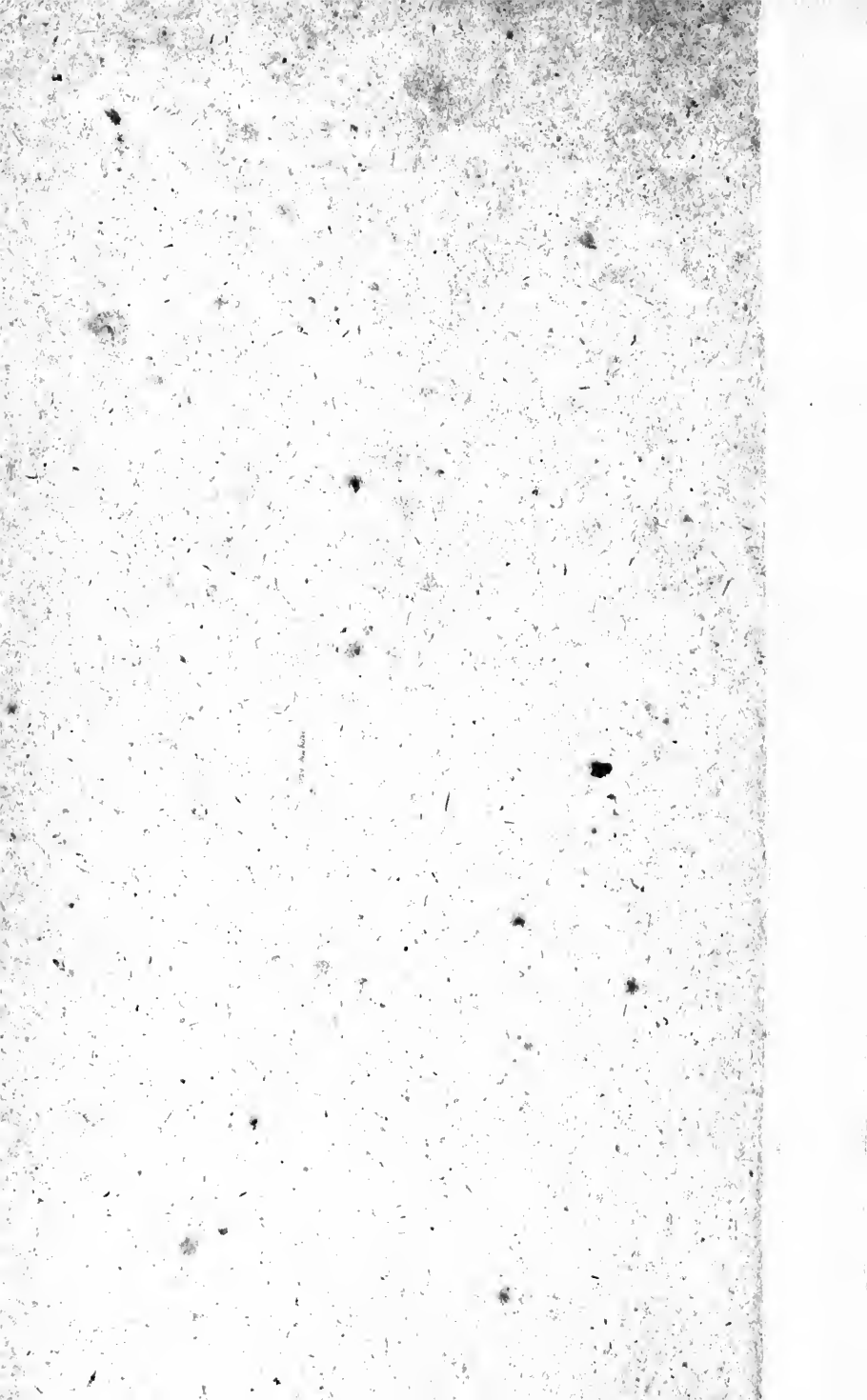


QL
638
K 58



GUIDES FOR VERTEBRATE DISSECTION

THE DOGFISH

(ACANTHIAS)

AN ELASMOBRANCH

BY

J. S. KINGSLEY

Professor of Biology in Tufts College

MBL/WHOI



0 0301 0017598 0

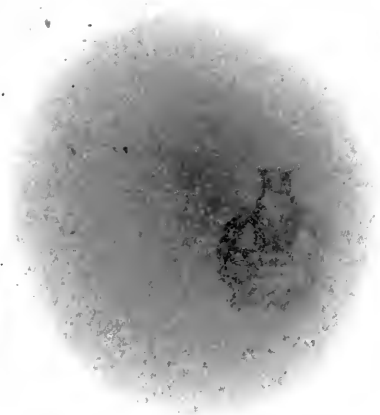


NEW YORK

HENRY HOLT AND COMPANY

1.1673
61





By J. S. KINGSLEY

VERTEBRATE ZOOLOGY.

8vo. \$3.00.

ELEMENTS OF COMPARATIVE ZOOLOGY.

12mo. \$1.20.

GUIDES TO VERTEBRATE DISSECTION.

8vo. Paper.

HERTWIG'S MANUAL OF ZOOLOGY.

Translated by Prof. J. S. KINGSLEY. 8vo.
\$3.00.

Henry Holt and Company

New York

Chicago

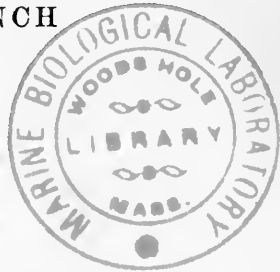
GUIDES FOR VERTEBRATE DISSECTION

K 6 1

THE DOGFISH

(ACANTHIAS)

AN ELASMOBRANCH




BY

J. S. KINGSLEY

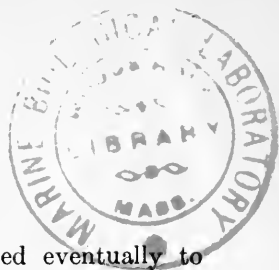
Professor of Biology in Tufts College



NEW YORK
HENRY HOLT AND COMPANY



Copyright, 1907,
BY
HENRY HOLT AND COMPANY



INTRODUCTION

THESE directions for dissection are intended eventually to include representatives of all the major groups of vertebrates. Each is complete in itself and is issued separately so that laboratories may select those forms best adapted for their courses. The directions have been tested by several years' use and are thought to have a distinct pedagogic value in that they do not so much tell the student what he will find, but instead ask him what he does find. He thus obtains his information from the specimen, not from the printed page. For similar reasons illustrations have been omitted; students sometimes find it easier to copy the published figure than to work out the points for themselves.

No attempt has been made to follow out every system of organs completely, but each has been traced far enough to give a good knowledge of the more important structures to use as a basis for comparisons. The student by following the directions may obtain a knowledge of the general anatomy of the animal studied, but this knowledge of itself has little value. More important is the benefit to be gained by comparing the different forms dissected, tracing as far as possible their resemblances and differences. Hence in his dissection the student should continually recall the conditions existing in all other animals as he is tracing out each part.

More than this: he should read the general statements given in manuals of vertebrate structure as he takes up each organ or system of organs, thus correlating his discoveries and making them a part of one general whole. It would be well to go farther and read the accounts of the development of the organs in question in some of the text-books of vertebrate embryology. It is only in this way that an explanation of many peculiarities of structure may be obtained.

Unless explicitly used otherwise the terms **right** and **left** in the following directions apply to the right and left of the animal being dissected, not of the student. **Anterior** and **posterior**

indicate relative position with regard to head and tail, while **dorsal** and **ventral** are used for the anterior and posterior of human anatomy. **Medial** is used to imply proximity to the middle line, **lateral** being the contrasting term. **Proximal** refers to that part of an organ or structure nearest to its centre or to its attachment to the body, **distal** being the opposite adjective. In speaking of muscles the fixed point of attachment is the **origin**, the attachment on the part to be moved is its **insertion**.

INJECTING.—In many cases it is almost impossible for the beginner to trace the blood-vessels unless they are filled with some colored substance which renders them more easily seen. This is especially true of the smaller vessels. Injection is also frequently convenient in tracing other vessels like those of the urogenital system.

Various substances ('injection masses') have been devised for filling the vessels. The essential features of a mass are that it have color, that it flow freely when injected, and that it soon harden so that it will not escape from a vessel accidentally cut. Within recent years a starch mass has been largely used, and as this answers all the purposes of these guides it is described here:

Corn-starch.	400 pts. by volume
2% chloral hydrate in water.	400 "
95% alcohol.	100 "
Color and glycerin (equal parts)	100 "

The mixture should be thoroughly mixed by stirring and strained through cheese-cloth or paper cambric, stirring during the operation. The starch and color quickly settle, hence the mixture has to be stirred while using. It will keep indefinitely, but of course must be thoroughly mixed each time before using.

The colors commonly used are vermillion,* insoluble Prussian blue, chrome green, and chrome yellow. The vermillion is usually used for the arterial, the blue for the venous system, but it is often advantageous to use chrome yellow instead of blue, as it contrasts better with dark organs like the liver and kidneys, while, when a blood-vessel occasionally bursts in injection, the viscera are not so badly stained.

* Care should be taken to get true vermillion (mercuric sulphide), as much that masquerades under that name is red lead colored with eosine. This works disadvantageously as the eosine dissolves in the liquids in which the specimens are preserved and stains everything indiscriminately.

An extremely fine chrome yellow may be made by dissolving 200 parts of acetate of lead and 105 parts by weight of chromate of potash in separate dishes of water. After complete solution mix and allow the precipitate to settle. Pour off the supernatant fluid and wash the precipitate with several waters so as to remove the potassium acetate which would injure the specimen.

Many instruments—syringes, water-pressure apparatus, etc., have been proposed for injecting, but a considerable experience has led to the conclusion that for small animals there is nothing better than a large rubber bulb for the pressure. This is connected by rubber tubing with the canula which is inserted in the vessel to be filled. Use the largest canula possible and keep it free from precipitated mass.

SKELETONS.—The skeletons made by the average student are likely to be imperfect, but the knowledge which he obtains in preparing them is of value. The laboratory should have skeletons well prepared, but the student should clean those which he studies. In the case of fishes it is sufficient to remove the skin from the body, next to place the animal for a few minutes in water near the boiling-point, and then to remove the flesh by hand. With other animals the tissues are more resistant, and in these cases the animal, after removal of the skin, should be boiled in a **scap solution** made as follows:

Thoroughly mix with heat 75 grams of hard soap, 12 grams of potassic nitrate (saltpetre), 150 cc. of strong ammonia, and 2000 cc. of soft water. For use, one part of this 'stock' is diluted with three of water and the body is boiled in this, the length of time varying with the size and consistency of the animal, care being taken not to boil it long enough to soften the ligaments unless it be desired to separate the bones from each other.

For decalcification of skulls in order easily to get at the brains, **nitric alcohol**, made by mixing equal parts of ten per cent nitric acid and ninety-five per cent alcohol, is useful.

Material for dissection can be obtained from

Supply Department, Marine Biological Laboratory, Woods Hole, Mass.

Dr. F. D. Lambert, Tufts College, Mass.

H. H. and C. S. Brimley, Raleigh, N. C.

H. A. Ward, Rochester, N. Y.

Kny-Scheerer Co., 225 Fourth Ave., New York.





THE DOGFISH

Acanthias vulgaris

Two species of dogfish are common on the New England coast, *Acanthias vulgaris* (*Squalis acanthias*) and *Galeus canis*.* *Acanthias* has a stout spine in front of each dorsal fin and sharp and cutting teeth; *Mustelus* lacks fin-spines and has flattened, pavement teeth. The following directions are based upon *Acanthias*, but, except in regard to the exits of the nerves through the wall of the cranium, will apply well to the other form.

Dealers supply *Acanthias* of three ages: 'pups,' about 8 to 9 inches long; 'garters,' 18 to 20 inches long; and adults, from 2½ to 3½ feet total length. For all purposes except the study of the brain and cranial nerves and the fully developed sexual organs the 'garters' are the most favorable. Each student will require two specimens, one for skeleton and one for dissection, while an adult head for the brain, etc., is valuable. Two students can readily compare specimens in order to see the other sex.

The specimen for dissection should be injected. Dealers supply them with the vessels filled with red and blue (or yellow, preferable), but it is possible to inject formalin material. The arterial system is filled by cutting off the tail behind the last dorsal fin and forcing the fluid forward through the caudal artery. The venous system requires more trouble. Inject, first, forward and back through the portal vein; second, in both directions through one of the lateral abdominal veins; and third, forward through the caudal vein which lies just ventral to the caudal artery.

* Some would refer the latter to the genus *Mustelus*, but the differences in internal structure between *Galeus* and *Mustelus* are sufficient to warrant their separation, even if there are no corresponding differences in the superficial characters relied upon by the systematist.

EXTERNAL ANATOMY

Is the body **compressed** (flattened from side to side), **depressed** (flattened horizontally), or cylindrical? Is it the same in all parts? Can you distinguish other regions than head, trunk, and tail?

The Skin.—Rub the body in various directions with the finger; what differences are noted? Take a bit of skin from the side of the body and place for 24 hours in glycerine. Then examine under a low power of the microscope, drawing the scales. Each consists of a basal plate from which arises a central spine. Such scales are known as **placoid scales**. In which direction does the spine point? How are the scales arranged? Isolate other scales by boiling the skin in weak caustic potash.

Examine the side of the trunk and make out a lighter line (**lateral line**) running from head to tail.

Fins.—Note that the fins may be placed in two categories: **median** or **azygos**, and **paired**. The azygos fins are called the **dorsal**, on the back, and the **caudal**, at the end of the tail. Examine the caudal. How many lobes does it present? Into which lobe is the axis of the body continued? Caudal fins of this type are called heterocercal. In some sharks there is an **anal fin** on the ventral side behind the anus.

The anterior paired fins are the **pectorals**, the posterior the **pelvic** or **ventral fins**. In the female the pelvic fins are simple; in the male each has a small inner lobe, the **clasper**, the fin thus being bifid. What is the sex of your specimen?

The head extends back to the pectorals. Are the nostrils (**nares**) dorsal, lateral, or ventral in position? Each is provided with a flap. Does this tend to divide the naris? What function can you suggest for this condition? Probe the nostril; does the probe enter mouth or throat? How does the mouth compare in position with the mouth in other vertebrates? Are lips present? Do the scales pass inside of the mouth? At either angle of the mouth is an **oro-nasal groove** which in some sharks runs to the naris. Does it do so in your specimen?

Draw a ventral view of the head, natural size, showing mouth, nostrils, etc.

Examine the eyes. Could the fish see any object with both eyes at the same time? Are eyelids present? Make out in the eye an outer ring, the **iris**, and in its centre an opening, the **pupil**. (In preserved specimens the pupil is light-colored owing to the opacity of the lens.) On each side of the head, a little above and behind the eye, is an opening, the **spiracle**, while between the two spiracles, and nearly in the median line of the top of the head, are two small openings of the **endolymph-ducts**, connected with the internal ears.

Examine the skin of the head carefully and note the minute 'mucous pores,' mapping the patches you find in an outline of the head. These pores are connected with the lateral-line organs and with small bodies (**ampullæ** of **Savi** and **Lorenzini**) in the skin. These are probably sensory in function.

On the sides of the 'neck' just anterior to the pectoral fins are openings, the **gill-slits** or **branchial clefts**. How many on each side? Do you find the vent? What relations does it bear to the ventral fins?

Make a drawing of the dogfish from the side, six or eight inches long, naming the parts made out.

THE SKELETON

The skeleton of the dogfish is readily prepared for study by taking fresh or pickled * material and placing it for a few minutes (5-10) in hot water. This softens flesh, skin, and ligaments so that they are readily removed by the hand. When the skeleton is roughly blocked out the head, visceral arches, and the fins and their girdles should be removed and cleaned separately from the trunk. Of the axial skeleton it is only necessary to keep a short piece of the trunk and tail.

In cleaning the visceral arches and fins great care must be taken not to separate the jaws from the head, or the branchial rays and extrabran- chials from their arches. In spite of the utmost care of the ordinary student some of these will be lost, but usually enough will remain in position to demonstrate the structures. Similarly, great care must be exercised in cleaning the skeleton of the fins.

The prepared skeleton may be kept in weak formalin or in alcohol. In the latter case it should be removed to water shortly before study, so that parts contracted may regain their original condition.

* It is very difficult to prepare skeletons from specimens put up in formalin or chromic mixtures, as these 'tan' the connective tissues so that they no longer are softened by heat.

The skeleton consists of **axial** and **appendicular** parts; the axial embracing the skull and the vertebral column, the appendicular including the supports of the fins and of the structures (girdles) which unite these to the trunk.

Study a bit of the vertebral column taken from the tail (**caudal vertebræ**). Note the elements (**vertebræ**) of which it is composed. There is an axis composed of separate bodies (**centra**), and dorsal and ventral to this are two **arches**, flattened from side to side, a **neural arch** above and a **hæmal arch** beneath. More careful study will show that these arches are composed of several parts. Continuous with each centrum is a **neural** and a **hæmal process** on either side, and between the successive neural processes a **neural or intercalary plate**. (In the young the top of each neural process is a distinct and additional **neural plate**. In specimens not thoroughly cleaned the neural spines will be found to be connected by an **interspinous ligament**. Notice the notches or openings (**foramina**) in processes and plates for the passage of spinal nerves. Should you judge that dorsal and ventral nerve-roots passed through the same or through different foramina? The arches are completed above by small bodies, the **neural spines**. Are these equal to the centra in number? Do you find analogous **hæmal plates** and **hæmal spines** in the hæmal arch?

Draw several vertebræ, $\times 3$, from the side. Also cut and draw two transverse sections of the column, one between two centra, the other in the middle of a centrum, naming the parts.

Study a few vertebræ from the middle of the trunk (**dorsal vertebræ**), making out centra, neural arches, and the components as before. Are the neural spines arranged as in the tail? Projecting laterally from each side of each centrum is a **transverse process**. Could you compare this with a hæmal plate? Attached to the tip of each transverse process is a short **rib**.

Draw several dorsal vertebræ, $\times 3$.

Split a bit of this part of the vertebral column in the sagittal plane, and study the cut surface. See that each centrum is concave at each end (**amphicœlous**), and that the concavities are filled with a gelatinous substance (intervertebral expansions of the **notochord**). Do the cavities of the two ends of a centrum connect? Make out on the inner surface of the neural arch the parts already seen from the side.

Draw the section, $\times 3$.

The **skull** consists of a **cranium** which encloses the brain and the special sense-organs, and of a **visceral skeleton**, developed in the walls of the mouth and pharynx, which is more loosely connected to the cranium in the Elasmobranchs than in most vertebrates, hence especially interesting as explaining structures in the other groups.

In the cranium do you find joints (**sutures**) separating it into parts such as are noticeable in the skulls of other vertebrates? Make out in it a median portion, the **brain-case**, with at either side, in front, a **nasal capsule**, and a projection behind, the **otic capsule**, the space between the two being the **orbit**. The anterior median prolongations of the brain-case in front of the nasal capsule is the **rostrum**. In *Mustelus* and some other sharks this consists of three bars, one median and ventral the others dorsal and paired. In *Acanthias* the three are united by cartilage into a single structure. Are there any large gaps (**fontanelles**) in the floor or roof of the brain-case?

In the **base** of the cranium (i.e., that side of it which joins the trunk) is a large opening, the **foramen magnum**, for the passage of the spinal cord. Ventral to this is a cup-like depression (posterior end of **cranial notochord**) similar to those in the vertebral centra. Lateral to this are a pair of small projections (**occipital condyles**); still more lateral, a large foramen for the vagus nerve, and nearly at the postero-lateral angle of the skull a similar foramen for the glossopharyngeal nerve.

Draw the base of the cranium natural size, including the otic capsules, naming parts.

In the dorsal view the foramen magnum is still visible. A little in front of it is a large pit with the paired openings of the **endolymph-ducts** in its bottom. Lateral to this pit and extending backward to the base of the cranium and forward to the strong **postorbital process** is the otic capsule. The orbits are, in part, overhung by a strong **supraorbital crest**, extending from the postorbital to a **preorbital process**, which bounds the nasal capsule behind. Note the row of small foramina (for twigs of the superficial ophthalmic nerve) at the base of the crest, and, farther forward, a longer **ophthalmic foramen** by which this nerve emerges to the top of the skull. In front of the ophthalmic foramen are two **ethmoidal canals**. Probe them and see where they lead. Between the roof (**tegmen cranii**) of the brain-case

and the rostrum is a large **anterior fontanelle**. (In some Elasmobranchs there is also a posterior fontanelle.) The roof of the nasal capsule is thin and is usually torn. On the roof of the otic capsule are two ridges running from near the endolymph depression, one forward and outwards, the other obliquely backward to the posterior angle of the skull. These indicate respectively the position of the anterior and posterior semicircular canals of the inner ear.

Draw the cranium from above, natural size.

In the lateral view see that the orbit is bounded in front and behind by strong vertical ridges continuous with the ant- and postorbital processes. Make out also the regions of the nasal and otic capsules. In the orbit recognize foramina for the passage of nerves as follows: Near the ventral middle the largest, **optic foramen**, for the optic nerve; in the roof of the orbit the **ophthalmic foramen** already seen; at the lower posterior angle a large **foramen lacerum anterior** for the fifth, sixth, and part of the seventh nerves; directly in front of the last an **oculomotor foramen** for the third nerve; and about half way between the lacerum and the ophthalmic a small **trochlear foramen** for the fourth nerve. A little ventral and in front of the lacerum is the opening of the **transbasal canal**. At the antero-ventral angle of the otic capsule is a large **facial foramen** for the main trunk of the seventh nerve. In the lateral wall of the otic capsule is a longitudinal ridge indicating the position of the external semicircular canal of the ear.

Draw a side view of the cranium, natural size.

In the ventral view of the cranium note the strong keel produced by the median bar of the rostrum. In the nasal capsule the narial opening is seen, and in the deeper portion of the capsule the large opening by which the olfactory nerve enters. Note also the narrow region between the orbits bounded behind by a pair of **basilar processes** each bearing on its lateral surface a **palatobasal articular** surface against which the palatal process of the upper jaw plays. A little behind this basal process is a median foramen for the passage of the united internal carotid arteries. Note also the articular surface on the strong postero-lateral angle of the ventral surface of the otic capsule with which the dorsal end of the hyomandibular articulates.

Draw a ventral view of the cranium, natural size.

Split the cranium longitudinally in the middle line and study the internal surface. In the floor see how far forward the notochord extends. In front of its tip is an internal projection, the **clinoid process**, in front of which is a depression, the **sella turcica**, occupied by the hypophysial structures of the brain. Probe the transbasal canal from the outside and see where it appears on the inner surface; also trace the course of the foramen for the internal carotid artery. Recognize as far as possible the foramina in the orbital wall. Above and a little behind the clinoid process is a double depression for the auditory-facial and Gasserian ganglia. Probe the foramen lacerum and the facial foramen from the outside and see where they connect. Behind the inner end of the facial foramen is the opening for the passage of the auditory nerve into the inner ear. In the same way find the inner end of the vagus foramen and look half-way between vagus and facial for the inner end of the glossopharyngeal foramen.

Draw the inner surface of the cranium, natural size, indicating the variations in thickness of the walls.

Cut across the otic region of one-half of the bisected cranium, laying open the otic capsule and its system of cavities, the **skeletal labyrinth**. See the large central chamber and trace the connection with it of the several semicircular canals, the position of which has been recognized from the surface.

The **visceral skeleton** consists of a series of seven **visceral arches**, two of which are united by ligaments to the cranium, while the others are placed posterior to it. These really belong to the skull, their position being due to growth greater in the ventral region than in the dorsal. This matter of position as well as differences in structure serves to divide the arches into two groups, the posterior five, the **branchial** or **gill arches**, being much alike, while the most anterior, the **mandibular arch**, and the second, or **hyoid arch**, differ from each other as well as from those farther back. All of the arches present right and left halves and can also be divided into dorsal and ventral portions.

The first or mandibular arch consists of two cartilages on either side: a dorsal, or **pterygoquadrate**, which forms the upper jaw, and a ventral, or **Meckel's cartilage**, the lower jaw. These are hinged at their posterior ends, the angle of the jaws. External to each jaw, and nearly meeting at the angle of the mouth (not jaw), are three **labial cartilages** on either side. How are they

arranged and how far forward do they extend? Are all of equal size?

The pterygoquadrate bears near the middle of its dorsal surface a strong **palatal process** which extends dorsally to articulate with the basilar process of the cranium. Near the angle the upper jaw is expanded into a large **quadrate process**, excavated externally for the attachment of muscles and produced downward for the articulation of Meckel's cartilage.

Meckel's cartilage presents no special features except the articular surface of the angle for articulating with the pterygoquadrate.

(There is a **spiracular cartilage** in the anterior wall of the spiracle. It is lost in preparing a skull in the ordinary way.)

The hyoid arch also consists of dorsal and ventral portions, the dorsal being the **hyomandibular** and the ventral the **hyoid proper**. The two are hinged together and are connected by ligament with the Meckelian. The hyomandibular also articulates with the cranium, and hence the jaws are indirectly connected with the rest of the skull, the hyomandibular forming the suspensorium.

The hyoid proper lies behind and between the two halves of the lower jaw. It consists of a pair of **ceratohyals** united medially by an unpaired **basihyal**. On the posterior margin of both ceratohyal and hyomandibular are a number of cartilaginous **branchial rays** which support the gill.

Study the second branchial arch. Make out from above downward in each half four cartilages: (1) a **pharyngobranchial** lying in the roof of the pharynx and directed backwards; (2) an **epibranchial** forming the rest of the upper half of the arch; (3) a **ceratobranchial**; and (4) a small backwardly curved **hypobranchial** in the floor of the pharynx. Which of these elements bear branchial rays? Why are they not present on all? Also note on the inner surface of the arch shorter cartilages supporting the 'gill-strainers'. Lying external to the ends of the branchial rays but approaching the arch above and below are a dorsal and a ventral **extrabranchial cartilage** (better seen when dissecting the gills).

Compare the other branchial arches with this one. Do all have the same parts? Note how the first ceratobranchial articulates with the hyoid arch, and that the first hypobranchial

is connected with the second by a median plate, the anterior **basibranchial**; and that a posterior basibranchial occurs farther back. With what are the other hypobranchials connected? What are the peculiarities of the pharyngobranchials of the fourth and fifth arches?

Draw the whole visceral skeleton from the side and from the ventral surface, natural size.

The **pectoral girdle** or **shoulder-girdle** is the U-shaped arch of cartilage which supports the anterior pair of fins. It is composed of halves united by ligament in the mid-ventral line. Is there any articulation between the pectoral girdle and the axial or branchial skeleton? At about the middle of each half of the girdle is a **glenoid surface** for the articulation of the skeleton of the fin. This divides the girdle into dorsal (**scapular**) and ventral (**coracoid**) regions, the upper portion of the scapular region being a distinct **suprascapular cartilage**. Close to and hardly below the glenoid surface is a foramen for the passage of nerves to the fin, while behind, the coracoid gives off a strong **coracoid process**.

In the skeleton of the fin make out three cartilages (**basalia**) which articulate with the glenoid surface; in front a **propterygium**, a middle **mesopterygium**, and a posterior **metapterygium**, the middle one being much the larger, and undivided, while the others are transversely divided (into how many elements?). All three basalia bear several cartilaginous **radialia** or **fin-rays**, while the distal portion of the fin is supported by numerous horny threads or **actinotrichia**. Are any of the radialia jointed?

Draw the girdle from the side, and the fin from above, natural size.

The pelvic girdle supports the hinder pair or ventral fins. It consists of a transverse cartilage bar which projects slightly on the dorsal superior surface as an **iliac process**. Just medial to this process the bar is perforated by two **foramina**, the medial of these being the **obturator foramen** for the passage of the nerve of the fin. On the lateral posterior angle of either side are the large **acetabular facets** for the articulation of the skeleton of the fin.

The skeleton of the fin consists of two basal portions which bear a number of slender cartilaginous radialia, and these are continued by numerous actinotrichia, as in the pectoral fin. The anterior basale, the **prebasale**, projects almost laterally from the

pelvic girdle and bears a few radialis on its posterior surface. The **basale metapterygii** extends directly posterior and bears a larger number of radialis on its lateral surface. In the skeleton of the pelvic fin of the male note that the posterior radial is enlarged and extends directly posteriorly into the clasper in such a way that it appears as a direct continuation of the basale metapterygii.

Sketch the skeleton of the fin, natural size, bringing out all of these points.

In the skeleton of the anterior dorsal fin make out a large basal plate (**basale**) bearing in front the strong spine of the fin and behind a few (how many?) polygonal **radialis**, beyond which are actinotrichia as in the paired fins. Compare the second dorsal with the first. Is there any basal skeleton in front of the spine? To which category—basalia or radialis—does the spine belong?

Sketch the skeleton of both dorsal fins, natural size.

INTERNAL STRUCTURE

Lay the fish on its back on the dissecting-board and, beginning just in front of the pelvic fins, make an incision about a quarter of an inch to one side of the median line. Carry the cut forward until you reach the skeletal arch (pectoral girdle) between the pectoral fins. Be careful not to cut anything except the body wall, especially in front. (Most of the material supplied by dealers has this cut when sent out.)

This lays open the body cavity or **cœlom** (better, **metacœle**), lined with a smooth membrane, the **peritoneum**. Notice that the peritoneum covers not only the outer wall of the body cavity but extends over all the enclosed viscera.

Pull apart the body walls and, without disturbing anything, make out the chief viscera as follows: Anteriorly a large **liver** with two main lobes. Which lobe bears a smaller lobule? Dorsal to the liver and extending a little beyond it on the left side is the **stomach** which bends on itself posteriorly like the letter J. The bend divides it into an anterior (left) **cardiac** and a posterior **pyloric** portion.

At the bend of the J is a large triangular **spleen**. At the end of the pylorus the short **duodenal** portion of the intestine begins. This is succeeded almost immediately by the **large intestine**,

through the walls of which the outlines of the **spiral valve** may be seen. Behind the large intestine is a short tube, the **colon**, which, in turn, passes into the **rectum**, the line between colon and rectum being marked on the dorsal side by a finger-shaped **rectal gland**. The hinder part of the digestive tract will be studied later. At the junction of pylorus and duodenum is the lobate **pancreas**; how many lobes and how arranged?

Sketch the viscera thus far made out, labelling the parts in the sketch.

Now lay out the parts already studied, taking care not to injure the delicate membranes by which they are held in position. See how the various viscera are attached to the dorsal wall of the metacœle by membranes (**mesenteries**). Are these mesenteries continuous or interrupted? Make out the following regions in them: (1) a **mesogaster** attached to the stomach; (2) a mesentery proper, supporting the large intestine; and (3) a **mesorectum** with similar relations to rectum and rectal gland.

Also make out similar membranes (**omenta**) connecting portions of the digestive tract to each other: (1) a **gastro-hepatic omentum** connecting the stomach and liver; (2) a **gastro-splenic omentum** extending from stomach to spleen; and (3) an **hepato-duodenal omentum** between the liver and duodenum. In these mesenteries and omenta trace the following blood-vessels.

Arteries.—The most anterior of these, the **cœliac axis**, emerges from the dorsal wall of the body cavity in the middle line, passes to the right of stomach and enters the hepato-duodenal omentum, where it divides into **gastro-hepatic** and **anterior intestinal arteries**. The gastro-hepatic almost immediately divides into **hepatic** (going to the liver) and **gastric arteries**, the latter supplying the cardiac end of the stomach. Trace the anterior intestinal artery backwards to the pylorus, noting the twigs to the pylorus and the **duodenal artery** to the duodenum. How does the main trunk pass the pancreas to reach the ventral surface of the large intestine? Notice the branches of this intestinal portion following the lines of insertion of the spiral valve. Do any of them make the complete circuit of the intestine? How far back on the intestine does this anterior intestinal artery extend?

The **superior mesenteric artery** arises from the mid-dorsal line in the posterior two thirds of the body cavity, dividing almost immediately into an anterior **gastro-splenic artery** and a **posterior**

intestinal artery. Trace the first of these to stomach, spleen and pancreas. What portion of the stomach does it supply? Also trace the posterior intestinal to the dorsal surface of the intestine. Does it send branches to the spiral valve like those of the anterior intestinal? How far forward and backward does it extend?

The **inferior mesenteric artery** courses in the anterior margin of the mesorectum. Trace it to the mid-dorsal line and to the rectum and rectal gland.

Sketch these arteries (in red) so far as made out on a sheet large enough to accommodate the whole fish and put it aside for later additions.

Veins.—The **anterior intestinal vein** runs on the anterior surface of the large intestine parallel to the similarly named artery. Does it receive branches from the spiral valve? Trace it forward into the hepato-duodenal omentum, noting the point at which it receives a **splenic vein** from the spleen. On the dorsal side of the intestine the **posterior intestinal vein** can be traced forward from the rectum and rectal gland to about the middle of the spiral valve region. Thence it ascends in the mesentery, passes directly to the spleen, where it receives several **splenic** branches as well as some from the cardiac region of the stomach. Follow the main trunk along from the spleen to the pancreas, not overlooking the entrance of a **gastric vein**, to its union with the anterior intestinal vein to form the **hepatic-portal vein** which is to be traced to the liver. Just in front of the union of the two intestinals the portal vein receives a **duodenal vein**, the origin of which should be traced.

Sketch these veins on a separate sheet (in blue) and put aside for other additions.

Alimentary Canal.—Examine the cardiac portion of the stomach more closely, noting the ramifications of the gastric branch of the **vagus nerve** on its walls.

In the hepatoduodenal omentum find the **bile-duct**. Where does it connect with the intestine? Trace it forward into the **gall-bladder** and into the liver. In which lobe of the liver is the gall-bladder imbedded? Add bile-duct and bladder to the drawing of the alimentary canal.

Cut away about a quarter of the surface of the large intestine with the scissors for three or four inches, making a 'window'

and displaying the spiral valve. Sketch this structure. What purpose can you suggest for it?

Cut through the rectum and through the liver and stomach about an inch from the anterior ends of the latter and then trim the mesenteries close to the alimentary canal, removing the latter from the body. This will leave the main blood-vascular trunks so that their position may be recognized later.

Split the alimentary canal lengthwise, wash it out and sketch the character of its walls in the different regions. Are the transitions from one to the other abrupt or gradual?

Urogenital Organs.—In the dorsal wall of the metacæle, after removal of the other viscera see the **mesonephroi** or **Wolffian bodies** (so-called **kidneys**), a pair of low ridges one on either side of the attachment of the mesentery and extending nearly the length of the body cavity. Note the short **renal arteries** passing from the middle line into each mesonephros, adding them to the sketch of the arterial circulation. The other urogenital structures vary with the sex.

Male.—The testes are a pair of small flattened lobes dorsal to the anterior part of the liver, each attached to the body wall by a mesentery-like membrane, the **mesorchium**. Is this attached lateral or medial to the mesonephros?

Open the **cloaca** by inserting the scissors in the anus, and carry the incision forward into the rectal region. In the surface thus exposed note the sudden transition from the smooth lining of the cloaca to the plicate condition in the rectum.

On either side in the posterior part of the cloaca find a small opening, the **abdominal pore**. Probe it; where does the probe appear?

In the dorsal wall of the cloaca is a prominent **urogenital papilla** with an opening at its tip. Cut off the tip of the papilla and with probe and scissors follow the tube forward, noting that at first it is a simple cavity, the **urogenital sinus**, which branches in front into two tubes, the **Wolffian ducts**, which can be traced forward on the ventral surface of the mesonephros. (Behind, the duct is straight; farther in front, tortuous. It receives tubules from the mesonephros and others, indirectly, from the testis. These points are not readily made out by the student.)

Female.—The **ovaries** are attached to the dorsal surface of the cœlom, dorsal to the liver, by thin membranes, the **mesovaria**.

Judging from the attachment of the mesovaria are the ovaries to be regarded as medial or lateral to the mesonephroi?

Running along the ventral surface of each mesonephros, near the medial side, is a slender tube (larger in the sexually mature fish), the **oviduct** or **Müllerian duct**. Trace this forward to the anterior end of the liver and thence ventrally to its antero-ventral surface and see the broad opening—the **ostium tubæ**—by which the Müllerian ducts of the two sides open into the metacœle.

Insert the point of the scissors into the anus and cut forward as directed for the male. Note the same sudden transitions between rectal and cloacal surfaces and the abdominal pores. See also the **urogenital papilla** in the dorsal cloacal wall, with a urinary opening at its tip and with the openings of the oviducts on either side. Trace the connection of these ducts with the parts farther forward.

Cut off the tip of the urinary papilla. A single cavity will be found. With probe and scissors trace this forward to its division into two **Wolffian** (urinary) ducts each of which may be traced parallel to and dorsal to the Müllerian duct of the same side.

Sketch the urogenital system as far as made out.

Circulatory Organs.—In the cut surface of the part of the liver which remains in position see the large vessels, the **hepatic veins**. With probe and scissors lay several of these open, following them forward to a pair of large sacs, the **hepatic sinuses**, just in front of the liver and between it and the thin wall, the **septum transversum** (or **false diaphragm**) which bounds the metacœle in front. Also examine the septum transversum for an opening of the **pericardio-peritoneal canal**, dorsal to the liver.

On either side, in the lateral wall of the metacœle, is a large **lateral abdominal vein**. Trace it forward into the region of the septum and backwards into the region of the hind limb.

Carefully cut through the ventral half of the septum transversum and the ventral wall of the body, from the metacœle as far forward as the level of the second gill-slit. This lays open the large **pericardial cavity** containing the heart. Cut away the ventral wall of the cavity so as to permit a good view of its contents. The cavity is seen to be lined with a smooth membrane, the **pericardium**, comparable to the **peritoneum** of the metacœle.

In the **heart** make out ventrally a thick-walled sac, the **ventricle** and, extending forward from this to the anterior wall of the pericardium, a muscular tube, the **truncus arteriosus**. Dorsal to the ventricle and visible on either side of it from below is a larger and thinner-walled sac, the **auricle**, behind which, and connecting it to the septum transversum, is a thin-walled cavity, the **sinus venosus**.

At the lateral angles of the sinus venosus trace the connections of the lateral abdominal veins, and in the middle line the hepatic sinus already mentioned. Other veins, to be added later, enter the sinus.

Insert heart, pericardium, hepatic veins, lateral abdominal veins, etc., in the sketches of the circulation already made.

Insert one point of the scissors in a gill-slit, the scissors pointing ventrally and toward the middle line. Carry the incision nearly to the middle and repeat the operation with the other slits of the same side. This will open the gill-slits, which are now seen to be separated by partitions, the **gill-septa**. In the middle cleft see the **gill-filaments** or, better, folds, on anterior and posterior walls. Does the septum project beyond the gill-folds? Are there any folds on the dorsal or ventral walls? If we speak of the gill-folds borne on a septum as constituting a gill or **branchia**, then those on either side of a septum would constitute a **demibranch**, while one gill-cleft will include demibranchs belonging to two gills.* Do all the gill-clefts bear two demibranchs? Split a bit of the septum near the dorsal and ventral margin of the gills and see, at the level of the ends of the gill-folds, the small extrabranchial cartilages (p. 8).

Sketch the gills as laid open.

Cut through the skin in the median line from the pericardial cavity to the symphysis of the lower jaw. In front, just behind the skeleton of the jaw (**Meckel's cartilage**) and the hyoid arch, find a large glandular mass, the **thymus gland**.

Now cut deeper in the middle line, beginning behind and following the truncus arteriosus from the pericardium through the muscles of the throat. This portion is known as the **ventral aorta**, or **aorta ascendens**. Notice the vessels arising from it

* Frequently the demibranchs of a cleft are regarded as forming a gill, but the view here adopted renders comparisons more easy with teleosts and amphibia.

(**afferent branchial arteries**) and trace them into the gill-septa of the uninjured side. How many of these afferent branchials do you find? How many trunks leave the aorta on either side? Is there an artery to the posterior side of the fifth gill-cleft? How does this agree with the distribution of the demibranchs? Trace twigs from the afferent branchials into the gill-filaments.

Add the ventral aorta and the afferent branchial arteries to the drawing of the arterial circulation.

Cut through the sinus venosus just behind the auricle, leaving it attached to the septum transversum. Tip the heart forward so as to examine the auricle. Is the heart bound dorsally to the pericardium? Notice on the ventral wall of the truncus a pair of **anterior coronary arteries** running back to the ventricle, and on the dorsal side of the truncus a similar pair of **posterior coronary arteries**. Which are the larger? Are the posterior pair distributed to the auricle or to the ventricle? Trace the coronaries forward into the region in front of the pericardium and thence to the vessels of the gill-slits. With which of these are the coronaries connected?

Cut through the truncus just inside of the pericardium and remove the heart from the body. Sketch it from the side, inserting the coronary arteries. Then, placing it in the normal position (i.e., with auricle uppermost) lay open the auricle from the dorsal surface and wash out the contents. Notice the projecting membranous folds—the **sinu-auricular valves**—bounding the opening between the sinus and the auricle. In the floor of the auricle is the opening (**auriculo-ventricular canal**) into the ventricle. Insert the scissors in this opening and split the ventricle longitudinally, carrying the incision through the truncus arteriosus. Notice the relative thickness of auricle and ventricle. Also see the **auriculo-ventricular valves** around the canal, and also the fibres passing from the wall of the ventricle to the free margins of the valves. Careful examination will show that these fibres have a muscular enlargement (**musculus papillaris**) at the base, the rest (**chorda tendiniæ**) being tendinous in character. See the pocket-like valves (how many rows and how many in a row?) in the region (**conus arteriosus**) where the truncus arises from the ventricle. These, like the other valves, prevent a back-flow of the blood. The muscular portion of the truncus in front of the conus is the **bulbus arteriosus**. Probe the pericardio-

peritoneal canal (p. 14) and see where it enters the pericardial cavity.

Sketch the heart in diagrammatic sagittal section, $\times 2$, bringing out these points and showing the varying thickness of the walls.

The pharynx is that portion of the alimentary canal which serves both for respiration and for the passage of food. In the dogfish, therefore, it extends from the spiracle to the last gill-cleft.

Cut from the angles of the mouth back through the middle of the gill-slits, removing the whole lower jaw and floor of the gill-region. In the roof of the mouth find the inner end of the spiracle. In the cut section make out various skeletal elements (cartilages) as follows: In front the arch of the jaws (**mandibular arch**); just behind this the **hyoid arch**; and a **branchial arch** in each gill-septum. Connected with hyoid and branchial arches are slender **branchial rays**. Find also in the pharyngeal wall the blood-vessels of each septum.

Draw the roof of mouth and pharynx and the cut surface, bringing out these points as well as the relation of gill-folds to the septa and the short finger-like processes, the **gill-strainers**, on the inner margins of the gill-clefts.

Slit the skin of the roof of mouth and pharynx in the middle line and remove it from either side, exposing the **efferent branchial arteries** running obliquely inward and backward from the septa. Dissect them free from the investing tissue and trace them into the septa, as well as backward to form a large vessel, the **dorsal aorta**. Running forward from the anterior end of the dorsal aorta, between the efferent branchials are a pair of **vertebral arteries**. How do they end in front? How many efferent branchials in all. How is this reconciled with the number of gills? Are the arteries in the gills connected by cross-trunks? How is blood brought back from the last demibranch?

From the anterior part of the first efferent branchial a **common carotid artery** extends forward and medially, soon dividing into an **external carotid artery**, which proceeds forward to supply the side of the head, and an **internal carotid** which continues to the median line to join its fellow of the opposite side, the common trunk thus formed passing upwards through the floor of the cranium to supply the brain.

Add all of these vessels to the drawing of the arterial system.

Now lay open the lateral portions of the sinus venosus (these parts are morphologically the **Cuvierian ducts**), wash out the contents, and find the following vessels entering them, in addition to the lateral veins already seen: (1) at the posterior dorsal surface a pair of **postcardinal veins** each of which expands almost immediately (dorsal to the base of the liver) into a **cardinal sinus** and then continues back, just to one side of the median line, along the mesonephros. Lay open the sinus and vein. In the sinus see the bands (trabeculæ) strengthening the walls, and farther back the openings of veins coming from the mesonephros. Do you find any communications between the postcardinals of the two sides? (2) Opposite the opening of each cardinal sinus the opening of a **jugular sinus** (a greatly enlarged **jugular vein**). Trace this forward with probe and scissors on one side, noticing that it contracts and then enlarges to form an **orbital sinus**, partly surrounding the eyes.

Add jugulars and postcardinals to the sketch of the venous system.

Follow the aorta backwards from the union of the efferent branchial arteries, noting the connection with it of the various arteries (cœliac axis, mesenterics, etc.) left in the mesentery which supplied the alimentary tract. Also notice small vessels (**renal arteries**) passing to the mesonephros, as well as others (**intercostal arteries**) distributed in pairs to the body wall. Besides these trace a **subclavian artery** on either side arising from the last efferent branchial and passing into the pectoral fin. In its course the subclavian gives off a small **lateral artery** which runs backward in the body wall, ventral to the lateral vein. Paralleling the subclavian artery in the more lateral part of its course is a **subclavian vein** which can be traced medially into the sinus venosus.

Connect the dorsal aorta, subclavians, and the roots of the arteries of the digestive tract with the sketches already made and insert the renals, intercostals, and laterals as well.

Cut off the tail about two inches behind the anus and in the cut-surface make out on either side, immediately beneath the skin, the small canal of the lateral-line system. The mass of the tail is made up of muscles on the right and left sides, and each side is divided into dorsal **epaxial** and ventral **hypaxial** parts. In the centre of the tail is the **vertebral column**, consisting of a

centrum, circular in outline, and extending dorsally from it a **neural arch**, enclosing the spinal cord; and ventrally a similar **hæmal arch** in which are two blood-vessels: above, the **caudal artery** (a continuation of the dorsal aorta); below, a **caudal vein**. Draw the section.

In the muscles of the tail note the concentric arrangement of the plates in each mass. Cut into the tail portion, splitting one of these masses longitudinally, and determine how this condition is brought about.

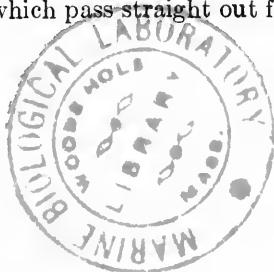
With probe and scissors follow the caudal vein forward to its division into right and left **renal portal veins** which pass along the dorsal surface of the mesonephros. Note, in this dissection, the **iliac arteries** passing from the dorsal aorta into the pelvic fins, and, in following these out, see also the **iliac veins** arising from the fins and passing into the lateral abdominal veins.

Add these arteries and veins to your drawings, which should now include the chief blood-vessels of the body.

Spinal Nerves.—Remove the roof of the sinus venosus and see, lying upon the muscles, the trunks of the spinal nerves which enter the pectoral fin. How many are there of these? Is there anything in their course to indicate a shifting of position of the fin? Do any of them pass through cartilage to enter the fin? Do you find any cross-connections (a **plexus**) between any of these nerves of the pectoral region?

Trace some of these nerves toward the middle line. Do you find any evidence that they are composed of two portions or roots? If so, do you find an enlargement (**ganglion**) on either root?

In the pelvic region work out in the same way the nerves which enter the pelvic fin. Dissect the nerves in front of the fin carefully and see that several (how many?) unite in a longitudinal trunk (**collector nerve**) which passes backwards to enter the fin, with others which pass straight out from the median line.



THE HEAD

Cut off the head just behind the pectoral fins and throw the body away. Remove the skin from the dorsal side of the head as far back as the gill-slits, noting in the operation the distal ends of the endolymph ducts (p. 3) passing from the skull to the skin, and also the numerous nerve-twigs (branches of the ophthalmicus superficialis nerve) going to the skin at the tip of the snout.

The Ear.—Remove, one by one, very thin slices of cartilage from one side of the skull between the endolymph duct and the spiracle, keeping close watch for the appearance of tubes in the hard material. First to be found will be the **longitudinal semicircular canal**, consisting of a tube in the cartilage filled with a fluid (**perilymph**), and in this a smaller tube free from the walls on all sides, a part of the **membranous labyrinth**. Continue to develop slowly in the same matter, making out a **horizontal canal**, lateral to that first found, and a **transverse canal**, posterior to the other two. Dissect these out very carefully and work out the entire membranous labyrinth consisting of the three semicircular canals (known also as external, anterior, and posterior) and a two-chambered portion with which the canals are connected at either end. How many enlargements (**ampullæ**) does each canal bear? Observe that the three canals are nearly at right angles to each other. (The two chambers, an upper **utricle** and a lower **sacculus**, are not so easily made out as the rest of the labyrinth, but a little patience will accomplish the task.) Cut into the central portion and extract some of the matter contained; place it in a drop of water on a slide and examine with the microscope, drawing some of the crystalline bodies (**otoliths**) which occur. Is the labyrinth in front of or behind the spiracle?

Also make a diagrammatic sketch of the membranous labyrinth.

Brain.—Now, in the same way, cut off the roof of the cranium in the middle line a little in front of the ear, removing the cartilage in small bits, thus exposing the brain. See that the cavity of the cranium is lined with a rather tough membrane, the **endorachis** (really the perichondrium). Take care that the nerves lying just lateral to the cranium are not injured. The brain as thus exposed is seen to be covered by a thin membrane, the

meninx primitiva, which should not be removed until later. Extend the opening so that all parts can be seen, and continue the opening back into the anterior part of the spinal column.

In the brain, as thus exposed, make out the following regions. In front (1) a paired **cerebrum (telencephalon)** composed of two indistinctly separated **cerebral hemispheres**, each prolonged laterally into a large **olfactory lobe (rhinencephalon)**. Behind the telencephalon is (3) the nearly equally large **mesencephalon**, consisting of a pair of **optic lobes**. Gently separate cerebrum and optic lobes and see (2) the **diencephalon (thalamencephalon)** or 'twixt-brain connecting the two but lying at a lower level. The **cerebellum** or **metencephalon** (4) is an unpaired oval body overlapping a part of the mesencephalon in front, while behind it overhangs a part of (5) the **myelencephalon** or **medulla oblongata**, a triangular region of the brain which tapers off into the **spinal cord (medulla spinalis)** behind. Note the position of a slender nerve (**trochlearis, IV**) which emerges from the dorsal surface of the brain between mes- and metencephalon. Follow it to its passage through the cranial wall. On the roof of the diencephalon look for the epiphysial structures. These are a slender stalk extending dorsally to the cranial wall, the epiphysis; and in front of this a flattened outgrowth, the paraphysis, which leans against the meninx on the posterior side of the telencephalon.

Now carefully remove the meninx from the top of the brain. See the entrance of the **choroid artery** into the cerebrum in the middle line in front. Are there any signs of division—longitudinal or transverse—in the cerebellum? In front and to the sides of the metencephalon the lateral portion of each side of the myelencephalon is folded into a projecting structure, the **corpus restiforme**. The removal of the envelopes from the dorsal surface of the myelencephalon exposes a triangular opening in the roof, the **fossa rhomboidalis**, leading into the cavity of this region, the **fourth ventricle** of the brain. In the floor of the ventricle, on either side of the middle line, are a pair of longitudinal ridges, the **fasciculi longitudinales mediales**. A little lateral to each of these is a second lobulated ridge, the **lobus visceralis**, while more anterior and in the upper lateral wall, extending forward under the cerebellum, is a third elevation, the **tuberculum acusticum**. Note also that there is a **dorsal fissure** in the spinal cord, a continuation of the fossa rhomboidalis.

Draw a dorsal view of the brain from above, $\times 4$, leaving space on one side of the sheet for the cranial nerves to be made out later. Name the parts on the drawing.

The Eye.—Dissect out the loose connective tissue above and internal to the eye, taking great pains not to injure muscles or nerves. Two muscles will be found attached to the upper medial surface of the eye, in front the **superior oblique**, farther back the **superior rectus**. Pull the eye outwards and note the point of attachment (**origin**) of these muscles on the side wall of the skull. See the fine nerve (**trochlearis**, IV) running from the wall of the skull to the superior oblique muscle. (Its intracranial course was noted earlier.) Dorsal to this and just lateral to the wall of the skull is a longitudinal nerve, the **ophthalmicus superficialis**, the origin and distribution of which will be traced later.

Pull the eyeball outwards and notice the **external rectus** muscle attached to its posterior surface, and the **internal rectus** inserted on the ball just below the superior oblique. Their origins are near that of the superior rectus. Compare with your own eye and see why these terms external and internal are used.

Cut these muscles close to the eyeball and roll the eye outwards so as to see two other muscles, the **inferior rectus** attached to the lower surface of the ball, the **inferior oblique** to its anterior surface beneath the internal rectus. Also note the attachment of each muscle to the cranium.

Two other connections may be noted now, the **optic nerve**, II, which proceeds from the cranium to the medial side of the eye; and the **optic pedicel**, a cartilaginous rod with expanded distal end which abuts against the eyeball. Crossing the inner surface of the ball below the superior rectus is the **ophthalmicus profundus** nerve. See its entrance into the orbit below the main trunk of the ophthalmicus superficialis and its exit in front.

Cut all the muscles and nerves loose from the ^{other} eye close to the ball and then dissect away the lid and remove the eyeball. Make a sketch of the ball and its muscles viewed from the medial side.

Is the eyeball spherical or is any part of it flattened? Lay it open by a cut around the equator and study the two halves in water.

In the inner half make out an outer cartilaginous layer, the **sclera**, against which lies a darkly pigmented **choroid coat**,

limited internally by a thin firmer layer with smooth surface, the **tapetum**. (In life the tapetum reflects brilliantly and produces the green color of the eye; in preserved specimens it largely loses this power.) Inside the tapetum is the **retina**, light in color, which in laboratory material has usually separated from the other layers except where it is connected with the optic nerve. Note the radiations from the point where the optic nerve enters.

In the outer half of the eye recognize the same parts and note also the large **lens** held in place by a delicate membrane from the margin of the retina. Remove the lens and see that the pigmented layer extends farther forward than the retina, this part being the **iris** with a central opening, the **pupil**. Observe that there is a space between iris and lens, the **posterior chamber** of the eye. See also that the irideal portion is free from the outer wall of the eye, there being an **anterior chamber** in front of it, and that the sclera passes into a transparent layer, the **cornea**, which forms the front of the eye. (Is really covered with a **conjunctiva**, but this cannot be demonstrated by ordinary dissection.)

Draw a diagrammatic section of the eye, showing the lens, iris, layers, etc.

The Cranial Nerves. — These are not readily followed in numerical order, as the dissection of one frequently involves the destruction of another. By following the directions here given all will at last be seen. As made out each should be inserted in its proper position in the sketch of the brain.

First follow the **ophthalmicus superficialis** nerve (p. 22) forward to the tip of the snout, noting its size and its numerous branches. Does it pass dorsal or ventral to the eye-muscles? Follow it backwards, cutting away the cartilage, to its point of emergence from the brain. From which of the divisions of the brain does it arise? Do you find any indications of a double origin to it, as if it were composed of two nerves?

Now follow the **olfactory nerve**, I, from the olfactory lobe forward to its expansion on the wall of the olfactory organ.

One of the eye-muscle nerves, the trochlearis, has already been seen. Look on the ventral surface of the external rectus for the **abducens nerve**, VI, and follow it back as far as possible without cutting anything. The **oculomotor nerve**, III, can be found on the ventral surface of the inferior rectus. Trace its

branches from there to other muscles and its trunk backwards.

The **ophthalmicus profundus** branch of the fifth nerve has already been seen forward to its entrance into the anterior wall of the orbit; where does it emerge?

The **maxillaris** branch of the fifth nerve passes from the cranium just beneath the ophthalmicus superficialis. It soon divides into a **maxillaris superior** which passes obliquely across the floor of the orbit, and a **mandibularis nerve** which courses straight outward at the posterior margin of the orbit. Ophthalmicus profundus, maxillaris superior, and mandibularis are the fifth or **trigeminal nerve**. Each should be traced to its distribution.

One branch of the seventh or **facial nerve**, the ophthalmicus superficialis, has already been traced, emerging from the cranium along with the fifth. The other trunk passes through the cartilage of the anterior wall of the otic capsule, dividing in its passage so that it emerges as two branches, an anterior **ramus palatinus** and a posterior **r. hyomandibularis**, the latter passing behind the spiracle. Trace each as far as possible. (Lateral-line fibres of the seventh, forming a **buccalis nerve**, accompany the maxillaris superior, and others, forming a **mandibularis externus**, are united with the mandibularis of the fifth, while fibres from the fifth accompany the ophthalmicus superficialis. These, however, cannot be recognized in the ordinary dissection, but are mentioned here to give completeness.)

In the otic capsule, after the removal of the membranous labyrinth, note the branches of the **auditory, VIII, nerve**, those going to the ampullæ and to the central portion being the most prominent. In the floor of the capsule the **glossopharyngeal, IX, nerve** is seen running obliquely outwards and backwards to the posterior lateral angle of the cranium. Cut away the cartilage so as to get at the root of this nerve; also follow it laterally. To which gill-slit does it go? What happens to it then?

In the same way follow out the **vagus, X, nerve** which passes through the cartilage behind the ear. How many roots of origin does it have? Trace it backwards, noticing its branches, including those which go to the gill-slits, the one going along the lateral line (**lateralis nerve**) and the **visceral trunk**, which passes backwards to the viscera (corresponds to the **pneumogastric** of human

anatomy), portions of which have already been seen (p. 12) distributed on the stomach.

Add all these nerves to the sketch, including II, III, IV, and VI.

Brain.—Cut off the olfactory nerves, lift up the cerebrum and see the intracranial parts of the optic nerves. Cut these close to cranium and continue to lift, noting and cutting the internal carotid arteries (see p. 17) as they pass from the cartilage to the brain. Now vertically below the optic lobes will be seen the roots of the oculomotor nerves. Do these come from the mesencephalon or the medulla oblongata? Cut in succession the roots of nerves V, VII–VIII, IX, and X on either side and lift the brain very carefully, noting the origin of the abducens nerve and taking great pains not to injure the prominent structures beneath the thalamencephalon. Finally, cut the spinal cord and remove the brain from the cranium. Insert the parts of the nerves II, III, and VI not already drawn in the sketch of brain and cranial nerves.

Study and draw the brain from the side and from the ventral surface, making out the regions already seen, as well as the following structures: (1) The **optic chiasma**, or crossing of the optic nerves beneath the diencephalon; (2) the **lobi inferiores**, a pair of prominences on the ventral surface just behind the chiasma; (3) an unpaired part, the **infundibulum**, lying between the inferior lobes, expanded behind into a pair of thin-walled sacs, the **sacci vasculosi**, and bearing on its ventral surface a narrower body, the **hypophysis** or **pituitary body**. Note the origin of the oculomotor nerves just in front of the vascular sacs. On the ventral surface of the mesencephalon is a longitudinal groove, continued as the ventral fissure on the spinal cord. This groove separates a pair of broad bands, the **crura cerebri**, which extend forward either side of the infundibulum just dorsal to the sacci vasculosi, while each crus is extended backwards beneath the medulla as one of the **anterior pyramids**.

Add to the sketch of the ventral surface of the brain the following blood-vessels. The **internal carotids** reach the brain on either side just behind the optic chiasma, dividing at once into anterior and posterior branches. The anterior branch sends a main trunk, the **middle cerebral artery**, which runs along the ventral surface of the cerebrum and the olfactory lobe; and an

inner cerebral artery, which meets its fellow of the opposite side and extends forwards and upwards between the hemispheres. The posterior branch forms a **posterior communicating artery** which extends back to meet its fellow beneath the medulla and there to form a **basilar artery** extending back beneath the medulla oblongata. It will thus be seen that the inner cerebrals and the posterior communicating arteries form a closed ring, the **circle of Willis**.

Bisect the brain and cut away one half of the cerebrum until the cavity it contains is exposed. Draw the section, noting the varying differences in the thickness of the walls and making out the lateral cavities (**ventricles**) in the cerebrum; a **third ventricle** in the thalamencephalon, extending into the infundibulum; and a **fourth ventricle** in the medulla oblongata, beneath the cerebellum. Are optic lobes, cerebellum, or corpora restiformia hollow?

Make a transverse cut through the snout passing through the nostrils, laying open the **olfactory sac**. See that this is enclosed in a cartilaginous **nasal capsule** and that the lining **olfactory membrane** is thrown into numerous leaves or folds, thus greatly increasing the surface. Draw the section $\times 3$.

Lay open the spiracle and notice the reduced gill or **pseudo-branch**. Would this be an anterior or a posterior demibranch? Draw.

LITERATURE

THE following list of books and papers relating to the Morphology of the Elasmobranchs is very incomplete. It however includes the more important articles dealing with the group, and may prove of value to both student and instructor.

TEXT-BOOKS AND GENERAL WORKS

BALFOUR, F. M. *A treatise on comparative embryology*. London, 1881.
— *Monograph on the development of elasmobranch fishes*. London, 1878.

DEAN, B. *Fishes, living and fossil*. N. Y., 1895.

DOHRN, A. *Studien zur Urgeschichte des Wirbelthierkörpers*. Mittheilungen a. d. zool. Station zu Neapel, 1882—date. (Much embryological material.)

GEGENBAUR, C. *Vergleichende Anatomie der Wirbeltiere*. 2 vols. Leipzig, 1898–1901.

GRIFFIN, L. E. *Dissection of the dogfish*. Missouri Valley College Bulletin, 6, 1907.

Handbuch d. vergleich. u. experiment. Entwicklungslehre der Wirbeltiere. Jena, 1902–6.

HASSE, C. *Das natürliche System der Elasmobranchier*. Leipzig, 1879–1882.

HERTWIG, O. *Lehrbuch der Entwicklungsgeschichte des Menschen und der Wirbeltiere*. Jena, 1902.

HERTWIG, R. *Manual of zoology*, translated by J. S. Kingsley. N. Y., 1902.

HOFFMANN, C. K. *Entwicklungsgeschichte der Selachii*. Morphol. Jahrb., 24, 25, 1896–7.

HUXLEY, T. H. *Comparative anatomy of the vertebrates*. N. Y., 1872.

JORDAN, D. S. *Guide to the study of fishes*. N. Y., 1905.

KEIBEL, F. *Die Gastrulation und Keimblattbildung*. Ergebnisse Anat. u. Entwicklungsgeschichte, 10, 1900.

KINGSLEY, J. S. *Vertebrate zoology*. N. Y., 1898.

LOCY, W. A. *Contribution to structure and development of vertebrate head*. Journal Morphol., 11, 1895.

MARSHALL, A. M. *Head cavities and associated nerves in elasmobranchs*. Quar. Jour. Micros. Sci., 21, 1881.

MARSHALL, A. M., and HURST, C. H. *A junior course of practical zoology*. London, 1888.

- MINOT, C. S. *Human embryology*. Philadelphia, 1892.
- NEAL, H. V. *The segmentation of the nervous system in Squalus*. Bulletin Mus. Comp. Zoology, **31**, 1898.
- OPPEL, A. *Lehrbuch der vergleichenden mikroskopischen Anatomie*. (5 vols. published.) Jena, 1896—
- OWEN, R. *Anatomy of vertebrates*. 3 vols. London, 1866–8.
- PARKER, T. J. *A course of instruction in zootomy*. London, 1884.
- PARKER, T. J., and HASWELL, W. *A text-book of zoology*. 2 vols. London, 1897.
- PRATT, H. S. *A course in vertebrate zoology*. Boston, 1905.
- RAND, H. W. *The skate as a subject for classes in comparative anatomy*. Amer. Naturalist, **39**, 1905.
- STANNIUS, H. *Handbuch der Zootomie*. Leipzig, 1854–6. (Practically a handbook of all then existing knowledge.)
- WIEDERSHEIM, R. *Vergleichende Anatomie der Wirbeltiere*. Jena, 1906.
- VAN WIJHE, J. W. *Mesodermsegmente und Entwick. der Nerven des Selachierkopfes*. Amsterdam, 1882.
- WYMAN, J. *Development of Raia batis*. Memoirs American Acad. Arts and Sciences, **9**, 1864.
- ZIEGLER, H. E. *Lehrbuch d. vergl. Entwick. d. niederen Wirbeltiere*. Jena, 1902.
- ZIEGLER, H. E. and F. *Entwicklungsgeschichte von Torpedo*. Archiv f. mikr. Anat., **39**.

TEGUMENTARY STRUCTURES AND EXOSKELETON

- HERTWIG, O. *Bau und Entwicklung der Placoidschuppen u. d. Zähne der Selachier*. Jena. Zeitschrift, **8**, 1874.
- KLAATSCH, H. *Zur Morphologie der Fischeschuppen u.s.w.* Morphol. Jahrbuch, **16**, 1890.
- MARKERT, F. *Die Flossenstrahlen von Acanthias*. Zoolog. Jahrbuch, Anatom. Abtheilung, **9**, 1896.

SKELETON

- BALFOUR, F. M. *Development of the skeleton of the paired fins of elasmobranchs*. Proc. Zool. Socy. London, 1881.
- BRAUS, H. *Die Extremitäten der Selachier*. Verhandl. Anat. Gesellschaft, **13**, 1898.
- BUNGE, A. *Ein biserial Archipterygium bei Selachiern und Dipnoern*. Jena. Zeitschr., **8**, 1874.
- DEAN, B. *Fin-fold origin of paired limbs*. Anat. Anz., **8**, 1896.
- DOHRN, A. *Die Flossen der Selachier*. Mittheil. zool. Station Neapel, **5**, 1886.

- FÜRBRINGER, K. *Zur Kenntniss des Viszeralskeletts der Selachier.* Morphol. Jahrbuch, **31**, 1903.
- GADOW, H., and ABBOTT, E. C. *Evolution of the vertebral column of fishes.* Phil. Trans., **186 B**, 1895.
- GEGENBAUR, C. *Untersuchung z. vergl. Anat. der Wirbelthiere.* Leipzig, 1864-72. (Skull, Fins.)
- *Über das Skelett der Gliedmassen u.s.w.* Jena. Zeitschr., **5**, 1870.
- *Über das Archipterygium.* Ibid., **7**, 1872.
- HASSE. *Die Entwicklung der Wirbelsäule der Elasmobranchier.* Zeitschr. wiss. Zoologie, **55**, 1892.
- HASWELL, W. A. *Studies on the elasmobranch skeleton.* Proc. Linnæan Socy. N. So. Wales, **9**.
- KOELLIKER, A. *Über die Wirbel der Selachier.* Abhandl. Senck. Gesellsch., **5**.
- MAYER, P. *Die unpaaren Flossen der Selachier.* Mittheil. zool. Stat. Neapel, **6**, 1885.
- MIVART, ST. G. *The fins of elasmobranchs.* Trans. Zool. Socy. London, **10**, 1879.
- PARKER, W. K. *On the structure and development of the skull in sharks and skates.* Trans. Zool. Socy. London, **10**.
- PARKER, W. K., and BETTANY, G. T. *Morphology of the skull.* London, 1877.
- REYNOLDS, S. H. *The vertebrate skeleton.* London, 1897.
- RIDEWOOD, W. G. *Extrabranhials.* Anat. Anzeiger, **13**, 1897.
- SEWERTZOFF, A. *Die Entwicklung des Selachierschädels.* Kupffer Festschrift, 1899.
- THATCHER, J. K. *Median and paired fins.* Trans. Connecticut Acad., **3**, 1878.
- WIEDERSHEIM, R. *Das Gliedmassenskelett der Wirbelthiere.* Jena, 1892.

MUSCLES

- BALLOWITZ. *Elektrische Organe der gewöhnlichen Rochen.* Anat. Hefte, **7**, 1897.
- BRAUS, H. *Entwicklung der Muskulatur u. d. periph. Nervensystem der Selachier.* Morph. Jahrb., **26** and **27**, 1898-9.
- EWART, J. C. *The electric organ of the skate.* Phil. Trans., **179** and **183**, 1888-1893.
- FÜRBRINGER, P. *Über die mit dem Viszeralskelett verbundenen spinalen Muskeln der Selachier.* Jena. Zeitschr., **30**, 1896.
- HUMPHREY, —. *The muscles of the smooth dogfish.* Jour. Anat. and Physiol., 1873.
- MARION, G. E. *Mandibular and pharyngeal muscles of Acanthias and Raia.* Tufts College Studies, **2**, 1905.

- SANDERSON and GOTCH. *Electrical organ of the skate*. Jour. of Physiol., 10, 1889.
- TIESING, B. *Augen-, Kiefer-, und Kiemenmuskulatur der Haie und Rochen*. Jena. Zeitschr., 30, 1896.
- VETTER, B. *Vergl. Anat. der Kiemen- und Kiefernuskulatur der Fische*. Jena. Zeitschr., 8 and 12, 1874, 1878.

NERVOUS SYSTEM

- ALLIS, E. P. *Lateral sensory canals, eye-muscles, and certain cranial nerves of Mustelus*. Quar. Jour. Micros. Sci., 45, 1902.
- BUSCH, W. *De Selachiorum et Ganoideorum encephalo*. Berlin, 1848.
- CHEVREL, O. *Système nerveux grand sympathétique des Elasmobranches*. Poitiers, 1889.
- FÜRBRINGER, M. *Spino-occipitalen Nerven der Selachier*. Gegenbaur Festschrift, 1896.
- GEGENBAUR, C. *Die Kopfnerven von Hexanchus*. Jena. Zeitschr., 6, 1871.
- GUTHKE, E. *Ganglien und Nerven des Kopfes von Torpedo*. Jena. Zeitschr., 42, 1906.
- JOHNSTON, J. B. *Das Gehirn und die Cranialnerven der Anamnier*. Ergeb. Anat. und Entwickl., 11, 1901.
- LOCY, W. A. *A newly recognized nerve connected with the forebrain of Selachians*. Anat. Anzeiger, 26, 1905.
- MARSHALL, A. M., and SPENCER, B. *Observations on cranial nerves of Scyllium*. Quar. Jour. Mic. Sci., 21, 1881.
- NEAL, H. V. *Development of ventral nerves in Selachii*. Mark Anniv. Volume, 1903.
- PUNNET, R. C. *Pelvic plexus and nervus collector in Mustelus*. Philos. Trans., 192, 1901.
- STRONG, O. S. *Cranial nerves of Acanthias*. Biol. Bull., 6, 1904.

PARIETAL ORGAN

- FHLERS, E. *Die Epiphyse der Plagiostomen*. Zeitsch. wiss. Zool., 30, 1879.
- GAUPP, E. *Zirbel, Parietalorgan und Paraphysis*. Ergebnisse Anat. u. Entwickl., 7, 1897.
- MINOT, C. S. *Morphology of pineal region based upon its development in Acanthias*. Amer. Jour. Anat., 1, 1901.

SENSORY STRUCTURES

- AYERS, H. *Vertebrate cephalogenesis*. (Ear and Lat. line.) Jour. Morphol., 6, 1892.
- BEARD, J. *Branchial sense-organs and associated ganglia in Ichthyopsida*. Quar. Jour. Mic. Sci., 25, 1885.
- BOLL, F. *Die lorenzini'schen Ampullen*. Arch. mikr. Anat., 4, 1868.
- COGGI, A. *Svillupo delle Ampolle d. Lorenzini*. R. Accad. Lincei, 1891

- EWART, J. C., and MITCHELL, J. C. *Lateral sense-organs of elasmobranchs.* Trans. Roy. Socy., Edinburgh, **37**, 1892.
- FRANZ, V. *Anatomie, Histologie und funkt. Gestaltung des Selachierauges.* Jena. Zeitschrift, **49**, 1905.
- GARMAN, S. *Lateral canal system of Selachia.* Bull. Mus. Comp. Zool., **17**, 1888.
- HASSE, C. *Vergl. Morphol. u. Histologie des häutigen Gehörorganes.* Suppl. Anat. Studien, **1**, 1873.
- LAMB, A. B. *Development of the eye-muscles in Acanthias.* Amer. Jour. Anat., **1**, 1902.
- MARSHALL, A. M. *Morphology of vertebrate olfactory organ.* Quar. Jour. Micr. Sci., **19**, 1879.
- PARKER, G. H. *Sense of hearing in fishes.* Amer. Nat., **37**, 1903.
- RETZIUS. *Das Gehörorgan der Wirbelthiere.* I. Stockholm, 1881.
- SOLGER, B. *Die Seitenorgane der Selachier.* Archiv f. mikr. Anat., **17**.
- VIRCHOW, H. *Über die Augen der Selachier.* Verhandl. physiol. Gesellschaft, Berlin, 1889-90.

TEETH

- HERTWIG, O. See Tegumentary Structures, supra.
- OWEN, R. *Odontography.* London, 1840-45.
- RÖSE, C. *Das Zahnsystem der Wirbeltiere.* Ergebnisse, u.s.w., **4**, 1894.
- TOMES, C. *Development of teeth of Selachii.* Philos. Trans., 1876.

THYROID AND THYMUS

- BEARD, J. *Origin and histogenesis of thymus in Raia.* Zool. Jahrb. Anat. Abth., **17**, 1902.
- DE MEURON, P. *Recherches sur le développement du Thymus et de la glande thyroïde.* Genève, 1886.

DIGESTIVE SYSTEM

- HOWES, G. B. *Intestinal canal of Ichthyopoida, etc.* Jour. Linn. Socy. London, Zool., **23**.
- MAYER, P. *Spiraldarm der Selachier.* Neapel Mittheilungen, **12**, 1897.
- OPPEL, A. *Vergleichende mikroskop. Anatomie. I. Magen.* Jena, 1896.
II. Schlund und Darm, 1897.
- PARKER, T. J. *Spiral valve in Raia.* Trans. Zool. Socy. London, **11**, 1880.
- SULLIVAN, M. H. *Physiology of digestive tract of elasmobranchs.* Am. Jour. Physiol., **15**, 1905.

RESPIRATION

- DROSCHER, W. *Struktur d. Kiemen der Plagiostomen.* Archiv für Naturgeschichte, **48**, 1882.
- RIDEWOOD, W. G. *Spiracle and associated structures.* Anat. Anzeiger, **11**, 1896.

VIRCHOW, H. *Spritzlochkieme der Selachier*. Sitzungsber. Gesellsch. Naturfreunde, Berlin, 1893.

PORI ABDOMINALES

AYERS, H. *Pori abdominales*. Morph. Jahrb., **10**, 1885.

BLES, E. S. *Abdominal pores and nephrostomes*. Jour. Anat. and Physiol., **32**, 1898.

TURNER, W. *Pori abdominales in some sharks*. Jour. Anat. and Phys., **14**.

CIRCULATION

CARAZZI, D. *Sistema arterioso di Selache, etc.* Anat. Anz., **26**, 1905.

GREIL, A. *Truncus arteriosus der Anamnier*. Verhandl. Anat. Gesellschaft, **17**, 1903.

HOCHSTETTER, F. *Venensystem der Amphibien und Fische*. Morph. Jahrb., **13**, 1888.

HOFFMANN, C. (Development.) Morph. Jahrb., **19**, 1893, **20**, 1893.

HYRTL, J. *Kopfarterien der Haiische*. Denkschr. Akad. Wiss. Wien, **1871**. (Of Skates, *ibid.*, **15**, 1858.)

— (Peculiarities.) Neapel Mittheil., **8**, 1888.

BAKER, G. H., and DAVIS, F. K. *Blood-vessels of the heart*. Proc. Boston Socy. Nat. Hist., **29**, 1899.

PARKER, T. *Blood-vessels of Mustelus*. Phil. Trans., **187**, 1886.

RABL, C. (Development venous system.) Leuckart Festschrift, 1892.

RAFFAELE, F. *Sistema vascolare nei Selacci*. Neapel Mitth., 1892.

RAND, H. W., and ULRICH, J. L. *Lateral vein of skate*. Amer. Naturalist, **39**, 1905.

REX, H. *Hirnvenen der Elasmobranchier*. Morphol. Jahrb., **17**, 1891.

RÖSE, C. *Vergleich. Anat. des Herzens*. Morph. Jahrb., **16**, 1890.

UROGENITAL SYSTEM

BOLAU, H. *Paarung und Fortpflanzung der Scylliumarten*. Zeitschr. wiss. Zool., **35**, 1882.

FÜRBRINGER, M. *Vergleich. Anat. u. Entwick. des Exkretionssystem der Vertebraten*. Morph. Jahrb., **4**, 1878.

HALLER, B. *Urniere von Acanthias*. Morph. Jahrbuch, **29**, 1901.

HUBER, O. *Kopulationsglieder der Selachier*. Zeitschr. wiss. Zool., **70**, 1901.

JUNGENSEN, H. F. E. *Kopulationsorgane der Selachier*. Anatom. Anz., **14**, 1898.

RÜCKERT, J. *Entstehung der Exkretionsorgane der Selachier*. Arch. f. Anat. u. Physiol., 1888.

— *Entwicklung der Exkretionsorgane*. Ergebnisse Anat. u. Entw., **1**, 1892.

SEMPER, C. *Urogenitalsystem der Plagiostomen*. Arbeiten a. d. zool. Inst. Würzburg, **2**, 1875.



