sinus divides into two wings or **cornua**; into the anterior extremity of each cornu a Wolffian duct discharges. Demonstrate their entrance. Since the Wolffian ducts in the female carry only the products of the kidneys, and since the oviducts do not discharge into the papilla, the latter organ is known as the **urinary papilla** (par. 81).
- (90) The ovaries are soft, paired, oval bodies lying in the anterior end of the abdominal cavity, dorsal and lateral to the cardiac stomach which they circle, the median ventral edge approaching the liver.
- (91) Each ovary is suspended by a mesenteric fold of the peritoneum, the **mesovarium**.
- (92) If the specimen is mature, **ova** of different sizes can be felt through the walls of the ovary.
- (93) In a cross-section of the tail identify the two blood vessels lying in the hæmal arch. The dorsal of these has already been identified as the caudal artery (par. 42). The ventral vessel is the **caudal vein**. It passes forward; when it reaches a point dorsal to the cloaca it branches into a right and left **renal portal vein**, taking blood to the kidneys. The renals

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extend lateral and dorsal to the kidneys, receiving **segmental veins** from the body wall and, in the female, **posterior oviducal veins** from the posterior portion of the oviduct. Prior to branching, the caudal vein likewise receives segmental veins. The further blood supply of the kidneys can best be described later.

**DRAWING 5.** Make a drawing eight inches long of the urogenital system of the female.

### SECTION III. THE PERICARDIAL CAVITY

*Cut through the mid ventral line of the pectoral girdle; prolong the incision forward to a point half an inch anterior to the first gill cleft, being careful not to cut the thin walled sac lying immediately anterior to the pectoral girdle, and just beneath the thin layer of muscles on the ventral surface.*

- (94) The **pericardial sac** lies anterior to the septum transversum. It is very thin walled. Note its shape.

*Make a median ventral incision into the sac.*

- (95) The **pericardial cavity** within the sac is triangular in shape, with its apex at the anterior end. It is the anterior termination of the coelom.

- (96) The **parietal pericardium**, the smooth, delicate membrane lining the cavity, is morphologically equivalent to the parietal peritoneum. Note that at the anterior end of the cavity it is deflected back over the heart to form the smooth outer coat of that organ, and is the **visceral pericardium**.

#### 1. THE HEART.

- (97) The **heart** lies in the pericardial cavity. Identify the following structures:
- (98) Extending from the apex of the pericardial cavity posteriad is the firm, thick-walled **conus arteriosus**.

- (99) The posterior termination of the conus is the pyramidal **ventricle**. Note that the **apex** is directed somewhat to the left.
- (100) Over the surface of the conus extends a pair of **coronary arteries** which ramify over the ventricle and send small branches to the walls of the pericardial cavity. The origin of these vessels, which supply the heart, will be seen later (par. 125).
- (101) Dorsal to the ventricle is the thin walled **atrium (auricle)**. Note its size in relation to the ventricle. It is shaped somewhat like an arrow-head, pointing forward dorsal to the conus, the posterior wings lying just lateral to the tip of the ventricle.
- (102) Gently lift the tip of the ventricle and discover the **sinus venosus**. It is a very thin walled, triangular sac lying dorsal and to the rear of the auricle. The wide base at the posterior end is continuous with the septum transversum; its roof is in contact with the dorsal surface of the pericardial cavity. Note the connection with the atrium.

## 2. VESSELS ENTERING THE HEART.

*Make a transverse incision through the ventral wall of the sinus close to its attachment to the atrium. Spread apart the cut edges. Since all of the systemic veins empty into the sinus, the apertures of these vessels are now visible. Wash out the sinus gently but thoroughly.*

*Identify the following features:*

- (103) The **trabeculae** are bands of muscle which strengthen the sinus. Note their distribution.

- (104) With a bristle probe the hepatic sinuses in the liver to demonstrate their entrance into the sinus venosus through the median portion of the posterior wall. Occasionally (but not frequently) the hepatic sinuses unite, to open through a single common aperture.
- (105) The right and left wings of the sinus terminate in a large opening, beyond which the sinus is prolonged into the **ductus Cuvierius (common cardinal vein)**. Opening into the ductus Cuvierius are the following veins:
- (106) On the posterior median wall a pair of large **postcardinal veins** enter. Insert a probe into the left postcardinal and note that posterior to the septum transversum the probe lies in an enlarged cavity, the **cardinal sinus**, which lies dorsal to the œsophagus and anterior and dorsal to the gonads. Probe the left and right cardinal sinuses anterior to the end of the liver. The anterior portion of the cardinal sinus receives **spermatic** or **ovarian veins** from the gonads, **oviducal veins** from the anterior portion of the oviduct and **segmental veins** from the trunk. Follow the postcardinal backward. The cardinal sinus narrows rapidly, to continue through the length of the abdominal cavity, lying dorsal to the median margin of the kidneys, the chief veins of the trunk. They receive paired **parietal veins** from the trunk, and **renal veins** from the kidneys. These small veins are often uninjected, in which case they are difficult to identify unless they chance to be filled with blood. Thus the blood brought to the kidneys by the

renal portal veins (par. 93) is returned to the heart via the postcardinal sinuses.

(107) Immediately anterior to the opening of the postcardinals are the large openings of the two **anterior cardinal sinuses**. They extend forward dorsal to the pharynx, to expand back of the eyes into the **orbital sinuses**. The orbital sinuses receive the **anterior facial veins** from the region of the snout, and the anterior cerebral veins from the fore part of the brain. The sinus receives, besides **nutrient veins** from the gills, the hyoidean vein, which passes along the base of the first gill and which connects ventrally with the inferior jugular vein (par. 109). A dissection of the anterior cardinals is not practical at this point.

(108) Along the lateral walls of the abdominal cavity the **lateral abdominal veins** lie just under the peritoneum. Trace one backward. At the posterior end of the body the lateral abdominal vein receives an important tributary in the **iliac vein**. This in turn is formed by a union of a **cloacal vein** from the region of the cloaca, and the **femoral vein** from the pelvic fin. Posterior to the cloaca, the right and left abdominals unite.

*Open a lateral abdominal vein and trace it forward to the heart.*

At the anterior end, near the pectoral girdle, the lateral abdominal receives the **brachial vein** coming from the pectoral fins where it in turn is formed by the union of a **dorsal, median and lateral pterygial vein**. After the

union of the brachial and lateral abdominal vein, the vessels thus formed extend forward as the **subclavian vein**, to enter the lateral extremity of the ductus Cuvierius.

- (109) The **inferior jugular** arises in the anterior roof of the pharynx. It receives as tributaries the **submental vein** from the tip of the lower jaw, the **thyroidean vein** from the thyroid (par. 121), the hyoidean vein (par. 131), together with **ventral nutrient** veins from the gills. It enters the ductus Cuvierius anterior and mesial to the entrance of the subclavian vein. Locate this entrance.

*Remove the heart by cutting the conus just inside of the pericardium. Place it under water, auricle uppermost.*

- (110) After removing the heart, identify the opening on the dorsal wall of the pericardial cavity, dorsal to the attachment of the sinus venosus. This is the anterior aperture of the **pericardiaco-peritoneal canal**, lying on the ventral surface of the œsophagus. Posterior to the septum transversum the canal branches, to open into the pleuroperitoneal cavity by a right and left canal. Of these the right is the larger. If difficulty is encountered in identifying these branches, inject the canal with india ink by means of a pipette.

### 3. CHAMBERS OF THE HEART.

*Return to the heart which you have removed. Cut open the dorsal surface of the auricle and wash out any blood within it.*

- (111) Identify the **sinu-auricular valves** which appear as membranous folds bordering the opening between the sinus venosus and the auricle, the **sinu-auricular aperture**.
- (112) In the floor of the auricle the **auriculo-ventricular aperture** permits the flow of blood into the ventricle.
- (113) The small muscles which strengthen the walls of the auricle are the **musculi pectinati**.

*Slit the ventricle longitudinally.*

- (114) The flaps guarding the auriculo-ventricular aperture constitute the **auriculo-ventricular valve**. Note that it is so constructed as to prevent the flow of blood into the auricle when the ventricle contracts.
- (115) The fibers which pass from the walls of the ventricle to the free margins of the auriculo-ventricular valve are the **columnæ carneæ**. Examine these fibers and note that they consist of a slender tendinous portion, the **chorda tendinea**, and an enlarged basal portion, the **musculus papillaris**.

*Slit the conus arteriosus.*

- (116) Note the rows of pocket-like **semilunar valves** on its inner wall. The number of these valves is somewhat variable. Compare the number in your specimen with that in other specimens if possible.

## SECTION IV. THE MOUTH AND PHARYNX.

In all vertebrates the organs of respiration—whether gills or lungs—are developed in close physical relationship with the anterior end of the alimentary canal, arising as pouches or diverticulæ from the digestive system just posterior to the mouth cavity. This region, a common passage for food and the respiratory medium (water or air), is designated as the pharynx. The respiratory organs of the dogfish are gills. They develop on the walls of the branchial (gill) clefts which pass from the pharyngeal region to the exterior. Since the anterior cleft is embryologically the first to develop, it is designated as the first branchial cleft. In the case of the dogfish this first cleft is modified as the spiracle by a reduction in size due to the closing of part of the cleft. The opening of the spiracle is on the dorsal surface of the head; the remaining gill clefts open on the lateral surface. It must be borne in mind, then, that the dogfish has *six* pairs of branchial clefts, the first pair being the spiracles, the remaining five pairs the true gill slits on the sides of the pharyngeal region. When we refer to the second gill slit we mean the first lateral cleft.

### 1. THE GILLS.

*Lay the dogfish ventral surface uppermost. Insert the point of a scissors into the first gill pouch on the left side and cut medial nearly to the mid ventral line, thus opening a gill chamber. Do the same for each succeeding gill chamber.*

- (117) The gill clefts are separated from each other by the **gill septa**. These are thin partitions, the outer edges of which bear scales and separate the **external gill slits**.
- (118) Referring to the second septum as typical, note a more or less elliptical row of **gill filaments** on both its anterior and posterior surfaces. These anterior and posterior filaments, borne on a septum, constitute a **branchia** or **gill**, while each of the component sets of filaments constitute a **demibranch**. The gill cleft, therefore, lies between demibranchs of consecutive gills. Note the condition on the posterior wall of the last cleft.
- (119) The mesial opening of the gill pouch into the pharynx is the **internal gill slit**. This opening into the pharynx is guarded by a row of finger-like projections, the **gill rakers**, which strain out foreign matter which comes in with the water through the mouth, and prevent such material from entering the gill chamber where it might damage the delicate gill filaments.
- (120) By rolling the septum beyond the gill filaments between the fingers, the curved **extrabranchial cartilages** may be felt. The septum is also supported by a series of fine cartilaginous rods, the **branchial rays**, which radiate from the epibranchial and ceratobranchial cartilages of the branchial arch (par. 274). The branchial rays can best be seen in cross-section by cutting the septum parallel to the outer margin of the gill filaments. Compare the conditions existing in the first and last gill pouches with that in the second.

**DRAWING 6.** Make a drawing showing the second gill slit opened widely. Label fully.

*Make a shallow mid-ventral incision through the skin from the anterior margin of the pericardial cavity to the symphysis of the lower jaw. This exposes a broad sheath of muscle, the first of the constrictores superiores ventrales (par. 303). Dissect through this to find the slender median coraco-mandibularis muscle. Transect this, and deflect it forward.*

- (121) Under the anterior end of the coraco-mandibularis muscle lies a flattened whitish organ, the **thyroid gland**, just posterior in position to the lower jaw.

## 2. AFFERENT BRANCHIAL ARTERIES.

*Starting with the cut end of the conus arteriosus, trace the course of the anterior prolongation of this vessel, dissecting away the muscles as you proceed.*

- (122) Beyond the pericardial cavity the thick-walled conus arteriosus continues forward as a much thinner walled vessel, the **ventral aorta**.

- (123) Immediately after leaving the pericardial sac the ventral aorta gives off two pairs of lateral branches, beyond which point it passes unbranching for a short distance, terminating in a pair of lateral branches just posterior to the thyroid gland. These three pairs of branches are the **afferent branchial arteries**, which carry non-aërated arterial blood to the gills. The ventral aorta and its branches are the only arteries in the dogfish which carry non-aërated blood.

*Carefully trace the afferent branchial arteries on the left side.*

- (124) The first (anterior) branchial artery divides almost at once into two arteries, the anterior one going to the first demibranch, the posterior entering the septum between the second and third gill clefts, and supplying the second and third demibranchs. The second branchial is undivided, passing directly to the septum between the third and fourth clefts, thus supplying the fourth and fifth demibranchs, The third afferent branchial usually divides immediately after leaving the ventral aorta. The anterior arm passes into the septum between the fourth and fifth clefts to supply the sixth and seventh demibranchs, while the posterior arm passes between the fifth and sixth cleft to supply the eighth and ninth demibranchs.

*It is necessary at this point to trace the coronary arteries (par. 100) to their source, although they do not belong to the afferent branchial system, but carry aërated blood from the gills to the heart.*

- (125) Locate the cut ends of the two coronary arteries on the conus arteriosus and trace them forward. Just beyond the anterior wall of the pericardial cavity they are found to arise from a right and left **hypobranchial artery** which in turn unite with each other dorsal to the posterior end of the ventral aorta. From the loop thus formed there arise a pair of small **pericardial arteries** which pass to the dorsal wall of the pericardial cavity and eventually to the floor of the pharynx and the œsophagus. The hypobranchial artery passes forward on each side just mesial and ventral to the

internal gill clefts, and connects at these points with the union of the efferent vessels (post- and pretrematic) which bring the blood back from the gills (par. 127). Just median to the gill cleft it gives off a small branch which passes forward into the ventral muscles of the head.

*Cut through the angles of the mouth and continue the incision through the gill clefts. Remove the floor of the mouth and pharynx.*

- (126) On the floor of the mouth lies the immovable **tongue**, the skeleton of which is formed by the basihyal cartilage (par. 270).

### 3. EFFERENT BRANCHIAL ARTERIES.

*Carefully remove the skin from the roof of the mouth and pharynx to expose the blood vessels just beneath the skin.*

- (127) Identify the four vessels extending diagonally backward and mesial from the median angle of the second, third, fourth and fifth internal gill slits. These are the **efferent branchial arteries** which carry the aërated blood away from the gills whence it was brought by the afferent arteries. The gills are, then, essentially intra-arterial capillaries. These four efferent branchials unite mesially to form the dorsal aorta (par. 42). Note that at the base of each internal gill cleft each efferent branchial is formed by the union of a **pretrematic** and a **post-trematic artery**. The pretrematic is formed by a union of the capillaries in the gill filaments composing the demibranch on the anterior wall of the gill pouch, the post-trematic from the blood supply of the demibranch on the posterior wall of

the gill pouch. Thus the gill septum contains both a pre- and post-trematic artery, and these are connected within the septum by a varying number of cross-vessels. The ninth demibranch is cared for by the fourth efferent branchial.

- (128) From the base of the loop around the second gill cleft, the **common carotid artery** arises and extends forward. After progressing a short distance it bends sharply mesiad.
- (129) At this bend a small vessel extends forward, passing into the cartilage of the cranium. This is the **external carotid artery** which supplies the general region of the sides of the head.
- (130) Anterior to the origin of the external carotid, the common carotid continues as the **internal carotid artery**, which joins with the corresponding vessel from the opposite side. After this union the internal carotid disappears at once into the cartilage of the cranium. Just out of sight within the cranium it divides again into a right and left arm. (By careful dissection, so as not to destroy any nerves, the branches of the internal carotid may be traced. A short distance after this internal branching the vessel divides again. The median of these branches passes anterior as the internal carotid to the brain where we will find it later (par. 222). The lateral branch sends off a small anterior lateral arm, the **ophthalmic artery**, to the eye. Beyond this point the lateral branch continues as the **ventral carotid artery** to the rudimentary gill of the spiracle, where it anastomoses with the next vessel to be discussed, the hyoidean artery.)

- (131) Just mesial to the middle of the first pretrematic artery there arises the **hyoidean artery**. It passes forward and turns sharply upward, to disappear. The hyoidean artery passes to the spiracle and can be found just posterior to the spiracle by dissecting through from the dorsal surface. In the spiracle it branches to the **pseudobranch** or rudimentary gill within that organ. Here anastomosis occurs with the ventral carotid branch of the internal carotid artery.
- (132) From the second efferent branchial artery near the union of its pre- and post-trematic loop, there arises a small **oesophageal artery**. This passes back, sending off tiny nutrient branches to the second, third, and fourth gills, terminating finally in the dorsal lateral walls of the oesophagus.
- (133) The pair of small arteries extending forward from near the median end of the first efferent branchials are the **vertebral arteries**. They unite with the common carotid artery just posterior to the origin of the external carotid arteries.
- (134) Arising from the dorsal aorta at a point between the union of the third and fourth efferent branchial arteries with that vessel, there arise a pair of **subclavian arteries**. The subclavian supplies the pectoral fin, passing over the dorsal side of the fourth efferent branchial and postcardinal sinus on its way.
- (135) When it reaches the lateral margin of the postcardinal sinus, the subclavian gives off a small **lateral artery**. This vessel sends off a large number of twigs to the body wall.

- (136) After passing the lateral artery, the subclavian gives off a much larger **ventral abdominal artery**. This lies ventral to the lateral line and is easily traced through the length of the coelom. At the posterior end it anastomoses with the arteries of the pelvic fin. It gives off many small branches to the body wall.
- (137) Beyond the origin of the ventral abdominal, the subclavian enters the pectoral fin as the **branchial artery**. Within the fin the branchial artery breaks into a **median pterygial artery** which supplies the median regions of the fin, and the **lateral pterygial artery** to the lateral portions of the fin. Both of these arteries send off a network of fine vessels to muscles of the fin.
- (138) Posterior to the origin of the subclavian, the celiac axis has its origin from the dorsal aorta. It arises posterior to the septum transversum (par. 43).

## SECTION V. THE DORSAL AORTA

It has been seen that at the anterior end of the body the dorsal aorta is formed by a union of four pairs of efferent branchial arteries. Embryologically the dorsal aorta arises as a pair of vessels which fuse into a single structure. Posterior to the fusion of the first efferent branchial arteries, the dorsal aorta is an unpaired, median vessel extending the length of the body dorsal to the coelom and entering the tail as the caudal aorta. The more conspicuous branches of the aorta have already been studied. The following branches should now be identified:

- (139) Throughout its length the dorsal aorta gives off small, paired **segmental arteries** to the right and left. The number varies somewhat, but thirty pairs is approximately the average number. The segmentals are typically three branches:
- (140) The **vertebromuscular artery** arises dorsally from the segmental and passes immediately to the mid-dorsal line of the body, circling the vertebral column. (It gives off lateral branches to the muscles, and a mesial **vertebrospinal artery** to the spinal cord. On reaching the spinal cord after having passed through the neural arch, the vertebrospinal breaks into a dorsal and ventral branch prior to entering the spinal cord.)
- (141) The median lateral branch is the **intercostal artery**. It is a small, fine vessel of considerable

length which passes dorsal to the peritoneum and supplies the muscles of the trunk.

- (142) The ventral branch of the segmental is the **renal artery**. It is a short, prominent vessel which passes directly to the mesonephros. (In the female certain renal arteries just posterior to the origin of the coeliac axis are modified as **oviducal arteries**, which pass to the oviducts, the number varying from one to three pairs. These anastomoses on the oviduct and send branches to the inner layer of the uterus. These are of particular importance in the case of viviparous elasmobranchs like *Acanthias*.)
- (143) Each member of the vertebral arteries gives off two tiny **musculospinal arteries** which pass laterally into the cranium. They are in reality persistent segmentals.
- (144) In the region of the rectal gland a pair of vessels, the **iliac arteries** (par. 42), pass toward the pelvic fin. About two thirds of the way to the fin they anastomose with the ventral abdominal artery. Beyond this point the iliac passes into the fin as the **femoral artery** where it breaks into dorsal and ventral branches to supply the fin.
- (145) The dorsal aorta continues into the tail as the **caudal aorta** (par. 42), where it gives off segmentals to the spinal cord and to the muscles.

We summarize the dorsal aorta as follows:

- 1) Four paired efferent branchial arteries and their branches.
- 2) The unpaired aorta.
  - a) The paired subclavian artery and its branches (par. 134).

- b) The unpaired coeliac axis and its branches (par. 43).
- c) The paired segmental arteries and their branches (par. 134).
- d) The unpaired anterior mesenteric artery and its branches (par. 51).
- e) The unpaired posterior mesenteric artery and its branches (par. 54).
- f) The paired iliac arteries and their branches (par. 144).
- g) The unpaired caudal aorta and its branches (par. 42).

**DRAWING 7.** Paste two sheets of drawing paper together end to end by means of a strip across the back. Assemble all the sketches you have made of the arteries and make a full double page diagrammatic drawing of the entire arterial system exclusive of the ventral aorta and its branches, as seen from the ventral side. Label every vessel identified.

**DRAWING 8.** Do the same for the venous system, including in this drawing the heart and the ventral aorta with its branches.

## SECTION VI. THE ORGANS OF SPECIAL SENSE

### 1. THE EYE

*Carefully dissect away the soft connective tissue surrounding the left eye; do not destroy any nerves or muscles. Sketch the eye muscles for future reference (page 62, drawing 11).*

- (146) The cavity in which the eye lies is the **orbit**. The eye is connected to the orbit by means of six **eye muscles** which attach to the outer coat of the **eyeball** and function in moving the eye. As each muscle is identified, determine its function. These muscles may be divided into an anterior and a posterior group according to the position of the origin of the muscles involved upon the wall of the orbit.

The anterior group consists of two muscles:

- (147) The **superior oblique** extends outward, upward and backward to insert upon the superior (dorsal) surface of the eyeball. The nerve supplying this muscle is conspicuous and is the trochlearis, the fourth cranial nerve (par. 196).
- (148) The **inferior oblique** extends outward, downward and backward to insert upon the ventral surface of the eyeball. The nerve supplying it is a branch of the oculomotor, the third cranial nerve (par. 197).

The posterior group consists of four **recti** muscles

which arise about a cartilaginous stalk, the **optic pedicle**, which supports the eyeball.

- (149) The dorsal muscle of this group is the **superior rectus**, with its insertion very close to that of the superior oblique. The nerve supplying it is a branch of oculomotor (par. 197).
- (150) Opposed to this, and attached to the ventral surface of the eyeball is the **inferior rectus** muscle. The nerve innervating it is a branch of the oculomotor.
- (151) The **anterior (internal) rectus** is the anterior muscle which passes between the inferior and superior oblique. It is supplied by a branch of the oculomotor nerve.
- (152) Opposed to the anterior rectus both in position and in function is the **posterior (external) rectus**. On the ventral surface identify its nerve, the abducens or sixth cranial nerve (par. 198).
- (153) The nerve which crosses the eyeball just ventral to the superior rectus is the ophthalmicus profundus, a portion of the fifth and seventh cranial nerves (par. 201).
- (154) The ophthalmicus superficialis nerve, branches of the fifth and seventh cranial nerves, extends along the lateral wall of the orbit, somewhat dorsal to trochlearis (par. 200).
- (155) The large nerve which enters the eyeball at right angles to it is the **optic** or second cranial nerve (par. 195).

*Free the nerves innervating the eye muscles; cut the muscles and the optic nerve in order to remove the eyeball from the orbit. Leave as much of all the nerves attached*

*to the cranium as possible; their origin will be traced later. Examine the eyeball externally.*

- (156) The outer **sclerotic coat**, or **sclera**, is a strong, protective layer, to which the muscles of the eye are attached. Over the front of the sclera is transparent, a region known as the **cornea**.
- (157) The outer face of the cornea is covered by a very thin **conjunctiva** which, beyond the eye, is deflected from the eyeball to form the smooth inner lining of the eyelids. It is a part of the epidermis, not a coat of the eye.
- (158) Through the cornea can be seen the pigmented **iris**, which gives color to the eye. The central perforation in the iris is the **pupil**, through which the light enters the eye. Note the shape of the pupil.

*Cut the eyeball into an outer two thirds and an inner third.*

- (159) Beneath the sclera, in the inner region of the eyeball, is a layer of connective tissue, the **supra-choroidea**. It does not encircle the eye.
- (160) Beneath this is the black pigmented **choroid coat**. Note that in the front part of the eye it drops like a curtain from its contact with the sclerotic coat, and forms the iris. The inner surface of the choroid coat is lined with a very thin, delicate membrane, the **tapetum**. The radiate folds of the choroid coat about the iris are the **ciliary processes**.
- (161) Lying behind the pupil is the spherical **crystalline lens**. In life it is transparent and elastic. It is attached to the ciliary processes by the **suspensory ligament**.

- (162) The iris thus divides the cavity of the eyeball into two chambers: the **anterior** or **aqueous chamber** and the **posterior** or **vitreous chamber**. The anterior compartment contains a fluid, the **aqueous humor**; the posterior contains a gelatinous mass, the **vitreous humor**.
- (163) The inner lining of the vitreous chamber is the **retina**, a soft, semitransparent nervous layer. Note that the retina does not completely line the chamber. Its irregular termination is the **ora serrata**. The point at which the optic nerve enters the vitreous chamber and spreads out to form the retina is clearly visible. This point is the **blind spot**.

**DRAWING 9.** Make a diagrammatic drawing of a section through the eye on a plane passing through the cornea, the blind spot and the optic nerve. Label all parts identified.

## 2. THE NOSE.

*Make a transverse incision through one nostril, exposing the olfactory organ.*

- (164) The olfactory organ is the **olfactory sac**. Note that it has no opening other than the external naris, or nostril.
- (165) The sac is lined by an **olfactory membrane**, the surface of which is thrown into numerous **Schneiderian folds**. The function of these folds is to increase greatly the amount of olfactory epithelium exposed within so limited a cavity.
- (166) The olfactory nerve spreads out to form the **olfactory bulb** from which small nerves can be seen to enter the organ. Within the sac these

nerves branch to enter the Schneiderian folds. The nerves constitute collectively the olfactory, or first cranial nerve (par. 194).

*At this point turn to the top of the head; locate the endolymphatic pores. Cut a small circular incision through the skin around them, thus isolating the pores. In subsequent dissection do not disturb or destroy this little island (par. 177).*

### 3. THE LATERAL LINE SYSTEM.

The lateral line and its branches form a sensory system found only in the fishes and aquatic amphibia, and hence must be considered as related to an aquatic existence. The system consists of tubes lined with sensory cells, lying deep in the skin and opening by lateral tubules through the epidermis by means of the mucous pores already noted (par. 8). The function is believed to be the perception of water vibrations.

(167) The **lateral line** itself has already been identified on the sides of the trunk, extending from the tip of the tail nearly to the ear. In the cross-section of the tail the **lateral line canal** is seen. Note that near the tip of the caudal fin the canal emerges from the skin and extends along the surface as an open **groove**. (While the innervation of the canal cannot be studied in gross anatomy, it is supplied by small branches of the lateral branch of the vagus (tenth cranial) nerve (par. 210).)

*Trace the lateral line toward the head, dissecting off the skin as you proceed.*

- (168) The canals of the head are known as the **cephalic canals** and are simply cephalic extensions of the lateral line.
- (169) In the region of the spiracle the right and left lateral lines are connected by the **supratemporal (commissural) canal** passing just posterior to the openings of the endolymph ducts.
- (170) A short distance anterior to the spiracle the lateral line gives off one branch, the **infraorbital canal**. This passes ventrad between the eyes and the spiracle. On the ventral surface of the head, just anterior to the angle of the mouth, it gives off the **hyomandibular canal**, a branch which extends to a point just posterior and lateral to the oronasal groove. Beyond the origin of the hyomandibular, the infraorbital passes forward and below the eye and, posterior to the nostril where it is joined by the supraorbital canal, it turns mesiad for a short distance. It then passes mesiad to the nostril, extending to the tip of the snout. (The infraorbital canal is innervated by branches of the buccalis nerve, a branch of the facial (par. 206); the hyomandibular is innervated by the mandibular branch of the trigeminal (par. 203).)
- (171) The canal system continues anteriad beyond the origin of the infraorbital as the **supraorbital canal**. This extends nearly to the tip of the snout, where it turns ventrad and forward, returning under the eye to join the infraorbital canal posterior to the nostril. (It is innervated by branches of ophthalmicus superficialis of the facial nerve).
- (172) A very short **mandibular canal**, unconnected

with any other part of the canal system, is found isolated just posterior to the lower jaw, behind the angles of the mouth. (It is innervated by branches of the mandibular branch of the trigeminal.)

#### 4. THE AMPULLA OF LORENZINI.

The presence of mucous pores over the dorsal and ventral regions of the head has already been noted. These pores can be grouped roughly into two areas:

(173) A **superficial ophthalmic group** on the top of the head, median and anterior to the eyes; and

(174) A **buccal group** on the ventral surface, extending from the mouth to the snout, surrounding the nostrils.

*Remove a piece of skin from the superficial ophthalmic region.*

(175) Beneath the skin each pore opens into a **canal of Lorenzini**, the individual canals varying in length.

(176) Each canal terminates in a small bulb, the **ampulla of Lorenzini**, and the fine nerve fibers attached to each ampulla can be seen. These are branches of the trigeminal.

#### 5. PIT ORGANS

These resemble closely the terminal mucous pores of the ampullæ of Lorenzini, but they differ from them histologically. There are approximately twenty-five of these pores arranged in a crescentic line between the first gill cleft and the mouth, dorsal to the lateral line on each side. They

are innervated by the dorsal ramus of the vagus (tenth cranial) nerve. Little is known of these organs at present.

## 6. THE EAR

*Locate again the openings of the endolymphatic ducts already isolated. Remove the skin from the remaining portion of the head. On the left side of the head remove the muscles from the posterior region of the cranium so as to clear the cartilage. Carefully shave off the cartilage between the spiracle and the mid dorsal line of the head, the cartilage of the otic capsule (par. 239). Do not destroy the small duct leading downward from the endolymphatic pores. The canals of the ear are visible through the cartilage as you approach them; two are in a vertical plane and are seen at once; the third lies horizontally and is more ventral. With great care remove the cartilage surrounding the ear so as to expose it fully. Do not destroy any nerves. Do not remove the ear until you have identified the parts and sketched it in situ. The danger of breaking it in removal is great.*

(177) Follow down the small duct leading ventrally from the endolymphatic pores. This is the **ductus endolymphaticus**. Just beneath the skin the duct makes a sharp bend and returns immediately to a vertical path. The crook thus formed is the **endolymphatic sac**. The duct enters a median sac of the inner ear (par. 181).

(178) The ear of the dogfish is known as the **inner ear** or **membranous labyrinth**. It is an organ of equilibrium entirely, not of sound perception. The labyrinth consists of three canals and a **central sac**:

- (179) The canals are known as the **semicircular canals**. The first of these lies anterior to the endolymphatic duct and is the **anterior vertical (oblique) semicircular canal**. Posterior to the endolymphatic duct lies the **posterior vertical (oblique) semicircular canal**. Both arise from a sac-like **vestibule**, immediately beneath the endolymphatic duct and into a portion of which this duct opens. The third canal lies horizontally at the base of the other two canals, but the posterior region rises to join the vestibule nearly on a level with the dorsal end of the posterior vertical canal. This is the **horizontal semicircular canal**. These canals, like the rest of the ear, are cartilaginous.
- (180) The ventral base of each vertical canal and the anterior end of the horizontal canal are swollen into a bulb-like **ampulla**. The ampullæ of the interior vertical and horizontal canals lie side by side and open into a small projection of the vestibule, the **recessus utriculi**. If the dissection has been done carefully the branches of the auditory nerve (par. 208) will be seen on the ampullæ and base of the vestibule.
- (181) The vestibule is divided into two regions which are not easily distinguished in the specimen. The dorsal (lateral) portion from which the semicircular canals arise, is the **utricle**; the median (ventral) region is the **sacculus**. The canals are joined at each end to the utricle; the endolymphatic duct enters the sacculus. The ventral projection or swelling on the posterior end of the sacculus just anterior to the

ampulla of the posterior vertical canal is the **lagena**.

*Cut open one of the ampullæ.*

- (182) The patches of whitish sensory epithelium on the inner surface are visible under a hand lens. They are the **cristæ acusticæ**.

*Cut open the vestibule.*

- (183) With a pipette withdraw some of the liquid from within the vestibule; examine it in water on a slide under a microscope. The liquid of the inner ear is (in life) **endolymph**; the small granular bodies, more or less crystalline in nature, suspended in the liquid are the **otoliths**.
- (184) The patches of sensory epithelium visible internally are the **maculæ acusticæ**.

DRAWING 10. Make a drawing of the lateral view of the entire ear, the horizontal canal toward you. Label all parts.

## SECTION VII. THE CENTRAL NERVOUS SYSTEM

### 1. THE BRAIN: DORSAL SURFACE

*Carefully shave and pick off the cartilage of the roof of the cranium, taking off very thin slices or small particles at a time. Be extremely careful not to break or cut any of the nerves found extending through the cartilage. Expose only the dorsal surface of the brain at first. Do not remove the brain from the cranium until you are instructed to do so. Read paragraph 185 before you begin to dissect.*

- (185) Identify a very fine thread-like strand of tissue extending from the anterior end of the brain to the skull. This is the **epiphysis**. Free it from its attachment to the cranium.
- (186) Note the two membranes, the **meninges**, which surround the brain and spinal cord. The outer coat is the **dura mater**, a relatively tough coat which lines the cavity in which the organs lie and which adhere closely to the cartilage; the inner coat is the **pia mater (primitive meninx)**, a delicate membrane encircling the nervous system closely. In life the space between the two coats is filled with lymph; the cavity between them is the **arachnoid cavity**.
- (187) The anterior portion of the brain is the **telen-cephalon**. It is composed of the following parts.
- (188) In the anterior region of the brain two narrow stalks, the **olfactory tracts**, leave the main por-

tion of the brain and extend anteriorly, to terminate against the dorsal surface of the nasal sac as the **olfactory bulb** as previously noted (par. 166). Identify again the short nerves extending from the sac to the bulb. The olfactory tract terminates posteriorly in a pair of **olfactory lobes**, the anterior end of the main mass of the brain. The bulbs, tracts and lobes together make up that region of the telencephalon known as the **rhinencephalon**, the olfactory portion of the brain.

- (189) Posterior to the olfactory lobes and separated from them only by an inconspicuous groove, lie the closely approximated **cerebral hemispheres**.
- (190) Posterior to the telencephalon is a small, depressed area, the **diencephalon**. It is from this region that the delicate epiphysis originates (par. 185). The roof of the diencephalon is very thin and easily destroyed; it is a **choroid plexus**.
- (191) Posterior to the diencephalon and extending dorsal to it, lie a pair of very conspicuous, rounded lobes, the **mesencephalon** or **midbrain**. The dorsal region now visible consists of two **optic lobes** or **corpora bigemina**.
- (192) Posterior to the mesencephalon and partially overhanging it, rises the **metencephalon**, or **cerebellum**. If the brain is well preserved, it will be noted that it is divided into quarters by shallow longitudinal and transverse fissures.
- (193) Posterior, finally, to the metencephalon is the triangular **myelencephalon**, or **medulla oblongata**. The apex of the triangle points posteriorly and is continuous with the **spinal cord**. The anterior wings of the medulla lie ventral and lateral to the

posterior half of the cerebellum, and are the **corpora restiformi**, or **posterior peduncles**. Remove the delicate choroid plexus covering the dorsal surface of the medulla. A large triangular opening, the **fossa rhomboidalis**, appears leading into the **fourth ventricle**, the posterior cavity of the brain. The apex of this ventricle is continuous with the cavity of the spinal cord. The remaining cavities of the brain will be discovered later.

## 2. CRANIAL NERVES.

*There are ten pairs of cranial nerves in the dogfish. As you identify each nerve, dissect out its path with great care, removing the cartilage of the cranium as you go along. If other nerves are encountered, note them, but do not destroy them. Make sketches and notes as you proceed. The nerves are here discussed in the order in which they are most readily dissected and identified, which is not their numerical order.*

- (194) The first or **olfactory nerve**. This nerve has already been identified (par. 166) as a series of fibers extending from the olfactory sac to the olfactory bulb of the telencephalon. It is a **sensory** nerve.
- (195) The second or **optic nerve** emerges from the eyeball, where it is formed from the retina (par. 163), as a short stalk beneath the internus rectus muscle, and passes to the ventral surface of the diencephalon. It is sensory in nature.
- (196) The fourth or **trochlear nerve** arises in the mesencephalon, emerging from the dorsal surface between the optic lobes and the cerebellum. It is a

very delicate nerve and is easily destroyed. Trace it to the superior oblique muscle of the eye, which it innervates. It is a **motor** nerve.

- (197) The third or **oculomotor** nerve arises from the ventral surface of the mesencephalon and supplies the following muscles of the eye: After entering the orbit it branches to the internal and superior recti muscles; a third branch passes below the eyeball, giving off a branch to the inferior rectus muscle, then turns sharply forward and passes on to the inferior oblique muscle. It is a motor nerve.
- (198) The sixth or **abducens** nerve arises from the floor of the anterior end of the medulla and passes to the ventral surface of the external rectus muscle of the eye. It is a motor nerve.
- (199) The fifth or **trigeminus** nerve arises from the anterior region of the medulla, where its roots cannot be separated from those of the seventh and eighth cranial nerves. Trace it in its anterior lateral path into the orbit, where it divides at once into four branches:
- (200) The **ophthalmicus superficialis** extends anteriorly in a dorsal position in the median wall of the orbit. It is a large nerve, passing through the ophthalmic foramen of the cranium on its way to the bulbs of the ampullæ of Lorenzini (par. 176). It is a sensory nerve.
- (201) The **ophthalmicus profundus** extends anteriorly in a ventral position, passing through the orbitonasal canal to join with the ophthalmicus superficialis in the region dorsal to the olfactory bulb. (A short distance anterior to its origin, the profundus gives off a thread-like **posterior ciliary nerve** to the posterior surface of the eye-

ball, and anterior to this a second slender nerve, the **anterior ciliary** to the anterior surface of the eyeball.)

- (202) The **infraorbital** nerve is an inseparable mixture of the **maxillary** branch of trigeminus and the buccal branch of the seventh cranial nerve (par. 206). It is a broad, flat nerve, lying in the floor of the orbit. Trace it forward and note that it terminates anteriorly in three branches. (The lateral branch passes to the skin anterior and lateral to the eye. The larger median branches pass downward to the skin of the ventral surface of the snout.) The fibers belonging to the maxillary branch innervate the skin; those that belong to the buccal nerve pass to the organs of the lateral line canal.
- (203) The **mandibular nerve** arises ventrally to the infraorbital. It passes ventrally to supply the muscles of the gills and to the skin of the lower jaw.
- (204) The seventh or **facial nerve** arises from the medulla, its roots being inseparable from those of five and eight. It divides into three branches:
- (205) The **ophthalmicus superficialis** nerve extends forward along with the branch of the same name belonging to the trigeminus nerve, from which it is inseparable. It goes to the supra-orbital branch of the lateral line canal (par. 171). It is a sensory nerve.
- (206) The **buccal nerve** has already been described as an integral part of the infraorbital nerve (par. 170). Its fibers pass to the infraorbital lateral line canal. A sensory nerve.

- (207) The **hyomandibular** nerve is a deep ventral posterior branch, the most median branch of the facial. Near the brain it bears a swelling, the **geniculate ganglion**. At this point the **palatine** branch is given off ventrally to the membrane of the mouth. (Small branches come off the palatine to the spiracle.) Follow the main trunk of the hyomandibular beyond the ganglion, where it will be found to break into several small branches. The hyomandibular supplies the mandibular and hyomandibular lateral line canals, skin organs, muscles of the hyoid arch, the tongue and floor of the mouth. It is a **mixed** nerve, having both sensory and motor fibers.
- (208) The eighth or **auditory nerve** arises along with five and seven from the anterior end of the medulla. Trace it toward the ear. The connections with the ear have already been noted (par. 180). It is a sensory nerve.
- (209) The ninth or **glossopharyngeal nerve** passes through the floor of the otic capsule, arising as a single strong nerve from the medulla just posterior to the eighth nerve. The enlargement is the **petrosal ganglion**, located near the upper margin of the second gill cleft. It breaks into a post- and pretrematic branch, circling the cleft. The pretrematic branch is sensory; the post-trematic is motor.
- (210) The tenth or **vagus (pneumogastric) nerve** arises by two distinct roots near the posterior limits of the medulla. The posterior root is small; the anterior root is flat and extends forward to the origin of the glossopharyngeal nerve. The **vagus**

## THE SPINY DOGFISH

is a very widely distributed nerve, and gives off the following branches:

- (211) The **supratemporalis**. (A very minute nerve extending dorsally through the posterior region of the otic capsule. It innervates the anterior region of the lateral line and pit organs. It is usually difficult to locate.)
- (212) The first conspicuous branch to arise from the vagus is the **first branchial** nerve. Its origin is more or less ventral and about half an inch posterior to the origin of the vagus nerve, and just posterior to the **vagus ganglion**. It is easily traced to the third (second true) gill cleft where it divides into pre- and post-trematics in the anterior and posterior septa respectively.
- (213) Just posterior to the origin of the first branchial on the median ventral surface of the vagus, there arises a large **ramus lateralis** or lateral line branch, which passes parallel to the vertebral column deep in the trunk muscles. It extends practically the length of the body, supplying the organs of the lateral line canal.
- (214) Posterior to the origin of the lateral line branch arise three more branchial nerves, which pass to the fourth, fifth and sixth gill clefts. Each breaks into a pre- and post-trematic branch.
- (215) Beyond the origin of the fourth branchial, the vagus extends unbranched for a short distance as the **ramus visceralis**, then breaks into a large number of branches in the region of the pectoral girdle. These branches pass to the heart, œsophagus, stomach (par. 24) and other visceral organs.

The next two nerves are in reality spinal nerves, but should be identified at this time as they will be destroyed shortly.

(216) The **occipital nerves** arise from the ventral surface of the medulla just posterior to the origin of the vagus. Normally there are two, but occasionally three are found. They pass directly into the muscles.

(217) The **hypobranchial nerve** arises posterior to the occipitals. It involves the fusion of two spinal nerves which join to form a plexus. It crosses the ramus visceralis of the vagus posterior to the last gill cleft and innervates the muscles along the floor of the mouth.

DRAWING 11. Make an eight inch drawing of the dorsal aspect of the brain. On the left side draw a dorsal view of the eye and its muscles and add cranial nerves 1, 2, 3, 4, 5, 6; add the remaining cranial nerves on the right side.

### 3. BRAIN: VENTRAL SURFACE.

*Carefully cut all cranial nerves as far from the brain as practicable. Dissect away the cartilage from below the brain; cut the spinal cord posterior to the medulla and remove the brain. If it sticks, do not pull it; a portion of the ventral surface of the mesencephalon is imbedded in a cartilaginous depression in the floor of the cranium and should be carefully dissected out.*

(218) The optic nerves cross as they enter the brain, forming the **optic chiasma** on the ventral surface of the diencephalon. The broad band extending dorsad and backward from the sides of the chiasma along the diencephalon is the **optic tract** leading to the optic lobes.

- (219) Posterior to the chiasma, the ventral wall of the diencephalon projects as the **infundibulum**, with two lateral lobes, the **lobi inferiores**.
- (220) From between the lobi there extends posteriad a median stalk, which expands posteriad to the lobi into a thin-walled sac. The median, ventral, posterior lobe is the **hypophysis** or **pituitary body**; the sac is the **saccus vasculosus**.
- (221) The ventral surface of the mesencephalon, dorsal to the saccus and lateral to the infundibulum, is in the form of two bands, separated by a shallow groove. The bands are the **crura cerebri**. To the rear, beneath the medulla, these crura become the **anterior pyramids**. The groove separating them continues along the ventral surface of the spinal cord as the **ventral fissure**.

#### 4. THE BRAIN: CIRCULATION.

The internal carotid artery was last seen to enter the cranium and to divide immediately into two branches (par. 130). These pass forward to reach the brain on its ventral surface just posterior to the optic chiasma, one on each side of the brain. At once each carotid divides into an anterior and a posterior branch.

- (222) The anterior branch is the **middle cerebral artery**. It extends forward along the ventral lateral surface of the cerebral hemispheres and the olfactory tract to the olfactory bulb. Immediately beneath the optic nerve, a small branch, the **inner cerebral artery**, arises and passes ventral and anterior, to anastomose between the cerebral hemispheres with the corresponding vessel from the opposite side.

- (223) The posterior branch is the **posterior communicating artery**. It passes posteriad, to unite with that vessel from the opposite side just dorsal to the saccus vasculosus. The single posterior continuation is the **basilar artery**, lying below the myelencephalon. The ring thus formed by the uniting of the inner cerebrals in front and the posterior communicating arteries behind, is the **circle of Willis**. All of these arteries send off small branches to the various regions of the brain.

DRAWING 12. Make a drawing of the ventral aspect of the brain; add to this the arteries as identified. Label all parts.

## 5. THE CAVITIES OF THE BRAIN.

*With a sharp knife or a razor blade make a median longitudinal section through the brain. This reveals the fact that the brain is hollow, and the cavities are to be explored. They can best be seen under water.*

- (224) The posterior cavity, the **fourth ventricle (myelocœle)**, of the medulla has already been seen (par. 193).
- (225) The narrow passage leading forward from the fourth ventricle is the **aqueduct or iter (mesocœle)**, the cavity of the mesencephalon. It has a dorsal connection with the **cerebellar ventricle**, the cavity of the cerebellum, and lateral connections with the **optic ventricles (epicœle)** of the optic lobes.
- (226) The anterior termination of the aqueduct is in the **third ventricle (diacœle)** the cavity of the dien-cephalon. The roof of this ventricle is the choroid plexus. A dorsal, finger-like projection of the

roof just anterior to this plexus is the **paraphysis**, in reality a portion of the telencephalon. Posterior to the base of the paraphysis the anterior passage from the third ventricle is nearly blocked by the **velum transversum**, a deep fold in the roof of the diencephalon anterior to the plexus. (The small thickening in the roof just posterior to the plexus is the **habenula**. Rising above this from its posterior margin is the **pineal body**.) A continuation of the third ventricle extends into the infundibulum on the floor of the diencephalon. The roof of the third ventricle is termed the **epithalmus**; the sides the **thalmi**; the floor the **hypothalmus**. These are regions, not structures.

- (227) A short passage, the **foramen of Monro (inter-ventricular foramen)** connects the third ventricle with the cavities of the telencephalon.

*Dissect the telencephalon to locate its cavities, which are lateral to the incision already made; they are paired.*

- (228) The cavities of the telencephalon are the **lateral ventricles (telocœles)**; they extend forward through the olfactory tracts to the olfactory bulbs.

DRAWING 13. Make a drawing to show a longitudinal section through the brain, showing the cavities and structures identified.

## 6. SPINAL NERVES.

*With great care shave the cartilage from the spinal cord just posterior to the medulla.*

(The most anterior spinal nerves, the occipitals and hypobranchials, have already been seen (par. 216, 217.) )

- (229) On the dorsal lateral surface of the spinal cord locate the very small enlargements, the **dorsal (spinal) ganglia**. The extremely delicate attachments, dorsal and ventral, constitute the **sensory** and **motor roots** respectively of the spinal nerves. (A demonstration of these roots is quite difficult in gross dissection.)

*Turn the dogfish ventral side up and examine the roof of the cœlom.*

- (230) Note the white cords emerging laterally and segmentally from the vertebral column. These are the **ventral rami** of the spinal nerves. They pass at once deep into the muscles of the trunk, following the myosepta (par. 288). However, they reappear again shortly and are easily seen through the peritoneum along the walls of the cœlom.
- (231) In the region of the pectoral and pelvic girdles these ventral rami pass into the paired fins to innervate the muscles. In the pectoral region these rami are interlocked to form the **lumbosacral plexus**; in the pelvic region they form the **cervico-brachial plexus**. Ten nerves are involved in the former; eleven in the latter.

## SECTION VIII. THE ENDOSKELETON

The endoskeleton of *Squalus acanthias* is entirely cartilaginous. Like the skeleton of the higher vertebrates, that of *Acanthias* may be divided into axial, visceral and appendicular regions, but it differs from the higher vertebrates in that the notochord is never entirely replaced.

### 1. THE NEUROCRANIUM.

Note that the skull lacks the individual cranial elements of the bony skull; there are no sutures present. Because of its cartilaginous nature it is known as a **chondrocranium**. The chondrocranium is composed of two regions, (a) the **neurocranium**, which protects the brain and sense organs; and (b) the **splanchnocranium** or **visceral skeleton** which forms the skeleton of the mouth and the gill arches. These will be discussed separately.

- (232) The neurocranium consists of a **median brain case** and three pairs of lateral **capsules** which contain the cephalic sense organs, the eye, ear and nose.

*On the dorsal surface of the neurocranium identify the following features:*

- (233) The anterior end of the neurocranium is the **rostrum**, the skeleton of the snout. It is oval in shape and is in the form of a trough, open dorsally. This opening is
- (234) the **anterior fontanelle**. The posterior wall of

- the fontanelle is the anterior wall of the brain case.
- (235) On each side and projecting laterad and posteriad from the tip of the snout extends a **rostral bar**. This bar terminates posteriorly on
- (236) the **nasal (olfactory) capsule**, which is fused to the brain case and houses the nasal sac (par. 164). Internally, an aperture on the posterior wall permits the entrance of the olfactory nerve (par. 194) from the brain to the nasal organ. The four small apertures in the roof of the capsule are the foramina of the ophthalmicus superficialis nerve (par. 200). The **rostral notch** separates the capsule from the rostrum.
- (237) Posterior to the capsule and forming the roof of the **orbit** in which reposes the eyeball, is the overhanging shelf-like **supraorbital crest**, terminating posteriad in the **postorbital process**. Seen from above, the orbit is nearly semicircular in outline. In the anterior portion the supraorbital crest is pierced by two foramina. The median is a foramen of the ophthalmicus profundus nerve, the lateral a foramen of the ophthalmicus superficialis (par. 200). Along the mesial border of the supraorbital crest is a line of foramina (nine are usually distinguishable) of ophthalmicus superficialis.
- (238) The **brain case** lies between the orbits, the roof being the **tegmen cranii**. On the median line near the anterior end is the **epiphyseal foramen**, through which extends the pineal body or epiphysis (par. 185) of the brain. The shallow longitudinal depression which separates the brain case from the supraorbital crest is the **sulcus**

## THE SPINY DOGFISH

**longitudinalis.** It is continued posteriad over the

(239) **auditory (otic) capsule.** This is the mass of cartilage lying posterior to the postorbital process, forming the posterior region of the neurocranium. It contains the inner ear or membranous labyrinth (par. 178). A large, ovoid, median depression, the **endolymphatic fossa**, occurs between the left and right capsules, in which occur two foramina. The very small anterior pair are the openings of the endolymphatic ducts (par. 13); the somewhat larger posterior pair are the apertures of the perilymph ducts. A small, inconspicuous projection, the **postotic process**, appears as a lateral ridge along the posterior lateral margin of the neurocranium.

(240) This posterior region of the cranium is marked by three ridges radiating from the posterior margin of the endolymphatic fossa. The mesial is the **crista occipitalis**, the covering of the anterior semicircular canal; the two lateral ridges protect and house the posterior semicircular canals. The posterior lateral wings of the neurocranium bear the **fenestra postotica**, each of which has a bar of cartilage as its posterior lateral margin.

*On the posterior face of the neurocranium identify the following, most of which structures can be seen less well from the dorsal aspect.*

(241) Immediately dorsal to the fenestra postotica is a large foramen of the glossopharyngeal nerve

(par. 209); mesial to this are two foramina of the vagus nerve (par. 210).

- (242) The large aperture on the median line is the **foramen magnum** through which the spinal cord passes to the brain.
- (243) Below the foramen magnum is the circular, cup-shaped disc, the posterior end of the **cranial notochord**, the articulation between the neurocranium and the vertebral column.
- (244) The lateral wings on either side of the articulation are the **occipital condyles**.

DRAWING 14. Make a drawing five inches long to show the dorsal aspect of the neurocranium.

*On the lateral face of the neurocranium identify the following structures:*

- (245) The rostral bar breaks posteriorly into two branches, the **dorsal** and **ventral rostral ramus**.
- (246) The ventral margin of the nasal capsule bears the **external nares** or nostrils.
- (247) Arising behind and dorsal to the nasal capsule is the **antorbital (preorbital) process**, which forms the anterior margin of the orbit.
- (248) Within the orbit appear numerous foramina. The anterior of these is the minute **ethmoid canal**. Just dorsal to this lies a foramen of ophthalmicus superficialis. Along the dorsal mesial wall is a series of small foramina also of ophthalmicus superficialis. Slightly below the middle of this series lies the **trochlear foramen** of the fourth cranial nerve (par. 196). Immediately below this and near the ventral margin of the orbit is the large **optic foramen** through which the second cranial nerve passes (par. 195).

- (249) At the posterior margin of the orbit, below the mesial line, is a group of apertures. The largest of these, lying under the postorbital process, is the **trigemino-facial foramen** through which pass branches of the fifth and seventh cranial nerves (par. 200). Below this is the **abducens foramen** of the sixth cranial nerve (par. 198), and ventral to this is the opening of the **transbasal canal**. A minute blood vessel passes through a tiny foramen just anterior to the opening of the transbasal canal, and the **oculomotor foramen** lies anterior and slightly above the foramen of trigemino-facial. The foramen near the middle of the mesial wall of the orbit is the opening through which passes the external carotid artery.
- (250) The posterior ventral margin of the orbit is marked by the **basal angle**, which in lateral view appears as a ventral projection.
- (251) The auditory capsule, posterior to the postorbital process, shows a series of foramina under the supraotic crest; these are for branches of ophthalmicus superficialis.
- (252) Extending horizontally and turning somewhat ventrally in its posterior region, is the swelling of the **horizontal canal** of the membranous labyrinth, terminating at the anterior lateral angle of the fenestra postotica. Extending dorsally from this angle is the **postotic process** which fuses dorsally with the supraotic crest.
- (253) The ventral margin of the auditory capsule shows two **hyomandibular foramina** through which pass the hyomandibular branches of the seventh cranial nerve (par. 207).

DRAWING 15. Make a drawing five inches long to show the lateral aspect of the neurocranium.

*On the ventral face of the neurocranium identify the following features:*

- (254) The **rostral carina** appears as a median crest or keel.
- (255) Lateral to the posterior end of the keel is a pair of **rostral fenestræ** which pass to the brain box.
- (256) The mesial ventral margin of the orbit bears the optic foramen and the previously mentioned ophthalmicus superficialis foramina are also seen.
- (257) The ventral face of the brain case is narrow, the narrowest portion being the **palatobasal articular surface**, to which a process of the lower jaw articulates (par. 265). The basal angle is just posterior to this.
- (258) On the median line, posterior to the basal angle, is the minute opening of the **carotid canal** through which passes the internal carotid artery.
- (259) Laterad to this aperture is a pair of **facial foramina** of the seventh cranial nerve.
- (260) The ventral face of the otic capsule is the **basal plate**, which forms the flat roof of the mouth.
- (261) Extending posteriad from the carotid canal down the midventral line of the basal plate is a line of cartilage slightly different in appearance from the rest of the neurocranium. This is the cephalic notochord.

## 2. THE SPLANCHNOCRANIUM.

- (262) The **splanchnocranium** consists of a series of seven paired cartilaginous arches. Of these the first

two pairs are most modified, the first pair, in close functional relationship with the neurocranium, being the **jaws**; the last five pairs, the **branchial** or **gill arches**, function as support for the respiratory apparatus.

- (263) The first (anterior) visceral arch is the **mandibular arch**. It is the largest of the arches and shows the greatest modification. It is divided into two portions, a **dorsal** and a **ventral segment**. Of these the former is the upper jaw, the latter the lower jaw, and each is bilateral.
- (264) The **upper jaw** consists of a pair of **pterygoquadrate (palatopterygoquadrate)** cartilages bound together by a median ligament. This cartilage bears the upper set of teeth. The **palatine (palatobasal) process** is a recurved dorsal outgrowth of the cartilage which makes contact with the palatobasal articular surface of the brain case (par. 257). The **labial cartilages** are attached to the corner of the arch and are two pairs. Approaching the angle of the mouth, the palatoquadrate expands into a concaved **quadrate** region, which bears a dorsal **adductor mandibularis process** on which is attached the muscle of that name. Note the **alveolar groove** in which are located both the functional and reserve teeth. The **ethmopalatic ligament** binds the anterior portion of the upper jaw to the neurocranium just anterior to the orbit. Posteriorly the cartilage articulates with
- (265) the **lower jaw** or **Meckel's cartilage**. This bears a similar **alveolar groove** for the teeth. Note that the border of the groove continues

backward into the **coronoid process**. Immediately behind this and on the dorsal surface of the cartilage, is the concave **facet** for the articulation with the palatoquadrate. Posteriorly the coronoid process articulates with the hyomandibular cartilage of the second visceral arch (par. 268).

- (266) Note the position of the spiracle between Meckel's cartilage and the second visceral arch. It is supported by two **spiracular cartilages** on the anterior wall.
- (267) The second visceral arch is the **hyoid arch**. Like the first, it is divided into a dorsal and a ventral region.
- (268) The dorsal, **hyomandibular**, portion is short and thick. It articulates dorsally with the posterolateral neurocranium near the horizontal semicircular canal. Ventrally it articulates by means of a ligament to Meckel's cartilage and thus becomes the **suspensorium** of the jaws. It bears on its posterior margin a number of cartilaginous **gill rakers** which support the gills. Ventrally the hyomandibular articulates with
- (269) the ventral, **ceratohyal cartilage**. This is in the form of a curved bar, bearing gill rakers on the posterior surface. Its mesial articulation is with
- (270) the **basihyal cartilage**, which is unpaired. Note the relative sizes of these parts.
- (271) The **branchial arches**. These are the splanchnocranial arches three, four, five, six and seven. They are all very similar in their composition, each having a right and left side consisting of

four cartilages arranged in an arc which is open dorsally.

- (272) The most dorsal of these four cartilages is the **pharyngobranchial**. This lies in the roof of the pharynx and extends backward. In the first three arches it is free distally, while the pharyngobranchial of the fourth arch is fused to that of the fifth. Note the longitudinal groove in the second, third and fourth in which blood vessels pass to the gill filaments.
- (273) Ventral to the pharyngobranchial lies the short **epibranchial cartilage**. It is a flattened bar, widened at its ends for the articulation dorsally with the pharyngobranchial and ventrally with the ceratobranchial (par. 274) cartilages. Note the dorsal **groove**. The first, second, third and fourth epibranchials bear gill rakers on the posterior edge.
- (274) The **ceratobranchial** cartilage is much longer than the epibranchial and the first, second, third and fourth bear posterior gill rakers. Mesiad, each ceratobranchial articulates with the one anterior to it, the first articulating with the ceratohyoid of the hyoid arch.
- (275) The median articulations of the ceratohyoids, besides their interceratobranchial articulations, differ somewhat. The first articulates with a backward curving **hypobranchial cartilage**. The right and left hypobranchials unite at their mesial ends with the **first basibranchial**, an unpaired, median plate. The second hypobranchials are similar to the first, but articulate medially with the mesial anterior end of the **second basibranchial car-**

**tilage**, the first basibranchial entering the anterior mesial angle formed by the joining of the second basibranchials. The third hypobranchials articulate laterally with both the third and fourth ceratobranchials, and join the second basibranchial just lateral to the articulation of the second hypobranchials. The fifth ceratobranchial articulates directly with the second basibranchial without any hypobranchial interposed, touching the lateral angle of the widest portion of that triangular plate. Note the expansion of this ceratobranchial.

- (276) Lying without and beneath the second, third, fourth and fifth branchial arches are three pairs of slender, curving rods, the **extrabranchial cartilages**, usually absent in prepared skeletons (par. 120).

**DRAWING 16.** Make a six inch drawing of the ventral aspect of the splanchnocranium.

### 3. THE VERTEBRAL COLUMN.

The **vertebral (spinal) column** of *Acanthias* is, like the chondrocranium, a cartilaginous structure. Its anterior end is in contact with the posterior face of the neurocranium, while its posterior end terminates in the tip of the dorsal lobe of the tail. It is a segmental, axial structure, surrounding and containing within it the unsegmented notochord which, in elasmobranch fishes, is persistent. The unit of the vertebral column is the **vertebra**. These units show modifications in different regions of the body, and on the basis of these modifications the vertebral column may be divided into abdominal and caudal regions.

- (277) The **abdominal vertebræ** extend from the cranial articulation to the region of the pelvic girdle, and are characterized by the absence of a ventral arch.
- (278) The large, massive ventral cylinder, the **centrum** or body of the vertebra, is hour-glass shaped, both ends being deeply concave. Such a centrum is **amphicælus**. Note the minute **canal** piercing the middle of the centrum. Through this canal extends the **notochord**, constricted as it passes through the centrum and swelling out to fill the diamond-shaped spaces between opposed faces of the concaved centra. The notochord is, therefore, **moniliform**, resembling a string of beads. A cross-section through the centrum shows it to be composed of eight radiating longitudinal plates. The ventrolateral edge of the centrum bears a pair of plate-like projections, the **transverse processes**, each bearing distally a slender **rib**.
- (279) The dorsal arch is the **neural arch**, rising above the centrum. This is composed of two broad **neural (basidorsal) plates**, extending dorsally from the centrum to unite above it. The dorsal mesial projection at their point of union is the **neural spine**. An **interspinous ligament** connects succeeding spines. Between the neural plates of succeeding vertebræ is a pair (right and left) of **intercalary plates**, uniting above the articulations of the central. The neural and intercalary plates together make up the roof and sides of the **neural canal** through which passes the spinal cord. Identify the small foramen on the ventral portion of the neural plate, and another on the middle portion of the inter-

calary plate. Through the former passes the ventral root of the spinal nerve; through the latter the dorsal root (par. 229).

(280) The **caudal vertebræ** occupy the region posterior to the cœlom. They are similar to the abdominal vertebræ in the possession of a centrum and a neural arch, except that the transverse processes of the centrum are lacking. They possess in addition:

(281) The **hæmal arch** on the ventral side of the centrum. This arch is composed of right and left **hæmal (basiventral) plates**, which unite below to form the **hæmal canal** through which pass the caudal artery and caudal vein. Note that in the caudal region the foramina of the spinal nerves occur only in alternate neural and intercalary plates instead of in each plate.

#### 4. THE GIRDLES AND PAIRED APPENDAGES.

Girdles are adaptations among vertebrates for the articulation of paired appendages. Since the stress of these appendages is lateral to the mid line and therefore to the axial skeleton, direct articulation of the appendages to the vertebral column is not possible.

(282) The anterior or **pectoral girdle** is a curved, U-shaped cartilage, which very nearly encircles the anterior portion of the trunk just posterior to the splanchnocranium. The mid-ventral portion, below the base of the attached fins, is the **coracoid**, bearing a posterior **coracoid process**. The region dorsal to the fin articulation is the **scapular process**, which terminates distally in small **supra-scapular cartilages**.

- (283) The base of the **pectoral fin** is composed of three **basal cartilages (basalia)**, consisting of an anterior (outer) **propterygium**, a mesial **mesopterygium**, and a posterior (inner) **metapterygium**, the latter being the largest. The basalia articulate with the pectoral girdle. Distal to these are three rows of **radial cartilages (radialia)**. The basalia and radialia together compose the **cartilaginous fin rays**. The distal portion of the fin is supported by a double series of **dermal fin rays (actinotrichia)**, one row beneath the skin on each face of the fin. They are in reality a party of the exoskeleton, arising as they do from the dermis.
- (284) The posterior or **pelvic girdle** is a slightly curved transverse bar across the ventral portion of the body only, this bar being the **ischiopubis**. The distal ends of the bar bear the **iliac processes** as slight outward projections. Identify the **obturator foramen** just mesial to the iliacs.
- (285) The **pelvic fins** articulate to the girdle at the base of the iliac processes. The cartilaginous fin rays consist of two basalia and a series of radialia. The anterior basale, the propterygium, projects laterad from the girdle and bears many radialia. In the case of the male, note that the posterior radial is enlarged, extending into the clasper (par. 4). As compared with the pectoral girdle, the dermal fin rays, distal to the radialia, are short.

##### 5. UNPAIRED APPENDAGES.

Located on the axis of the body, the stress of their activities falls on the vertebral column and no girdle supports them.

- (286) The skeleton of the first dorsal fin is composed of three rows of cartilages; the proximal row consists of a single long, flat plate and two (sometimes three) smaller posterior plates. These plates are attached to the vertebral column by a medial longitudinal **myoseptum**. The middle row is composed of several plates of equal size; the distal row of a series of minute plates. The dermal fin rays extend distal to these. The dorsal spine is dermal in origin (par. 17), and belongs to the exoskeleton.
- (287) The caudal fin. Note that the cartilaginous skeleton of the tail is confined to a single series of rods dorsal to the vertebral column. The dermal fin rays are the major support of the tail fin.

## SECTION IX. THE MUSCULAR SYSTEM.

### 1. MUSCULATURE OF THE TRUNK.

*Remove a band of skin three inches wide from around the posterior region of the body.*

(288) The muscular portion of the body is made up of a series of **parietal muscles**. These are arranged in a series of zigzag muscle plates, the **myotomes (myomeres)** which are separated from each other by a sheet of non-muscular tissue, the **myosepta (myocoma)**.

(289) Note the **linea alba**, the white line extending along the mid lateral line of the myomeres. This is a lateral septum which coincides with the lateral line, and divides the myomeres into two regions. The muscles dorsal to the linea alba are the **epaxial** muscles; those ventral to the line constitute the **hypaxial** muscles. The differentiation into epaxial and hypaxial muscles is best observed in a cross-section through the tail.

### 2. MUSCULATURE OF THE PELVIC FINS.

*Remove the skin from the base of one of the pelvic fins.*

(290) The dorsal muscle, the **abductor**, has its origin on the fascia of the trunk muscles; its insertion is upon the fascia of the levatores (par. 291).

- (291) The **levatores** are bundles of fibers, each constituting a small muscle. Each is attached to a cartilaginous fin ray, with its origin on the basal cartilage and its insertion near the tip of the ray.
- (292) The ventral muscle, the **abductor**, has its origin along the posterior lateral edge of the pelvic girdle; the insertion is upon the anterior mesial surface of the basal cartilage.
- (293) The **depressor** muscle consists of a series of small bundles corresponding to the levatores, a bundle for each ray. The origin is on the posterior lateral surface of the basal cartilage; the insertion is near the tip of the fin rays.

### 3. MUSCULATURE OF THE PECTORAL FINS.

*Remove the skin from the base of one of the pectoral fins.*

- (294) The dorsal muscle of this fin, the **levator-retractor**, arises on the scapular process (par. 282); the insertion is upon the dorsal surface of the cartilaginous fin rays.
- (295) The ventral muscle, the **depressor-protractor**, has its origin on the coracoid cartilage (par. 282); the insertion is upon the ventral surface of the cartilaginous fin rays.

### 4. MUSCULATURE OF THE HEAD AND VISCERAL REGION.

*Remove the skin from the dorsal and ventral surface of the head and visceral region. In so doing be careful that the muscles do not come off with the skin. Confine your dissection to one side, using the opposite side to check up*

*any points not fully determined in the first dissection. Make a series of sketches showing the distribution of the muscles as they are identified and before their removal.*

*On the dorsal surface of the head identify the following muscles:*

(296) The muscles which form the covering of the dorsal surface of the splanchnocranial region constitute the dorsal superficial constrictor group, consisting of six muscles.

(297) The **first constrictor superioris dorsalis** is a small muscle that is easily overlooked, having its origin on the lateral face of the neurocranium ventral to the posterior end of the postorbital process. The fibers extend forward and curve anterior to the spiracle to insert below the coronoid process of Meckel's cartilage (par. 265).

(298) The **second constrictor superioris dorsalis** is the largest of the group. It is a sheet of fibers covering the surface between the first gill cleft and the posterior margin of the spiracle. The anterior fibers have their origin on the posterior lateral surface of the otic capsule; the posterior fibers arise from a heavy fascia which covers the dorsal muscles. The insertion is diffuse. The anterior fibers pass to the quadrate of the upper jaw; the median fibers extend to the ceratohyal cartilage; the posterior fibers pass to and around the tendinous mass upon which fibers of the second ventral constrictor insert, between the hyoid arch and the first gill slit. Those fibers which pass around it unite with the fibers of the second ventral constrictor.

(299) The **third, fourth, fifth and sixth constrictores**

**superiores dorsales** are similar. The dorsal fibers are attached by a tendon which pierces a mass of muscle (trapezius, par. 301), arising among the dorsal longitudinal muscles of the posterior cranial region. The ventral fibers arise from the aponeurosis posterior to the muscle. The insertion is on the anterior aponeurosis, with some fibers passing across to unite with fibers from the corresponding ventral constrictor.

(300) The **levator maxillæ superioris** is a small muscle difficult to distinguish from the first dorsal constrictor. It is somewhat larger than the latter. Its fibers arise in common with those of the constrictor but they extend straight to the dorsal margin of the palatal process of the upper jaw, instead of curving around the spiracle.

(301) The **trapezius** is a muscle which finds its origin in the fascia of the dorsal longitudinal muscle mass of the posterior cranial region. The fibers extend backward and downward, to have their insertion on the anterior edge of the pectoral girdle. A few anterior fibers pass to the last gill arch. The function of the muscle is to raise and draw forward the pectoral girdle.

*On the ventral surface of the head identify the following muscles:*

(302) The muscles which form the covering of the ventral surface of the splanchnocranium constitute the ventral superficial constrictor group, consisting of six muscles.

(303) The **first constrictor superioris ventralis** is the most ventral of the group. It arises from a median aponeurosis. The fibers extend obliquely

forward to have their insertion upon Meckel's cartilage. A few of the posterior fibers insert upon another muscle (adductor mandibularis par. 307) posterior to the angle of the mouth. The median aponeurosis extends forward about three quarters the length of the muscle.

(304) The **second constrictor superioris ventralis** is a sheet muscle lying immediately dorsal to the first ventral constrictor. It arises at the same source as the first, but dorsal to it. It does not extend as far forward as does the first, the insertion of the anterior portion of the muscle being on the ventral edge of the ceratohyoid. The posterior fibers arise in the aponeurosis between the second and third ventral constrictors and insert upon a mass of tendon between the hyoid arch and the first gill slit. The most posterior fibers of this group pass posterior to this mass to unite with the posterior fibers of the second dorsal constrictor (par. 298).

(305) The **third, fourth, fifth and sixth constrictores superiores ventrales** are, like the corresponding dorsal constrictors, similar. Each arises in the aponeurosis between it and the preceding ventral constrictor, to insert in an anterior aponeurosis or to continue, in the case of the median fibers, over the gill slit to join its fellow from the dorsal side.

The combined function of the ventral constrictors is (1) to close the gill slits; (2) to compress the pharynx; and (3) by so doing to eject water taken into the pharynx through the spiracle, thereby aiding in the process of respiration, as the respiratory processes require a constant flow of water.

- (306) The **coraco-arcuales communes** should be noted at this time. This is a pair of muscles having their origin on the coracoid surface of the pectoral girdle. The pass forward to disappear under the first and second ventral constrictor. They will be traced later.

*On the lateral surface of the head identify the following muscles:*

- (307) Anterior to the second dorsal constrictor and lateral to the first lies the **adductor mandibularis**. It is visible from both dorsal and ventral surfaces. It is covered by a heavy fascia and has its origin on the quadrate of the upper jaw. The fibers insert upon Meckel's cartilage, extending across the full width of the lower jaw. The muscle closes the mouth.
- (308) The **interbranchiales** constitute a series of thin sheet muscles lying between the demibranchs of each of the four complete gills, anterior to the cartilaginous rays of each. The origin of the dorsal fibers is the aponeurosis of the dorsal constrictors, while some fibers arise from the fascia extending between the dorsal longitudinal muscles and the extrabranhial cartilages. Ventral fibers have their origin on the extrabranhials. The insertion is upon the epibranchial cartilages.
- (309) The deepest of the dorsolateral muscles, those in close association with the gill arches, are the **interarcuales**. They are divided into two groups of four muscles each, a lateral and a median group.
- (310) The **lateral interarcuales**. The **first, second and third** of these are similar in having a double origin. The major origin of each is the anterior

end of the first, second and third pharyngobranchials respectively; the minor origin, that of a few fibers only, is the pharyngobranchial immediately posterior to it. Thus the major origin of the first interarcular is the first pharyngobranchial, the minor origin the second. The insertion is on the dorsal face of the epibranchial cartilage, anterior to the groove (par. 273). The **fourth interarcular** has but a single origin as the fourth and fifth pharyngobranchial cartilages are fused (par. 272).

(311) The **median interarculars**. The **first** (anterior) **interarcular (subspinalis)** has a triple origin, arising from: (1) the fascia on the ventral surface of the dorsal longitudinal muscles; (2) the two anterior vertebræ of the vertebral column; (3) the ventral surface of the neurocranium just anterior to the foramen magnum. The insertion is by a single tendon attached to the median dorsal end of the first pharyngobranchial cartilage.

(312) The **second, third and fourth interarculars** are similar. They have their origin on the first, second, and third pharyngobranchials respectively, their insertions on the second third and fourth pharyngobranchials.

*Turn again to the ventral surface and identify the following features:*

(313) Anterior to the mouth, on the ventral surface of the cranium, the **levator labialis superioris** has its origin on the neurocranium between the antorbital shelves (par. 247). The fibers curve around the edge of the upper jaw to insert along with the

fibers of adductor mandibularis on the lower jaw. Note the direction in which the fibers extend.

- (314) Connecting the contiguous ends of the ceratobranchial and epibranchial cartilages of each gill arch is an **adductor arcus branchialis**, composed of only a few muscle fibers. The epibranchial is the **origin**, the ceratobranchial the **insertion**.

*Deflect the first and second ventral constrictors.*

- (315) Lying on the mid line immediately dorsal to the second ventral constrictor is an unpaired muscle, the **coracomandibularis**. It is the most ventral of three muscles forming a ventral longitudinal group. Its origin is the fascia between coracarculares communes (par. 306); its insertion on either side of the symphysis of the lower jaw. Dorsal to the anterior end of this muscle lies the thyroid gland (par. 121).

*Deflect the coracomandibularis muscle.*

- (316) Dorsal to coracomandibularis lies a pair of muscles, **coracohyoideus**. Each has an elongated origin along the aponeurosis with the ceratobranchialis (below it) and coracarculares communes. The insertion is the posterior margin of the basihyal cartilage.

*Deflect coracohyoideus.*

- (317) The most dorsal, hence the deepest, of the ventral longitudinal group is the paired **coracobranchialis**, which constitutes the lateral wall of the pericardial cavity. It is composed of five parts, four of which are similar in origin. The **first** division has its

origin in the aponeurosis beneath coracohyoideus above noted, and its insertion is on the median end of the ceratohyal cartilage. The **second, third, fourth** and **fifth** divisions have their common origin on a strong membrane about the pericardial cavity and the coracoid cartilage. As the fibers extend outward they separate into four groups, to insert, respectively, on the second, third, fourth and fifth branchial arches. The second, third, and fourth insert on the hypobranchial cartilages of their respective arches; the fifth has its insertion on the anterior lateral wings of the basibranchial and the adjacent expanded portion of the fifth ceratobranchial cartilage.

- (318) The coraco-arcuales communes have already been identified and their origin noted. Trace them forward to their insertion on the membranous floor of the pericardial cavity and the fascia immediately dorsal to the origin of ceratohyoideus.

The muscles of the eye have already been studied (par. 146).

**DRAWING 17.** Make a five inch drawing of the dorsal muscles to show the following: constrictores superiores dorsales 6-6; levator maxillæ superioris; adductor mandibularis; trapezius.

**DRAWING 18.** Make a five inch drawing of the ventral muscles to show the following: constrictores superiores ventrales 1-6; adductor mandibularis; levator labialis superioris; coraco-arcularis communis.

**DRAWING 19.** Make a six inch drawing of the ventral surface after constrictores superiores ventrales 1 and 2 have been removed to show the following: coracomandibularis; coracohyoideus.

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