CONTRIBUTIONS FROM THE BIOLOGICAL LABORATORY OF THE BUREAU OF FISHERIES
AT WOODS HOLE, MASS.

THE BLOOD-VASCULAR SYSTEM OF THE TILE-FISH, LOPHOLATILUS CHAMÆLEONTICEPS.

By C. F. SILVESTER,
Curator of the Morphological Museum and Assistant in Anatomy, Princeton University.

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INTRODUCTION.

In the following pages an effort has been made to present a fairly complete list as well as description of the blood vessels of *Lopholatilus chamæleonticeps*, with the hope that the results may serve as a basis for comparison with the blood vessels of other teleosts. Fifteen tile-fish were dissected, 11 for the arterial and 4 for the venous system. For purposes of comparison the arterial systems of 20 other teleosts also were examined, and many of them are figured in the present paper.

Since it has frequently been found difficult successfully to inject the blood vessels of teleosts, the method adopted by the writer, which has proved most satisfactory, may be mentioned: The best French gelatin, after being soaked for from five to ten hours in cold water, is rinsed and drained for a short time in order to get rid of the excess of water, then heated, and a 20 per cent glycerin solution stirred in until the whole possesses the consistency of cream. The coloring mass, either vermilion or insoluble Prussian blue, is then added. The arteries are usually injected from a branch of the cœliacomesenteric, the veins from one of the tributaries of the portal vein and the genital or caudal vein. In order to make a successful injection the specimen must be cold and the injection mass heated to about 39° C., or even warmer. After the injection the specimen should be plunged into cold water to facilitate the hardening of the gelatin. Injected specimens are preserved, as a rule, in a 5 per cent formalin solution.

The material for the subject under consideration was collected under the auspices of the United States Fish Commission at Woods Hole, Massachusetts, and I take this opportunity of expressing my thanks to Dr. H. C. Bumpus and Dr. H. M. Smith for their kind assistance in connection with this portion of the work. It is with pleasure that I acknowledge also my deep indebtedness to Prof. C. F. W. McClure for much valuable assistance throughout the research.

THE HEART.

The heart of *Lopholatilus chamæleonticeps* is similar in position and form to that of many other teleosts. It lies in the pericardial cavity between the two clavicles, just dorsal to the basipterygium and ventral to the œsophagus and first two or three vertebræ. Its chambers consist of a sinus venosus, an auricle, and a ventricle. The sinus is a transversely placed, thin-walled, tubular chamber, into which the Cuvierian ducts

empty, and communicates with the auricle by the large sinu-auricular opening, which is guarded by a two-lipped valve. The auricle is large, thin-walled, and situated cranial to the sinus and slightly cranial and dorsal to the ventricle. Its lateral angles project somewhat ventrad upon the sides of the bulbus arteriosus, and it opens into the ventricle by the auriculoventricular aperture, which is a transverse, elliptical opening with a two-lipped valve. The ventricle is thick-walled, and shaped like a triangular pyramid with the apex directed caudad. The bulbus arteriosus, which is quite large, extends craniad from the base or cranial portion of the ventricle, and tapers into the ventral aorta. The valve between the ventricle and bulbus consists of two segments and is of the usual semilunar type. According to Boas (1880), the small region between the bulbus and ventricle, in which the valve is situated, corresponds to the conus arteriosus of the elasmobranch heart.

THE ARTERIES.

THE VENTRAL AORTA AND THE AFFERENT BRANCHIAL ARTERIES.

The ventral aorta (figs. 16 and 18, pl. 1) extends craniad as a continuation of the bulbus arteriosus, and after giving off, in the order named, the fourth, third,

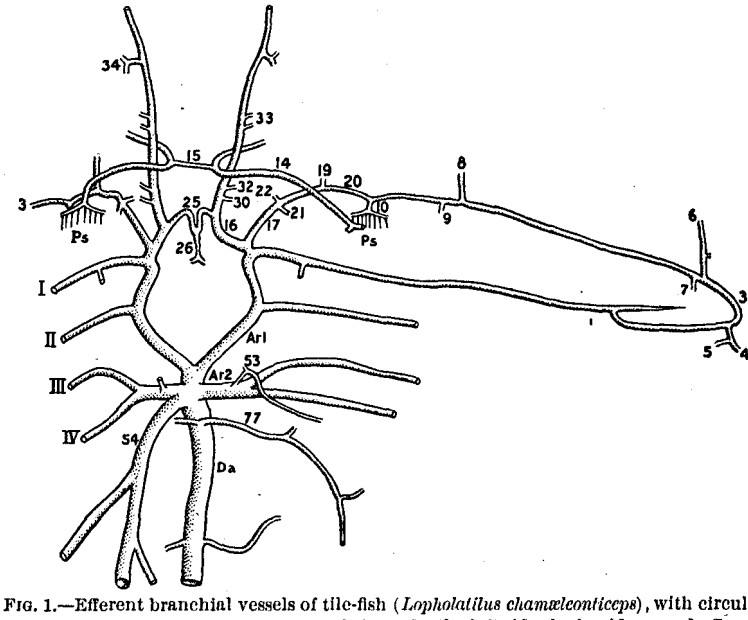

FIG. 1.—Efferent branchial vessels of tile-fish (*Lopholatilus chamælconticeps*), with circulus cephalicus. Ventral aspect, natural size. On the left side the hyoidean and afferent pseudobranchial arteries are shown; on the right side the efferent pseudobranchial artery.

and second pairs of afferent branchial arteries, bifurcates at its cranial end to form the first pair of afferent vessels. On each side the third and fourth afferent branchial arteries arise from a common stem. The second pair arise as separate vessels.

THE EFFERENT BRANCHIAL ARTERIES.

The efferent branchial arteries (I to IV, figs. 16 and 18, pl. 1) correspond pair for pair with the afferent vessels just described. They converge, one from each gill

arch, and run mesad; the first and second pairs unite to form the first aortic root (fig. 4, *Ar. 1*), while the third and fourth similarly unite to form the second (*Ar. 2*). The aortic roots of each side unite in the median line, ventral to the first vertebra, to form the dorsal aorta. The posterior arc of the circulus cephalicus is formed on the base of the skull by the proximal portion of the first pair of efferent branchial arteries and the first pair of aortic roots. In front the circulus is completed by the union of the internal carotids.

Ridewood (1899) has classified the circulus cephalicus of teleosts into four groups, A, B, C, and D, on the basis of the relationships held by the efferent branchial arteries to the circulus and the dorsal aorta. The groups A, B, and D are represented by *Pomolobus* (fig. 3), *Leptocephalus* (fig. 2) and *Microgadus* (fig. 9), respectively. The tile-fish would fall under group C, since the first and second efferent branchial arteries open into the circulus cephalicus and the third and fourth open into the aorta immediately behind the circulus (fig. 1).

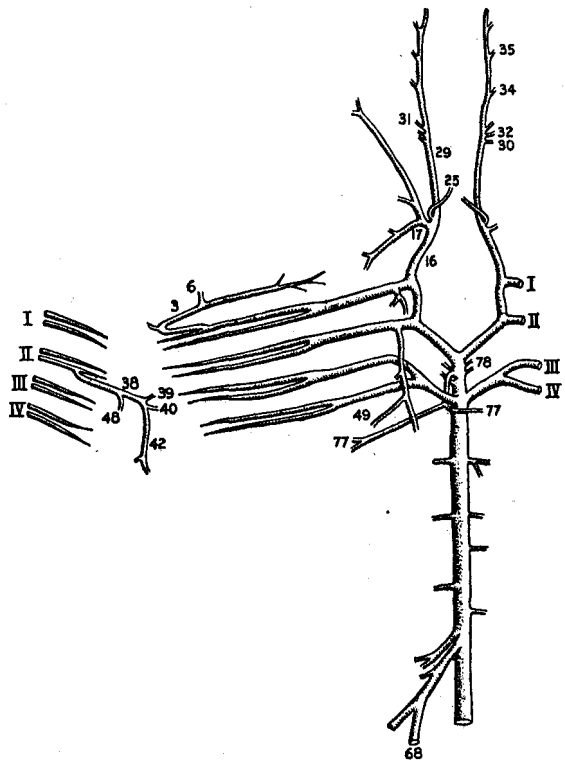

FIG. 2.—Efferent branchial and head arteries, with circulus cephalicus, in the conger eel (*Leptocephalus conger*). Ventral aspect, natural size. On the right side the efferent branchial vessels are shown reflected so as to bring them into one plane. The ventral ends of the left efferent branchial arteries are drawn to show their relation to those of the opposite side.

ARRANGEMENT OF THE BRANCHIAL VESSELS ON THE GILL ARCHES.

The efferent vessels.—The efferent branchial arteries are usually split for some distance at their ventral ends (fig. 12), the two branches lying one on each side of the afferent trunk. For the most part the efferent filamentar arteries open directly into the efferent trunk; the most dorsally situated, however, communicate with it by means of two collecting vessels (*2*, figs. 5 and 18), one from each hemibranch. (In a specimen 50 cm. long, these collecting vessels measured 1 to 3 cm. in length.) So far as known to the writer, the efferent branchial vessels of teleosts have been described as single, one vessel on each holobranch and the two series of filamentar vessels opening into it. Parker (1886, p. 689) states as follows regarding the efferent branchial vessels: "In *Holocephali* and *Teleostei* there is only one efferent artery to each gill, corresponding to the anterior of the two efferent arteries in the plagiostome holobranch." The writer finds, however, in a large number of teleosts in addition to the tile-fish, indications of two efferent branchial arteries on a single arch. In some instances these vessels are double for almost the entire length of the arch, as in the case of the conger eel (*Leptocephalus*, fig. 2), thus resembling in many respects the corresponding vessels in *Ceratodus*, described by Spencer (1893).

The afferent vessels (fig. 18, pl. 1). The afferent branchial arteries, as a rule, run some distance on the gill arches before branching to the gill filaments. At a point where the split ends of the efferent arteries join to form a single vessel, the afferent artery gives off a recurrent branch (*1*, fig. 18) which runs between the two efferent vessels and branches to the most ventrally situated gill filaments. Beyond this point the afferent vessel occupies a position lateral to the efferent trunk.

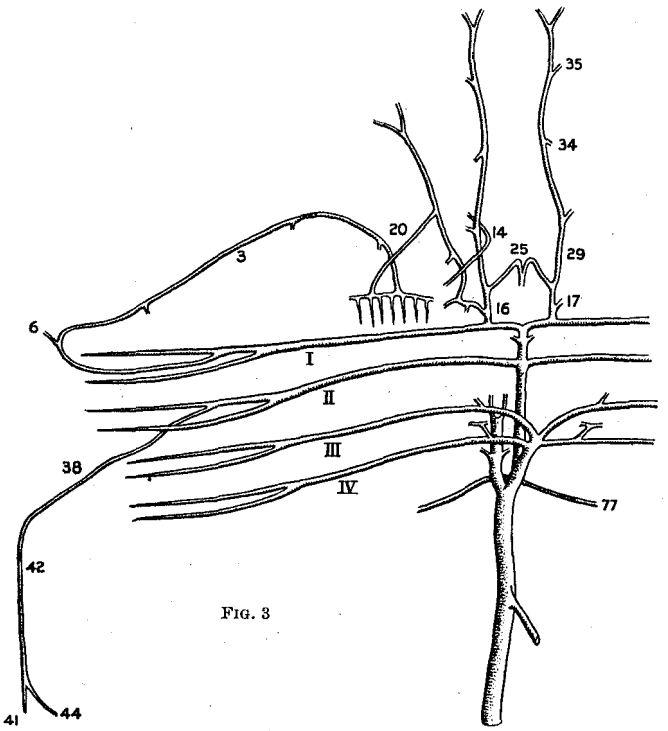

FIG. 3

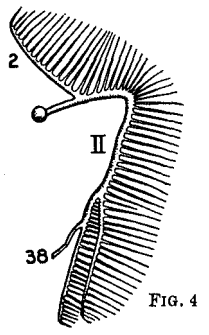

FIG. 4

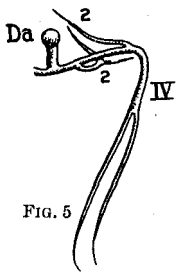

FIG. 5

FIG. 3.—Cranial portion of the arterial system in the hickory shad (*Pomolobus mediocris*). Ventral aspect, natural size. The efferent branchial arteries have their ventral ends reflected on the right side and cut off short on the left.

FIG. 4.—Second efferent branchial artery in the hickory shad, viewed from front, showing arrangement of efferent vessels. Natural size.

FIG. 5.—Fourth efferent branchial artery in the hickory shad, viewed from front, showing arrangement of efferent vessels on arch; filamentar vessels not shown.

BRANCHES OF THE EFFERENT BRANCHIAL ARTERIES.

The first efferent branchial artery (1, fig. 16, pl. 1). This artery gives off the following branches, which will be described in the order named: A. The hyoidean artery. B. The direct afferent pseudobranchial artery. C. A small vessel which lies dorsal to the gills. D. The carotid artery.

A. The *hyoidean artery* (*3*)[a] arises about 2 cm. from the ventral end of the first branchial arch, and pursues a course chiefly following the hyoid arch ultimately to reach the pseudobranch. Passing mesocraniad along the first branchial arch, it

[a] The hyoidean artery has been described by former writers under a number of different names, such as *A. hyoideo-opercularis* (Müller, 1839), *A. hyo-opercularis* (Owen, 1866), *A. hyo-mandibularis* (Maurer, 1888).

curves laterad through a foramen situated in the lower (ventral) end of the ceratohyal near its dorsal border, continues along the lateral or cranial surface of the ceratohyal and interhyal and passes through a fissure between the caudal angle of the quadrate and the dorsal end of the symplectic, still occupying a position lateral to the bones; then passes dorsad through a fissure between the ventral end of the hyo-mandibular and the metapterygoid and continues dorsad along the inner surface of this bone until it reaches the pseudobranch[a].

The following are its branches:

a. A vessel at the ventral end of the first branchial arch which divides into the nutrient artery to this arch (*5*, fig. 16) and into branches which go to the cranial part of the musculus sternohyoideus.[b] (*4*, fig. 16.)

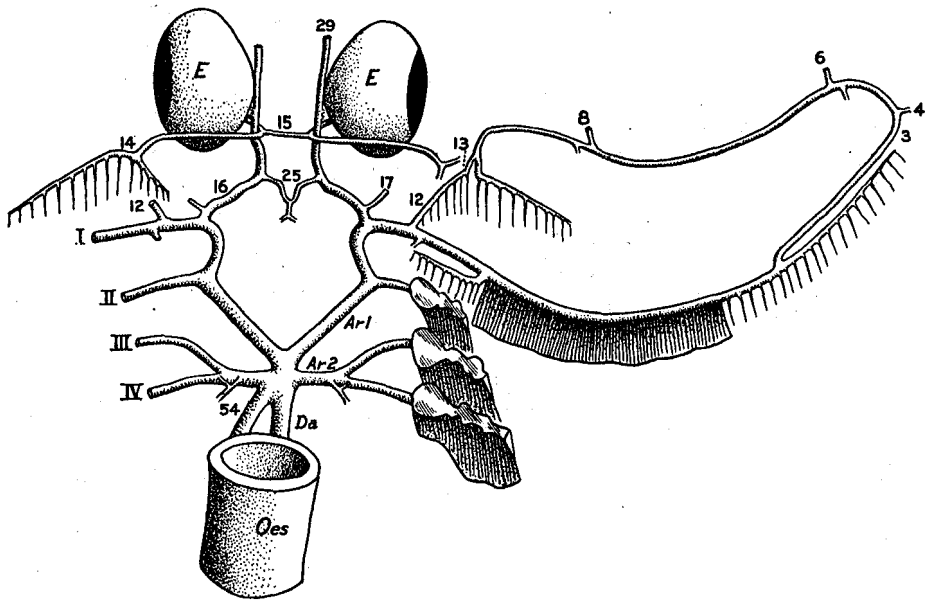

FIG. 6.—Efferent branchial vessels of tile-fish, with circulus cephalicus. Ventral aspect, natural size. On the left side the hyoidean and direct afferent pseudobranchial arteries are shown; on the right side the efferent pseudobranchial artery.

b. An anterior and a posterior branch shortly after passing through the foramen at the ventral end of the ceratohyal. The anterior branch (*6*) corresponds to the lingual artery of Wright (1885) and supplies the musculus geniohyoideus and structures on the floor of the mouth; it terminates in two vessels which accompany the rami of the dental bone. The posterior branch (*7*) is somewhat smaller than the anterior and runs caudad over the lateral surface of the ceratohyal to supply the branchiostegal region.

c. Two branches where the artery passes through the fissure between the quadrate and symplectic; the larger anterior branch (*8*) runs craniad and divides into

[a] The pseudobranch of the tile-fish consists of from 40 to 50 filaments, and occupies a position on the medial side of the dorsal end of the hyomandibular; its filaments are parallel to the most dorsally situated filaments of the first gill.

[b] For the muscular system the writer has followed the terminology of Allis (1897), and for the bones that of Reynolds (1897) and Parker & Haswell (1897).

several branches which supply the greater part of the musculus adductor mandibulæ; the posterior branch (*9*) runs ventrad and caudad, spreading out on the inner side of the infra- and subopercular.

The afferent pseudobranchial vessels (figs. 1 and 6). Before entering the pseudobranch the hyoidean artery usually anastomoses with or is joined by one of two arteries. The ordinary arrangement (fig. 1) is that where the hyoidean artery is joined by a branch (*20*) of the a. hyoöpercularis (*17*) and then enters the pseudobranch at its ventromedial angle to spread out over the surface which adjoins the hyomandibular bone. In the second arrangement (fig. 6) the hyoidean artery is joined, by means of a connecting branch (*13*), with a vessel which might be called the direct afferent pseudobranchial artery (*12*).

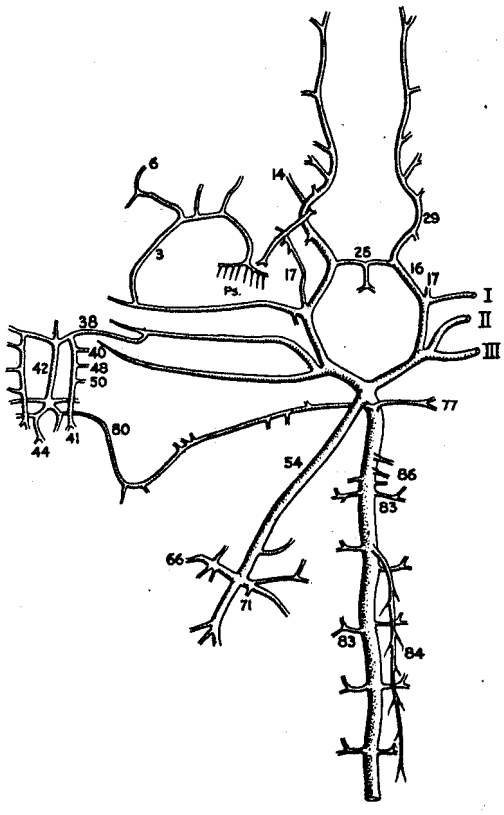

FIG. 7.—Cranial portion of the arterial system in the swellfish (*Spheroides maculatus*). Ventral view, natural size. On the right side the ventral ends of the efferent branchial arteries and their branches are reflected so as to bring them into one plane.

B. *The direct afferent pseudobranchial artery* (*12*) was present in only two of the nine specimens dissected, and only on one side. It was given off from the first efferent branchial artery just lateral to the carotid, and supplied the medial half of the pseudobranch. It also anastomosed with the hyoidean artery, and in this case the latter supplied the lateral portion of the pseudobranch. This arrangement resembles that found in *Gadus*, as described by Müller (1839), where the pseudobranch receives its blood from the hyoidean artery and from a branch which comes directly from the circulus cephalicus. The former condition, which is the one more generally met with among teleosts, resembles that described by Müller for *Sander* (*Lucioperca*), in which the pseudobranch receives blood from the hyoidean and hyoöpercular arteries.

There appears to be considerable variation among the teleosts with regard to the blood supply to the pseudobranch. Aside from the two methods described above for the tile-fish, the pseudobranch of teleosts in general receives its blood (a) entirely from the circulus cephalicus (pike, according to Maurer, 1888); (b) entirely by the hyoidean artery (*Spheroides*, fig. 7); or (c) by all three vessels—i. e., the hyoidean artery, a branch of the a. hyoöpercularis, and the direct afferent pseudobranchial artery (*Myoxocephalus*, fig. 8). In teleosts where the pseudobranch is wanting, the dorsal portion of the hyoidean artery is reduced in size, as in *Leptocephalus* (fig. 2), where it terminates in branches which supply the branchiostegal region and membranes at the dorsal end of the ceratohyal.

The efferent pseudobranchial vessel (fig. 16, pl. 1, and figs. 1 and 6). The efferent pseudobranchial or ophthalmic artery (*14*), arising from the caudal or exposed surface of the pseudobranch, leaves the latter at its ventromedial angle, and runs slightly

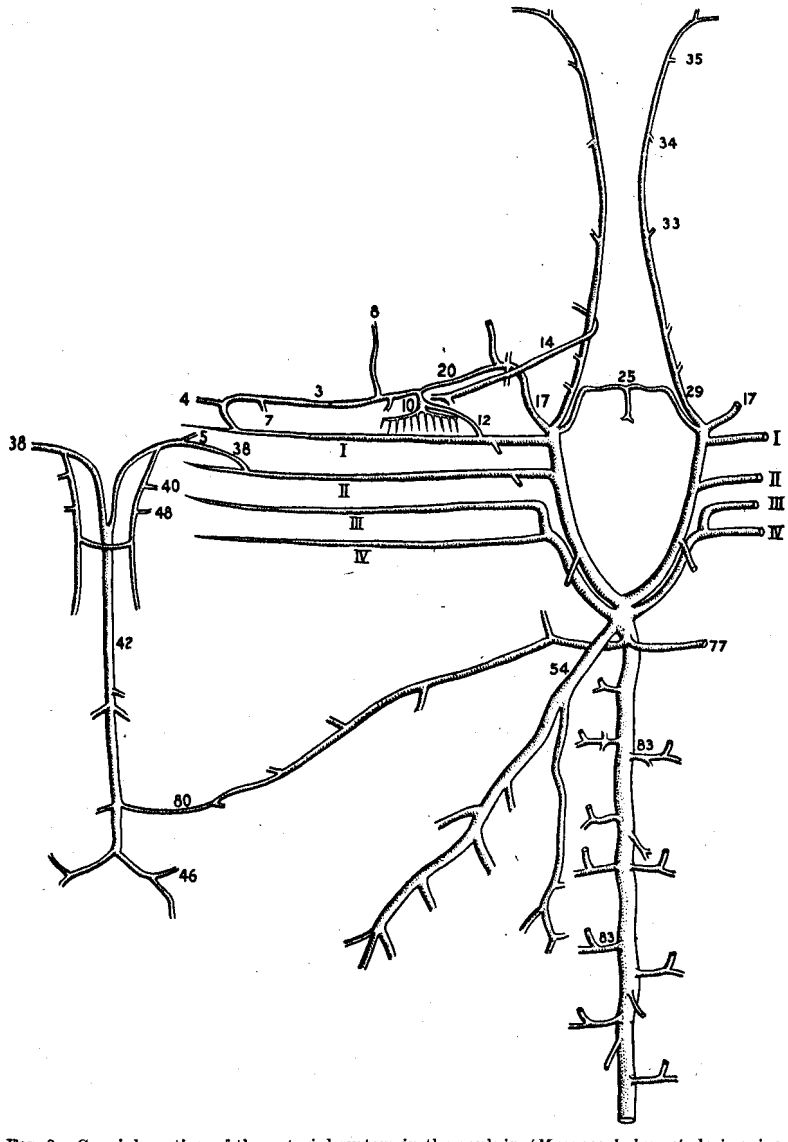

FIG. 8.—Cranial portion of the arterial system in the sculpin (*Myoxocephalus octodecimspinosus*). Ventral view, natural size. On the right side the ventral ends of the efferent branchial arteries and their branches are reflected so as to bring them into one plane.

craniad and mesad, piercing the m. adductor hyomandibularis; thence it continues dorsad to a point just cranial and ventral to the origin of the recti eye muscles, where it sends off a stout branch (*15*) which anastomoses with its fellow of the opposite side

directly dorsal to the parasphenoid. From this point it continues dorsad and craniad between the rectus inferior and rectus posterior and pierces the sclerotic at the lower edge of the optic nerve. Within the eye it forms an anastomosis known as the "choroid gland."

According to Maurer the hyoidean artery represents in teleosts the most anterior of the six aortic arches, or the mandibular aortic arch. He states that in the trout embryo two vessels are developed in connection with the hyoid arch, one of which is situated in front of and the other behind the cartilage. The former is regarded by him as equivalent to the mandibular aortic arch, the latter as equivalent to the hyoidean aortic arch. Since the vessel in front of the cartilage alone persists in the adult, becoming the hyoidean artery, it is the homologue of the mandibular aortic arch. Both of these vessels are originally connected with the anterior end of the ventral aorta, their connection with the first efferent branchial artery, which is characteristic of the adult, being a secondary one (Maurer, 1888). Allis (1901) also seems to regard the hyoidean artery as belonging to the mandibular rather than the hyoid arch. He says (op. cit., pp. 115–116), "This postero-ventral prolongation of the efferent pseudobranchial artery of 12 mm. larvæ of *Amia* thus has, in its dorsal portion, the same relation to the cartilage of the palato-quadrate arch that the branchial arteries have to the cartilages of their respective arches. * * * In its ventral portion this artery acquires relations to the hyoid arch, but it there lies anterior to the cartilage of the arch and not posterior to it. * * * It thus has a position it could naturally acquire by simply slipping backward off the hind edge of the mandibular cartilages. * * * In both its ventral and dorsal positions this artery seems to correspond closely, in general position, to the artery usually described in teleosts as the arteria hyoidea."

Wright (1885) regards the hyoidean artery as representing simply the enlarged nutritive branch to the hyoid arch. He says (op. cit., p. 486): "The condition of the parts in *Lepidosteus* proves that the arteria hyoidea of the teleosts is not the homologue of the hyoidean aortic arch, as is sometimes assumed, for the two vessels coexist in the genus. * * * It appears to me to be homodynamous with the nutritive or branchial arteries which spring from the succeeding efferent arteries, in the way this does from the first, and to owe its greater relative size in ganoids and teleosts to the development of the gill cover from the hyoid arch."

Owen (1866) and others, however, regard the hyoidean artery as equivalent to the hyoidean aortic arch. From the conditions found in the adult teleost, the writer can see no reason for assigning it to the mandibular rather than to the hyoid arch. It seems perfectly natural to regard it as belonging to the latter, and as representing the more cranial of the two efferent vessels which are present on each branchial arch in sharks and rays.

C. *The next branch of the first efferent branchial artery is a small vessel* (*11*) which arises near the dorsal end of the first gill, and, passing caudad, dorsal to the second and ventral to the third branchial artery, supplies the muscles and membranes at the dorsal ends of the gill arches.

D. *The carotid arteries and their branches* (fig. 16, pl. 1). The carotid artery (*16*) is given off at the angle where the first efferent branchial artery bends caudad to join the second. Almost immediately beyond its origin it sends off a large branch,

which extends dorsad, craniad, and laterad. This vessel (*17*), the "muscular branch" of many writers, has been called by Allis (1897), in his description of *Amia*, the a. hyoöpercularis. About 1 cm. from its point of origin the a. hyoöpercularis (*17*) passes through the facial foramen and then divides into three main branches.

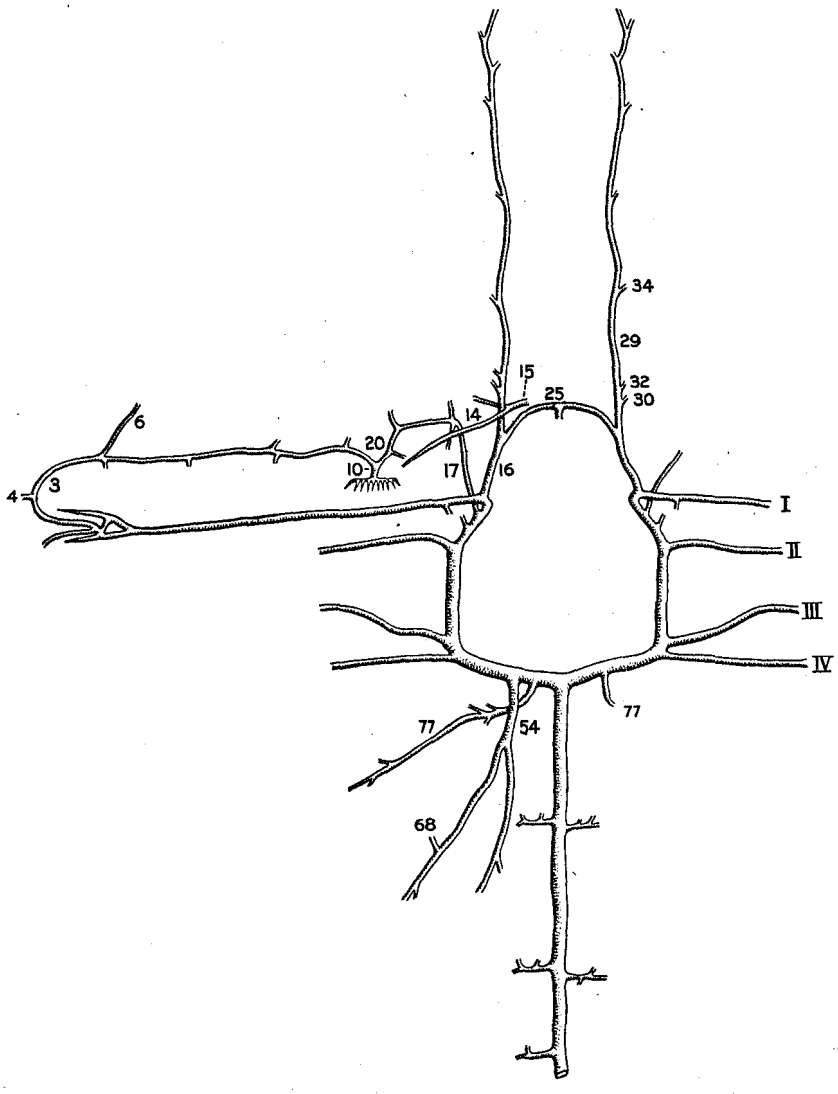

FIG. 9.—Cranial portion of arterial system in the tomcod (*Microgadus tomcod*). Ventral aspect, ×2. The first efferent branchial and hyoidean arteries of the right side are reflected so as to bring them into one plane.

The largest of these three branches runs craniad and ventrad below the orbit for about 1 cm., sends a small branch to the m. adductor hyomandibularis, and then divides into two branches; the larger (*19*) runs craniad and supplies the inner or deep division of the m. adductor mandibulæ; the smaller (*20*) running ventrad and slightly laterad for about 18 mm., in a groove which crosses the metapterygoid, joins the hyoidean artery,

and, in common with the latter, supplies the pseudobranch as described above. In the two cases where the direct afferent pseudobranchial artery was found to be present, this latter branch was small and did not join the hyoidean artery.

The second division of the a. hyoöpercularis (*21*), running caudad and ventrad just medial to the upper end of the hyomandibular, sends a small branch to the m. adductor hyomandibularis, and supplies the mm. adductor and levator operculi.

The remaining or third branch of the a. hyoöpercularis (*22*) divides into a supraorbital and a postorbital branch. The supraorbital branch (*23*) runs craniad on the dorsal wall of the orbit; the postorbital branch (*24*) supplies the m. levator arcus palatini and membranes behind the orbit. According to Allis (1901) the a. hyoöpercularis in *Amia* represents the dorsal portion of the hyoidean aortic arch.

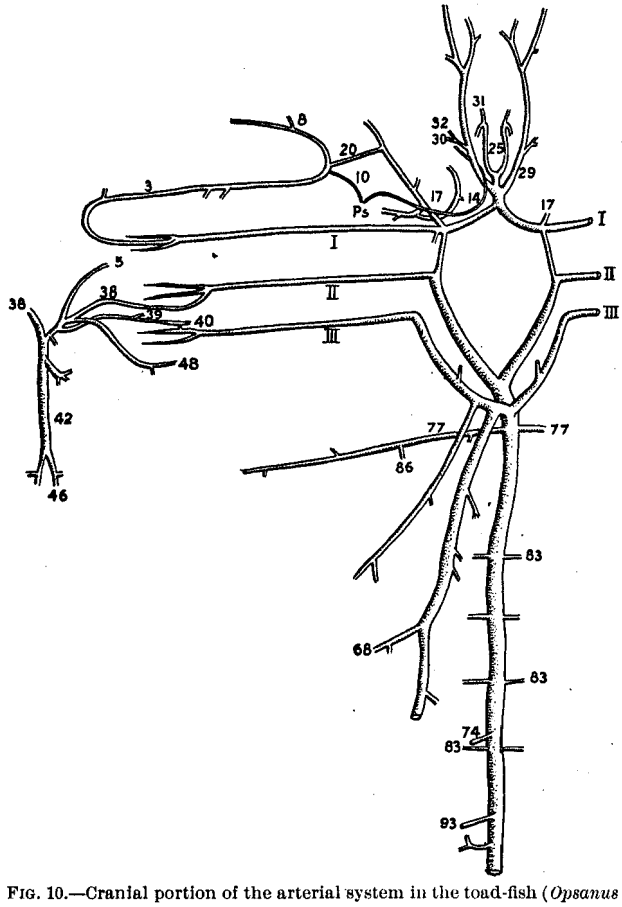

FIG. 10.—Cranial portion of the arterial system in the toad-fish (*Opsanus tau*). Ventral view, natural size. On the right side the ventral ends of the efferent branchial arteries and their branches are reflected so as to bring them into one plane.

In the teleosts this vessel may arise in three different ways: From the first efferent branchial artery, as in *Microgadus* (fig. 9); from the junction of the first efferent branchial artery with the carotid, as in *Opsanus* and *Spheroides* (figs. 10 and 7); and from the common carotid, as in the tile-fish.

After giving off the a. hyoopercularis, the carotid continues craniad for a short distance, pierces the skull wall between the parasphenoid and proötic, and immediately divides into the internal and external carotid arteries.

The external carotid artery and its branches (fig. 16, pl. 1). (a) Two small branches are given off from the external carotid near its origin. The larger (*30*) runs laterad and divides into two branches which supply the external and superior recti muscles of the eye. The artery that supplies the latter muscle runs along its inferior border and pierces the sclerotic to enter the eye (*31*). The other branch is a small vessel (*32*) which supplies the inferior and internal recti muscles of the eye. These two arteries frequently arise by a single trunk from the external carotid.

(b) Beyond the point of origin of the arteries supplying the recti muscles, the external carotid artery lies close to the eyeball and in this position gives off two

small branches (*33*) to the membranes lining the orbit. It then curves slightly dorsolaterad and, passing between the oblique muscles of the eyeball, gives off a small branch (*34*) which divides to each of these two muscles and to the mucous lining of the orbit. The main trunk continues craniad and, passing through a foramen in the prefrontal bone, occupies a position just ventral to the olfactory organ, which it supplies by means of one or two small branches (*35*). At this point, also, a branch (*36*) runs ventrocraniad to supply the maxilla, the roof of the mouth, and the maxillary breathing valve (Dahlgren, 1898). The direct continuation of the main artery extends craniad ventral to the nasal bones, where it gives off small branches to the upper lip and membranes of this region, and finally pierces the premaxilla as the superior dental artery (*37*).

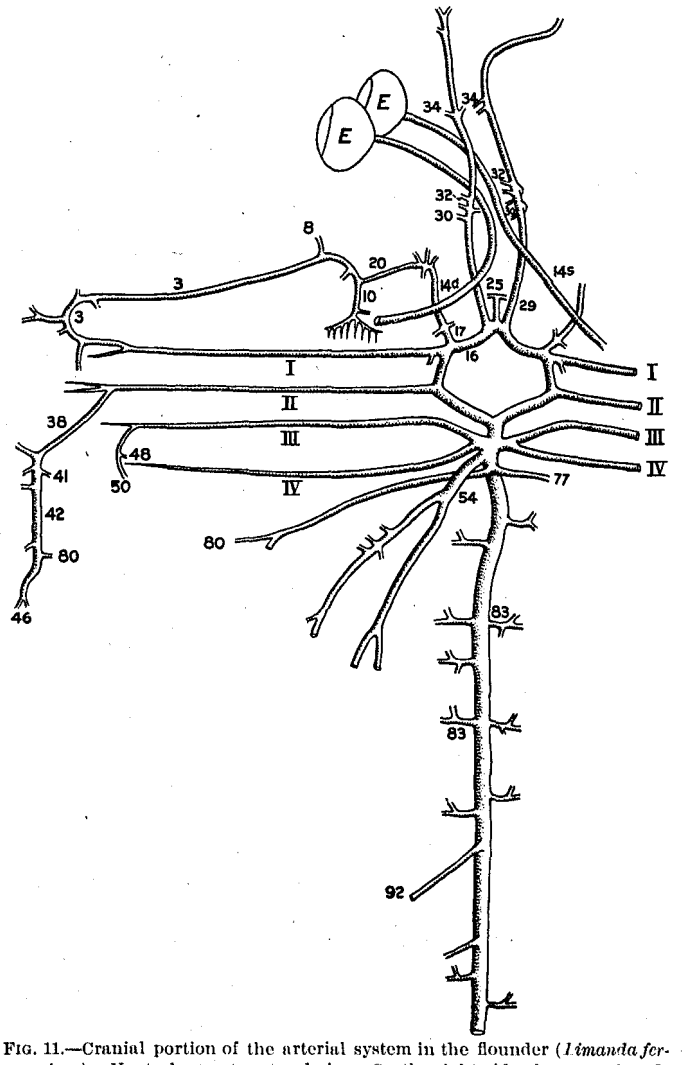

FIG. 11.—Cranial portion of the arterial system in the flounder (*Limanda ferruginea*). Ventral aspect, natural size. On the right side the ventral ends of the efferent branchial arteries and their branches are reflected so as to bring them into one plane.

The internal carotid artery and its branches (fig. 16, pl. 1). The internal carotid artery (*25*) runs mesad and slightly craniad until it reaches the median line, then dorsad for a short distance, accompanied by the internal carotid of the opposite side, with which it anastomoses to form a single median vessel, the carotis interna impar (*26*). The latter continues dorsad, passing through a median foramen in the basisphenoid, and on the ventral surface of the hypophysis divides into two pairs of vessels, the anterior and posterior cerebral arteries.

The anterior cerebral arteries run craniad, side by side, to supply the telencephalon. The posterior vessels curve laterad and caudad over the lobi inferiores to join again in the median line on the ventral surface of the medulla near its cranial end. At this point they give off anterior and posterior branches, the former supplying the

greater portion of the brain, while the latter run caudad, on the ventral surface of the medulla, to reach the spinal cord. On the sides of the lobi inferiors the posterior cerebral arteries usually give off several small branches, one or two of which supply the ear.

In some teleosts (*Opsanus* and *Limanda*, figs. 10 and 11) the internal carotids join near their points of origin to form an arteria carotis interna impar; in others (*Leptocephalus*, fig. 2) union does not take place until they reach the base of the brain. The position and constant occurrence of the arteria carotis impar of teleosts suggests its homology with the cranial end of the primitive dorsal aorta (Ayres, 1889) of the lower elasmobranchs.

The second efferent branchial artery (fig. 16, pl. 1, and fig. 12). About 2 cm. from its ventral end the second efferent branchial artery (11) gives off a large branch (*38*) corresponding to the fourth[a] commissural artery of *Amia* as described by Parker and Davis (1899). This vessel (*38*) runs toward the median line and joins its fellow of the opposite side at a point ventral to the thyroid gland and ventral aorta, forming the median hypobranchial artery (*42*), which runs caudad, passing below the ventral ends of the clavicles, and terminates in branches which supply the ventral fins.

The fourth commissural artery gives off three small branches, namely, two nutrient arteries, one to the second (*39*) and one to the third (*40*) branchial arch, and a ventral coronary artery (*41*), which is given off near the median line or, in some cases, from the median hypobranchial artery itself, which runs caudad on the ventral aorta and, in combination with a coronary artery that usually arises from the fifth commissural artery, supplies the bulbus arteriosus and the heart.

The median hypobranchial artery divides into the thyroid artery (*43*), which immediately enters the thyroid gland; two small branches (*44*) which supply part of the m. sternohyoideus; and finally a branch (*45*) which supplies the muscles attached to the clavicles. Opposite the cranial end of the basipterygium the coracoid artery (*80*) anastomoses, by means of a small branch, with the median hypobranchial, which terminates (*46*) in the ventral fin. Since the coracoid artery is a branch of the subclavian, it will be described in connection with that artery. In teleosts where the ventral fins are wanting (*Leptocephalus* and *Spheroides*, figs. 2 and 7), or where they are situated far back on the abdomen (*Pomolobus*[b], fig. 3), the median hypobranchial artery is somewhat reduced in size and terminates in the m. sternohyoideus. Parker and Davis (1899) have described it as dividing into coronary and epigastric branches, but in many teleosts this description will not hold, for the coronary may be a branch of the commissural artery. For this reason the entire median vessel formed by the joining of the commissural arteries is designated in this paper as the median hypobranchial artery.

The third efferent branchial artery (fig. 16, pl. 1, and fig. 12). Like the second of the series, the third efferent branchial artery usually has but one branch, which corresponds to the fifth commissural artery of Parker and Davis. This branch (*47*)

[a] Parker and Davis in numbering the visceral arches followed the scheme laid down by Gegenbauer (1898), in which the first visceral arch is represented by the upper and lower jaws, the second by the hyoid arch, the third by the first branchial arch, etc.

[b] In *Pomolobus* the ventral fins are supplied by a pair of somewhat larger peritoneal branches.

arises about 2 cm. from the ventral end of the artery and runs toward the median line, where it may join the corresponding artery of the opposite side to form a single vessel—the dorsal median hypobranchial artery (*52*). As a rule, however, it does not reach the median line, but curves caudad dorsal to the fourth division of the musculus obliquus ventralis, and terminates, like the dorsal median hypobranchial, in the musculus constrictor pharyngis and inferior pharyngeal teeth. The branches of the fifth commissural artery are the dorsal coronary artery (*49*), which is given

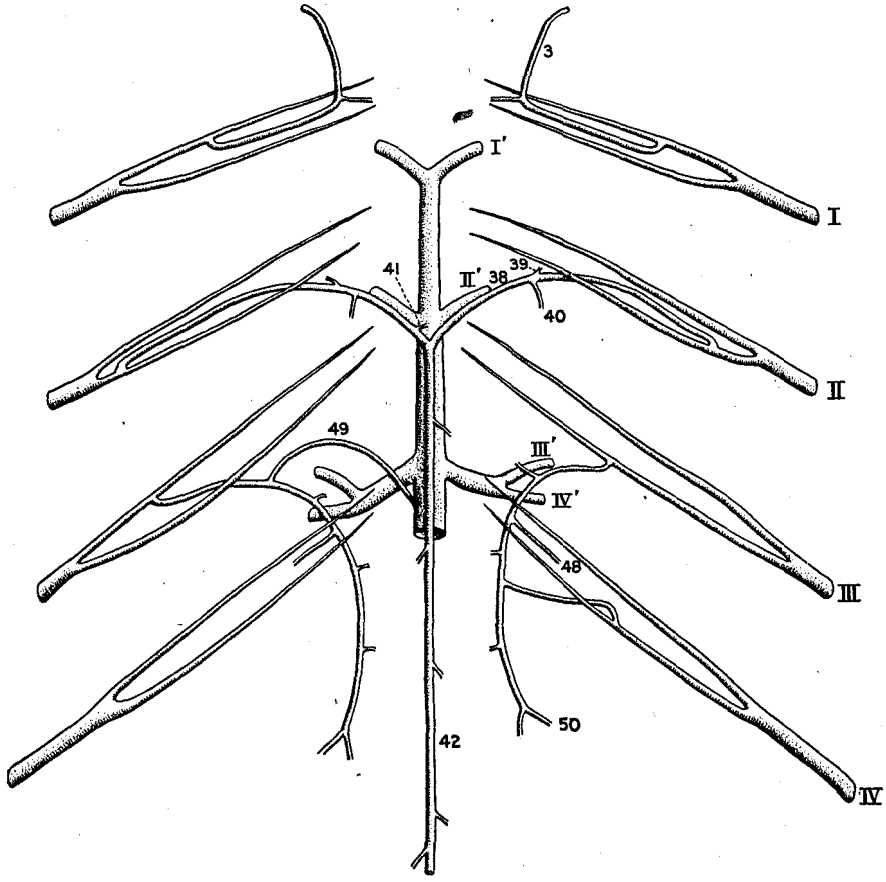

FIG. 12.—Ventral ends of the efferent branchial vessels and their branches in the tile-fish. Ventral aspect, ×2.

off from either the right or left side, and two pairs of nutrient branches which go to the fourth (*48*) and to the rudimentary fifth (*50*) branchial arch. In one case the vessel which supplied the rudimentary fifth arch was joined by a branch (*51*, fig. 12) from the left fourth efferent branchial artery; also, in one individual the fifth commissural artery was wanting, its place being taken by the sixth, which was present only on one side and arose from the fourth efferent branchial vessel.

Summing up the arrangement of these vessels in the tile-fish, it will be seen that the species possesses dorsal as well as ventral coronary arteries, a dorsal and

ventral median hypobranchial artery, fourth, fifth, and sixth commissural arteries, and indications of a lateral hypobranchial artery.

In individuals of the same species, as well as in species, teleosts show much variation as to the arrangement of their hypobranchial and commissural vessels, all tending to indicate a primitive condition, such as is found in the Elasmobranchii, where the ventral ends of all the efferent branchial arteries of each side are connected by means of a lateral longitudinal vessel—the lateral hypobranchial artery of Parker & Davis—and where vessels (commissural arteries) from these lateral hypobranchial arteries run toward the median line and unite to form the median hypobranchial artery. As Parker & Davis have pointed out, the usual arrangement of these vessels in teleosts is a single pair, the fourth commissural arteries running toward the median line, where they join to form the median hypobranchial artery. Parker (1899 and 1900), however, describes for *Mola* the presence of dorsal as well as ventral coronary arteries, and considers more than one pair of commissural arteries a remarkable condition not likely to be possessed by a teleost. The writer has found lateral hypobranchial arteries, as well as dorsal coronary arteries, in a number of teleosts in addition to *Mola*. In a kingfish (*Menticirrhus*) the ventral ends of the first, second, and third efferent branchial arteries were connected by a lateral hypobranchial, while in a tomcod (*Microgadus*, fig. 13) the ventral ends of all four of the efferent brancial arteries were connected. The third, fourth, and fifth pairs of commissural arteries were also present in this individual.

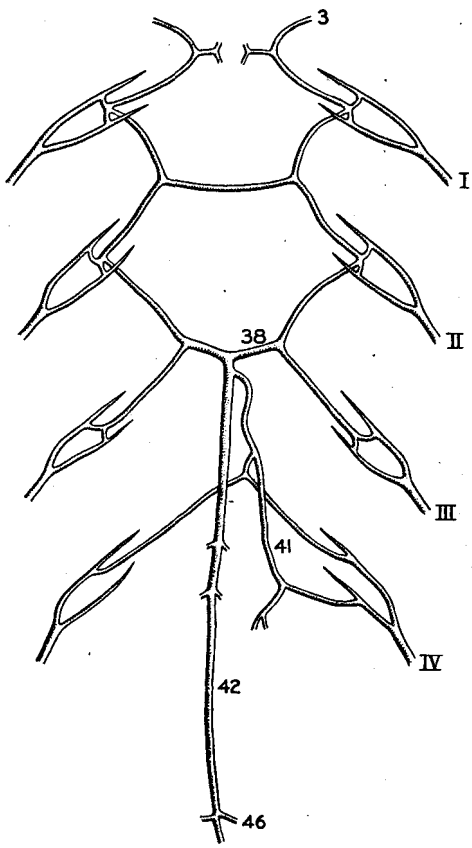

FIG. 13.—Ventral ends of the efferent branchial vessels and their branches in the tomcod. Ventral aspect, × 4.

The fourth efferent branchial artery (fig. 16, pl. I, and fig. 12). This artery, which as a rule has no branches, joins the third efferent branchial artery to form the second root of the dorsal aorta. A small artery (*53*) arises from the ventral surface of the second aortic root, and, running ventrad and laterad, divides into branches which supply the sides of the pharynx, superior pharyngeal teeth, and membranes on the rudimentary fifth branchial arch.

THE DORSAL AORTA AND ITS BRANCHES.

The dorsal aorta (fig. 16, pl. I, and fig. 15) is formed by the junction of the two pairs of aortic roots, and extends caudad along the ventral surface of the vertebral column in a series of undulations which correspond to the topography of the ventral

surface of the vertebral column. That portion of the dorsal aorta which runs in the abdominal region lies free, while that in the tail is inclosed by the hæmal arches.

The cœliacomesenteric artery. The cœliacomesenteric artery (*54*) is not, strictly speaking, a branch of the dorsal aorta, as it arises in common with the latter and the second right aortic root. It is an artery of considerable size, running caudad and dividing into numerous branches.

The first branch (*55*) arises about 1 cm. from the origin of the artery, runs caudad along the right dorsal surface of the œsophagus and right side of the stomach, and curves upon the ventral surface of the latter, where its main termination runs ventrad and caudad, in the gastrohepatic omentum, as the left hepatic artery (*61*). It gives off the following vessels: (a) Œsophageal branches (*56*) to the right side of the œsophagus; (b) the right ovarian or spermatic artery (*57*), which is given off at the junction of the œsophagus and stomach and runs directly caudad to supply the genital gland; (c) a small branch (*58*) which is given off on the ventral surface of the stomach and crosses the ductus choledochus to the central portion of the liver; (d) several small gastric branches (*59*), which run to the ventral surface of the stomach

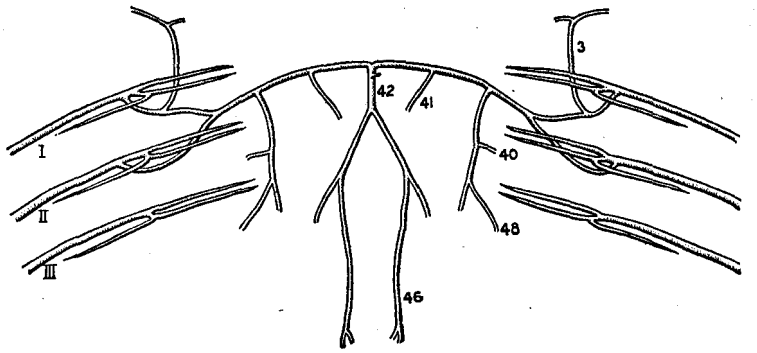

FIG. 14.—Ventral ends of the efferent branchial vessels and their branches in the goose-fish (*Lophius piscatorius*). Ventral aspect, × ½.

and proximal portion of the intestine, one or two of them usually anastomosing with a branch (*66*) of the second branch (*62*) of the cœliacomesenteric artery.

The second branch (*62*) of the cœliacomesenteric artery arises about 1 cm. caudal to the first. It runs caudad on the left dorsal surface of the œsophagus and left side of the stomach, dividing into a left spermatic or ovarian artery (*64*) which runs directly caudad to supply the genital gland of the left side, and into several gastric branches (*65*) which supply the left side of the stomach. As stated above, one or two of these gastric branches usually anastomose on the ventral surface of the stomach with a gastric branch (*60*) of the first branch of the cœliacomesenteric. The anastomosis of these two vessels (*60* and *66*) may form an artery (*67*) which runs in the gastrohepatic omentum close to the left hepatic artery (*61*), supplying a portion of the liver. The second branch of the cœliacomesenteric artery also sends out a small artery (*63*) to the left side of the œsophagus.

The third branch (*68*) of the cœliacomesenteric is a vessel of considerable size, given off about opposite the middle of the stomach, and itself giving off two branches (*69* and *70*), beyond which point it runs caudad to enter the swim-bladder at

the ventral surface and to break up into the rete mirabile. As already stated, it has two main branches, which are given off near its origin. The first is a gastric branch (*69*) and supplies a part of the left side of the stomach; the second is the right hepatic artery (*70*) which supplies the gall bladder and right side of the liver.

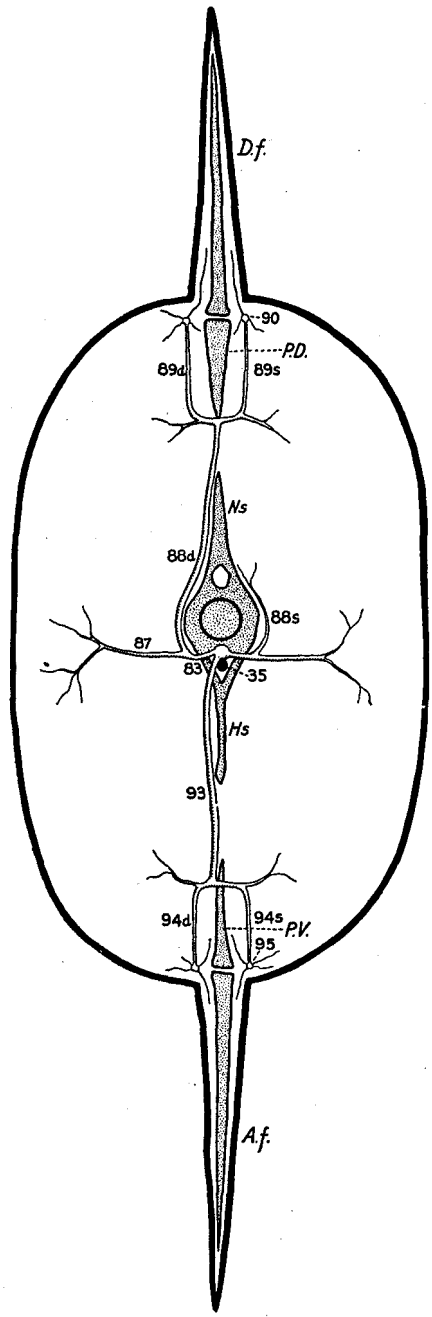

FIG. 15.—Diagrammatic cross section of body of tile-fish in tail region, showing arrangement of parietal arteries. Natural size.

The fourth branch of the cœliacomesenteric artery is the pancreatic artery (*71*). This is a small vessel which is given off about 1 cm. caudal to the third branch and almost immediately enters the pancreas.

Beyond its fourth branch the cœliacomesenteric artery continues caudad, passing to the right of the stomach to divide, at a point just cranial to the spleen, into four branches (*72*, *74*, *75*, *76*). The first branch, or gastrosplenic artery (*72*), runs ventrad along the cranial border of the spleen, which it supplies by a branch (*73*) immediately entering that organ. After a short distance the main trunk of the artery (*72*) divides into several branches, which supply the cæcal portion of the stomach and the distal loop of the intestine. The remaining three branches (*74*, *75*, *76*) are mesenteric arteries; two of them (*74*, *75*) supply the proximal portion of the intestine; the remaining one (*76*), which is the largest, runs caudad in the mesentary, and supplies the distal portion of the intestine and rectum.

Numerous variations occur in connection with the branching of the mesenteric vessels; for example, branches *74* and *75* often send twigs to the distal, as well as to the greater part of the proximal loop of the intestine.

The subclavian arteries (fig. 16, pl. 1). The subclavian arteries (*77*) arise in common from the ventral surface of the dorsal aorta just caudal to the origin of the cœliacomesenteric artery. They run laterad, caudad, and somewhat ventrad to the base of the pectoral fin, where they terminate in two branches, the brachial artery and the ramus epigastricus descendens of Müller (1839). They give off a number of branches:

(a) About 1 cm. from the dorsal aorta, a branch (*78*), which runs dorsad and

craniad, giving off a small branch to the cranial portion of the kidney, several branches to the muscles on the dorsal and caudal surface of the skull in the region of the supraoccipital bone, and finally, branches which terminate in the skin and cephalic crest. (b) A branch (*79*) which supplies the thymus gland[a] and adjacent muscles. (c) In addition to several small muscular branches, the coracoid artery (*80*) of Parker & Davis (1899) a short distance from the base of the pectoral fin, this vessel extending ventrad, close to the pericardium, and giving off numerous small muscular branches. At a point opposite the cranial end of the basipterygium, either the right or left coracoid artery joins the median hypobranchial. (d) The brachial artery (*81*) which supplies the pectoral fin. (e) The ramus epigastricus descendens (*82*), which runs caudad close to the skin and supplies the ventral abdominal muscles as far as the cloaca.

The parietal arteries and their branches (fig. 16, pl. 1, fig. 15). The parietal arteries (*83*) arise from the dorsal aorta along its entire length, a pair opposite every other vertebra. They will be described in order.

The first pair are given off, as a rule, opposite the third vertebra, and, one on each side, curve laterad, dorsad, and craniad, then, after sending small branches to the cranial portion of the kidney, run dorsad to supply the dorsal parietal muscles.

The second pair are given off opposite the fourth vertebra, and run laterad through the kidney, to which both send one or more small arteries (*84*). At a point just lateral to the kidney each of the pair divides into a peritoneal, an intermuscular, and a dorsal branch. The peritoneal branch (*85*) runs ventrad close to the peritoneum and supplies the lateral abdominal muscles of that region. The intermuscular branch (*87*) extends laterad along the intermuscular bone to supply the adjacent muscles. The dorsal branch of the left side (*88*s) is small and runs dorsad to the membranes and muscles adjoining the fourth vertebra; the corresponding artery of the right side (*88*d) is quite large and runs dorsad, between the neural spines of the fourth and fifth vertebræ, to the lower end of the pterygiophores of the dorsal fin, where it divides into several muscular branches, two of which run dorsad, one on the right (*89*d) and one on the left (*89*s). Close to the skin each of these two branches divides into an anterior and a posterior vessel, the anterior running craniad and supplying the skin, while the posterior runs caudad to anastomose with the corresponding anterior branch of the next dorsal artery. The pairs of dorsal branches are throughout bilaterally asymmetrical, the larger branches being sometimes on one side and sometimes on the other. The smaller branch of each pair supplies the structures adjacent to the vertebral column. The larger branch, as already described, sends off on each side of the base of the dorsal fin an anterior and a posterior vessel which anastomose, respectively, with the posterior and anterior corresponding adjacent arteries, thus forming a more or less continuous vessel (*90*) on each side of the base of the dorsal fin. These vessels send numerous small branches (*91*) to the skin and dorsal fin.

[a] The thymus gland of the tile-fish is situated in the dorsal part of the gill chamber just cranial to the supra-clavicle. In fishes of about 50 cm. in length it is a triangular gland about 17 mm. long and 9 mm. wide; in the large individuals—those of about 85 cm.—it is very much reduced in size, traces of it, however, being always present.

The third pair of parietal arteries are given off opposite the sixth vertebra and have the same branches as the second, described above, with the addition of a small branch to the swim-bladder. This additional branch (*86*) arises from the peritoneal branch of each parietal artery and immediately enters the swim-bladder to supply, with its fellow of the opposite side, the anterior dorsal portion.

The fourth pair of parietal arteries arise opposite the eighth vertebra and have branches corresponding to those of the third. The vessel to the swim-bladder, however, is larger than the corresponding branch from the third pair, and supplies the median dorsal portion.

Between the origin of the fourth and fifth parietal arteries, though but slightly anterior to the latter, the dorsal aorta sends a large branch to the kidneys. This vessel, the posterior renal artery (*92*), leaving the ventral surface of the aorta, runs caudad and ventrad in the posterior division of the kidney, which it supplies, and sends a branch also to the bladder. A short distance beyond its origin it gives off two vessels, each of which almost immediately divides into a peritoneal branch (*85*) and a branch (*86*) which supplies the posterior dorsal surface of the swim-bladder.

The fifth pair of parietal arteries is given off opposite the tenth vertebra, just caudal to the posterior renal artery, as stated above. Each divides into a dorsal and an intermuscular branch. The peritoneal branch belonging to this segment arises from the posterior renal artery, as already stated.

The dorsal aorta at this point leaves the abdominal cavity and continues as the caudal aorta, inclosed by the hæmal arches of the caudal vertebræ. It gives off, opposite alternate vertebræ, three branches, two lateral, one on each side, and a median ventral branch. Each lateral branch divides almost immediately into an intermuscular (*87*) and a dorsal artery (*88*). The ventral branches (*93*) arise as median vessels from the ventral surface of the caudal aorta. They run ventrad in front of the hæmal spines of their respective vertebræ and divide into right (*94*d) and left (*94*s) branches which run ventrad, one on each side of the pterygiophores of the anal fin. At the base of the anal fin each one of these branches divides into an anterior and a posterior branch. These anastomose with corresponding vessels, thus forming a continuous artery on each side of the base of the anal fin (*95*) in the same manner as do the dorsal branches at the base of the dorsal fin, these continuous arteries (*95*) giving off small branches (*96*) to the skin and fin. The first ventral branch of the caudal aorta, which is given off opposite the eleventh vertebra, is somewhat larger than the more caudally situated ventral branches, and its anterior branch extends craniad to supply the muscles around the cloaca.

The caudal aorta terminates in two branches which run dorsad and ventrad, respectively (*97*), in a groove at the base of the caudal fin, supplying the latter by means of numerous small branches (*98*).

THE VENOUS SYSTEM.

The veins (fig. 17, pl. 1) will be described in the following order:

I. The hepatic portal system.

II. The veins opening into the sinus venosus.

III. The veins opening into the Cuvierian ducts.

IV. The caudal vein and venæ advehentes of the kidney.

I. THE HEPATIC PORTAL SYSTEM.

The arrangement in the abdomen of the veins which form the hepatic portal vein is not at all constant. The order generally met with will be described.

At the base of the liver two main trunks (*41*, *50*) enter the large transverse hepatic portal vein (*40*) which distributes the blood through the liver. The larger of these two trunks (*41*) is formed by the union of the following vessels: (a) Branches from the rectum and distal portion of the intestine (*49*); (b) branches from the distal loop of the intestine (*47*) (principally from its left side); (c) a gastric branch (*46*) from the cæcal portion of the stomach; (d) a vein (*45*) from the spleen and distal loop of the intestine (principally right side) which joins the trunk opposite the right side of the stomach; (e) the small pancreatic vein (*44*), and a large vein (*43*) which leaves the ventral surface of the swim-bladder and returns the blood of the rete mirabile; and finally (f) a vein from the œsophagus (*42*) which joins the trunk just before it enters the liver. The second trunk, which helps to form the portal vein (*50*), returns blood to the liver from the greater part of the proximal loop of the intestine (*52*), and from the stomach by several gastric branches (*51*); it also, at times, receives branches from the distal loop of the intestine.

II. VEINS OPENING INTO THE SINUS VENOSUS.

A. The hepatic veins (*2*), which are two in number, leave the right and left segments of the liver, one on each side of the median line, and empty immediately into the sinus venosus.

B. A large vein (*4*) from each side opens into the ventral surface of the sinus venosus near the Cuvierian duct. This vessel is formed by the union of the following three veins: (a) The brachial branch (*5*), which returns blood from the pectoral fin and from the anterior part of the lateral muscles of the abdomen (*6*); (b) a vessel (*7*), which returns blood from the ventral fin and adjacent muscles, and (c) a vein (*8*), which returns blood from the thyroid gland and muscles ventral to the ventral aorta. Sometimes this latter vein (*8*) unites with its fellow of the opposite side by a small trunk (*9*) just below the ventral aorta. These three veins (*5*, *7*, and *8*) run close to the pericardium and, after uniting to form a single vessel on each side of the heart, open into the sinus venosus, as described above.

C. The Cuvierian ducts (*3*) open into the lateral extremities of the sinus venosus. They are two large vessels, about 2.5 cm. in length, situated on each side of the œsophagus just behind the fifth branchial arch.

III. THE VEINS OPENING INTO THE CUVIERIAN DUCTS.

A. The inferior jugular vein (*10*), a large single vessel, its cranial end situated in the median line, returns blood from the lower jaw and floor of the mouth. Just caudal to the hypohyal, it receives two veins (*11*), one from each side, which return blood from the branchiostegal and ceratohyal regions, and, continuing caudad just dorsal to the ventral aorta, it curves to the right of the heart, close to the pericardium, and opens into the right Cuvierian duct near its junction with the sinus venosus.

B. The spermatic or ovarian veins (*13*), which return blood from the genital organs, run craniad in the abdominal cavity, emptying posteriorly into the Cuvierian ducts.

C. The jugular veins (*15*), two large vessels, one on each side, return blood from the head region. Behind the orbit each jugular vein is situated directly dorsal to the branchial arches and between the base of the cranium and the hyomandibular bone.

Branches of the jugular vein.—(a) The most cranial tributaries of the jugular vein are vessels (*26*) that return blood from the upper jaw and contiguous structures.

(b) About 1 cm. in front of the orbit the jugular receives a vein (*25*) from the olfactory organ and adjacent tissue.

(c) Ventral to the middle part of the orbit it receives the facial vein (*22*), which is formed by the union of a vessel (*24*) from the angle of the mouth and the m. adductor mandibulæ, and a branch (*23*) which returns blood from the operculum.

(d) Directly behind the orbit the right and left jugular veins are connected by the transversely situated interorbital vein (*19*). This vessel (*19*), which is about 2.5 cm. in length, arches between the two jugulars and in the median line receives the cerebral vein (*21*), which returns blood from the brain. It also receives the ophthalmic veins (*20*), which, one on each side, leave the eye at a point near the entrance of the optic nerve, and after passing between the rectus superior and externus usually receive branches from the eye muscles and open into the interorbital not far from the jugular. Sometimes, however, the vessels from the eye muscles open directly into the interorbital vein.

The jugular vein from this point continues caudad, partly surrounded by the cranial end of the kidney (K′), from which it receives branches, and opens into the dorsal end of the Cuvierian duct with the posterior cardinal vein of the same side. Three important vessels enter the cranial end of the kidney to empty into the jugular vein: The postorbital vein (*18*), which returns blood from the muscles of the head behind the orbit; the pharyngeal vein (*17*), which returns blood from the superior pharyngeal teeth, the muscles, and contiguous structures dorsal to the branchial arches; and a vein (*16*), which returns blood from the thymus gland, muscles, and membranes on the outer surface of the clavicle. These three veins (*16*, *17*, and *18*) enter the cranial end of the kidney, and, after giving off several venæ advehentes, usually unite to form a single vessel, which opens into the dorsal surface of the jugular vein.

D. The posterior cardinal veins (*14*) lie immediately ventral to the vertebral column, embedded in the substance of the kidney, and are asymmetrically developed. The left (*14*s) is small and its cranial portion, which is about 3 cm. long, functions as a vena revehentis renalis. The right cardinal vein (*14*d) is a vessel of considerable size; it receives at its caudal end a large vein (*37*) from the posterior division of the kidney, a connecting trunk (*36*d) from the caudal vein, and revehent branches from the kidney, as well as branches directly from the parietal veins; it then empties with the corresponding jugular vein into the right Cuvierian duct.

IV. THE CAUDAL VEIN AND VENÆ ADVEHENTES RENALES.

The caudal vein (*35*) is situated in the hæmal canal just ventral to the caudal aorta. After receiving branches from the caudal fin (*39*) it collects blood from the tail region by means of ventral (*38*), dorsal (*29*), and intermuscular (*30*) veins. These are received opposite every other vertebra, and alternate with the arteries. After leaving the hæmal arches at the caudal extremity of the kidney the caudal vein divides into a right (*36*d) and a left (*36*s) branch. The right branch is short (*36*d) and opens directly into the right cardinal vein. The left branch (*36*s) runs forward in the substance of the kidney as an advehent vein, which, according to Parker (1884), is the remains of the posterior portion of the left cardinal vein.

Four veins empty into the enlarged posterior division of the kidney, two from each side of the body. The posterior pair (*34*) return blood from the ventral muscles just behind the cloaca, while the anterior pair (*33*) return blood from the posterior lateral muscles of the abdomen.

The parietal veins in the abdominal region consist of dorsal, intermuscular, and peritoneal branches. The dorsal (*29* to *29''*) and intermuscular branches (*30*) are received opposite every other vertebra, alternating with the arteries. The peritoneal branches (*31*) return blood from the lateral walls of the abdomen, and, in addition, each peritoneal vein receives a vessel (*32*) from the dorsal surface of the swim-bladder. The parietal veins in the abdominal region either enter and break up in the substance of the kidney as venæ advehentes (*31'*) or, after sending out advehent branches, connect directly with the right cardinal vein (*31*).

REFERENCES TO FIGURES.

d. and s. denote *dextra* and *sinistra*, respectively.
A., auricle.
Af., anal fin.
Ar^1., first aortic root.
Ar^2., second aortic root.
B., branchial arch.
Ba., bulbus arteriosus.
Da., dorsal aorta.
Df., dorsal fin.
E., eye.
Hs., Hæmal spine.
K., kidney.
K'., cranial portion of kidney.
L., liver.
Ns., neural spine.
Œs., œsophagus.
P. D., pterygiophore of dorsal fin.
Ps., pseudobranch.
P. V., pterygiophore of anal fin.
V., ventricle.
Va., ventral aorta.

ARTERIAL SYSTEM.

I' to IV'. First to fourth afferent branchial arteries.
1. Recurrent branch to ventralmost filaments.
I to IV. First to fourth efferent branchial arteries.
I. First efferent branchial artery.
2. Branch for dorsalmost filamentar vessels.
3. Hyoidean artery.
4. Muscular branch.
5. Nutrient branch to first gill arch.
6. Lingual artery.
7. Branch to branchiostegal membrane and rays.
8. Muscular branch to angle of mouth.
9. Opercular branch.
10. Afferent pseudobranchial artery.

11. Small muscular branch.
12. Direct afferent pseudobranchial artery.
13. Connection between direct afferent pseudobranchial and hyoidean arteries.
(*14.* Efferent pseudobranchial artery or ophthalmic artery.)
(*15.* Anastomosing trunk between the two ophthalmic arteries.)
16. Carotid artery.
17. Hyoöpercular artery.
Branch which divides into *19* and *20.*
19. To m. adductor mandibulæ.
20. Branch which joins the hyoidean artery.
21. Muscular branch to adductor and levator operculi.
22. Divides into *23* and *24.*
23. Supra-orbital branch.
24. Post-orbital branch.
25. Internal carotid artery.
26. Carotis interna impar.
Anterior cerebral artery.
Posterior cerebral artery.
29. External carotid artery.
30. Artery to rectus externus and superior.
31. Ocular artery.
32. Artery to rectus internus and inferior.
33. Small artery to membranes lining orbit.
34. Oblique artery.
35. Olfactory artery.
36. Branch in region of maxilla.
37. Superior dental artery.
II. Second efferent branchial artery.
38. Fourth commissural artery.
39. Nutrient artery to second gill.
40. Nutrient artery to third gill.
41. Coronary artery.
42. Median hypobranchial artery.
43. Thyroid artery.
44. Muscular branch.
45. Muscular branch at ventral end of clavicle.
46. To ventral fins.
III. Third efferent branchial artery.
47. Fifth commissural artery.
48. Nutrient artery to fourth gill.
49. Dorsal coronary artery.
50. Nutrient branch to rudimentary fifth branchial arch.
51. Sixth commissural artery.
52. Dorsal median hypobranchial artery.
IV. Fourth efferent branchial artery.
53. Artery to superior pharyngeal teeth and membranes behind rudimentary fifth gill arch.
54. Cœliacomesenteric artery.
55. First branch which sends out the following six branches:
56. Right œsophageal artery.
57. Right genital artery.
58. Hepatic branch.
59. Gastric and intestinal branches.
60. Branch which anastomoses with *66.*
61. Left hepatic artery.

62. Second branch of the cœliacomesenteric artery.
63. Left œsophageal artery.
64. Left genital artery.
65. Left gastric branch.
66. Branches of the latter which anastomose with *60* to form
67. Hepatic artery.
68. Artery to rete mirabile of swim-bladder.
69. Gastric branch.
70. Right hepatic artery.
71. Pancreatic artery.
72. Gastrosplenic artery.
73. Splenic artery.
74. Mesenteric branch.
75. Mesenteric branch.
76. Mesenteric branch.
77. Subclavian artery.
78. Muscular branch.
79. Artery to thymus gland.
80. Coracoid artery.
81. Brachial artery.
82. Ramus epigastricus descendens.
83. Parietal arteries.
84. Renal branches.
85. Peritoneal branches.
86. Branches to swim-bladder.
87. Intermuscular arteries.
88. Dorsal branch.
89. Branch on side of pterygiophores of dorsal fin.
90. Longitudinal vessel formed on each side of body at base of dorsal fin.
91. Branch to skin and dorsal fin.
92. Posterior renal artery.
93. Ventral branches.
94 d. and *s*. Right and left branches of *93*.
95. Longitudinal vessels.
96. Branch to anal fin and skin.
97. Bifurcation of caudal aorta.
98. Branches to caudal fin.

VENOUS SYSTEM.

1. Sinus venosus.
2. Hepatic vein.
3. Ductus Cuvieri.
4. Vein which receives blood from *5*, *7*, and *8*.
5. Brachial vein.
6. Branch from lateral abdominal muscles.
7. Vein from ventral fin.
8. Vein from thyroid gland and muscles ventral to the ventral aorta.
9. Anastomosing trunk.
10. Inferior jugular vein.
11. Vein from branchiostegal regions.
12. Vein from teeth of lower jaw and floor of mouth.
13. Genital vein.
14. Posterior cardinal vein.
15s. Left jugular vein.

16. Vein from thymus gland and contiguous muscles.
17. Pharyngeal vein.
18. Postorbital vein.
19. Interorbital vein.
20. Ophthalmic vein.
21. Cerebral vein.
22. Facial vein.
23. Branch from inside of operculum.
24. Branch from m. adductor mandibulæ and angle of mouth.
25. Vein from nose and adjacent region.
26. Vein returning blood from lips and teeth of upper jaw.
27. Venæ advehentes of kidney.
28. Venæ revehentes of kidney.
29, *29′*, *29″*. First, second, and third dorsal branches of parietal veins.
30. Intermuscular veins.
31. Peritoneal veins.
32. Veins from dorsal surface of swim-bladder.
33. Vein from lateral abdominal muscles.
34. Vein from muscles behind the cloaca.
35. Caudal vein.
36d. Connection between caudal vein and the right postcardinal.
36s. Left branch of caudal vein.
37. Venæ revehentes of the posterior enlarged portion of kidney.
38. Ventral parietal branches.
39. Branches from caudal fin.
40. Hepatic portal vein.
41. Branch which receives the following eight veins (*42* to *49*, incl.):
42. Oesophageal branch.
43. Vein from of rete mirabile of swim-bladder.
44. Pancreatic vein.
45. Vein from spleen and intestine.
46. Gastric branch.
47. Intestinal branch.
48. Branch of proximal loop of intestine.
49. Branch from distal portion of intestine.
50. Branch from stomach and proximal portion of intestine.
51. Gastric branch.
52. Vein from proximal loop of intestine.

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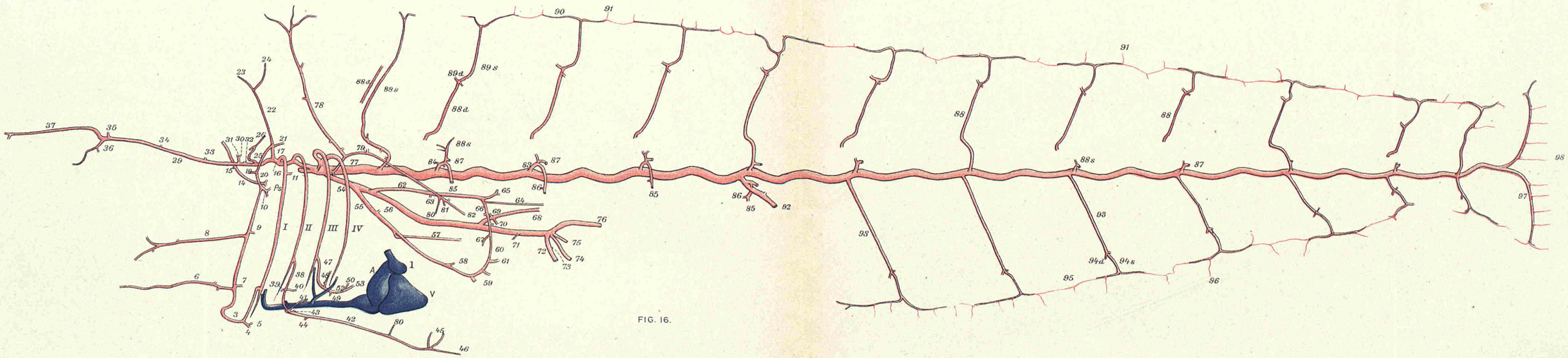

FIG. 16.

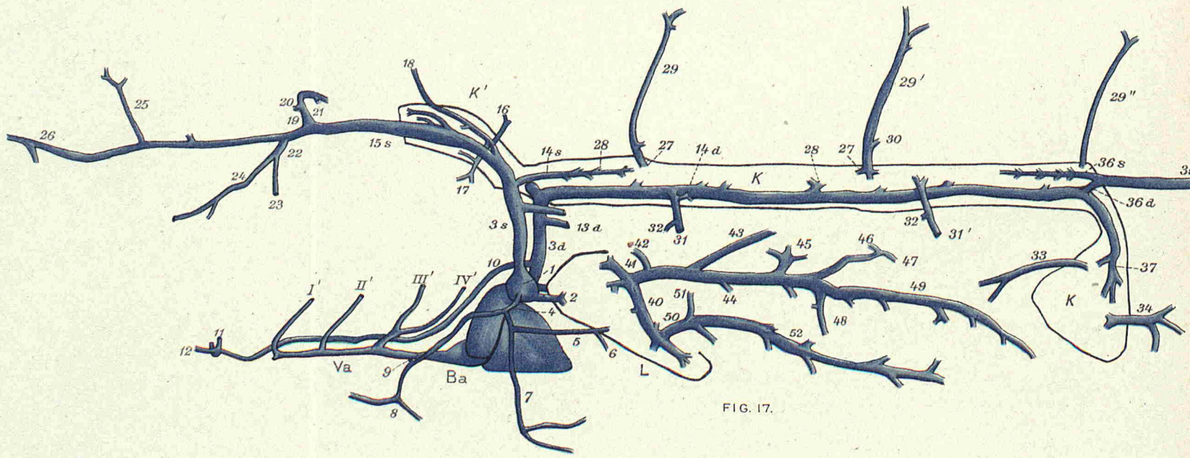

FIG. 17.

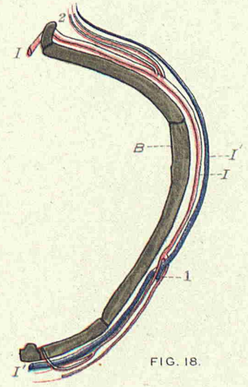

FIG. 18.

LOPHOLATILUS CHAMÆLEONTICEPS.

(NATURAL SIZE.)

FIG. 16. ARTERIAL SYSTEM VIEWED FROM LEFT SIDE.