XXVII. *Additions to an Account of the Anatomy of the Squalus Maximus, contained in a former Paper; with Observations on the Structure of the Branchial Artery. By Sir* Everard Home, *Bart. F. R. S.*

Read June 24, 1813.

My former account was taken from a Squalus Maximus caught at Hastings, in November, 1808, and the parts which I examined were brought to London by Mr. Clift, who went down, at my desire, to dissect them; but the weather being stormy and cold, the fish was brought no further than the beach, so that the examination was conducted under great disadvantages, and the parts brought away were in a mutilated state. The sketch of the fish made upon the spot by Mr. Clift is now found to be generally correct, except the omission of a small fin between the anus and tail, which had been buried by the weight of the fish in the sand.*

Two fishes of the same species have since been caught at Brighton, and one of them was brought to London in December, 1812, which I had an opportunity of examining, assisted by Mr. Clift. It is not my intention, on the present occasion,

* The omission of this small fin in the drawing is an error of considerable importance, as it deprived the fish of one of its characteristic marks, and has led naturalists, who have since had the opportunity of examining other specimens with more accuracy, to conclude that this fish was a distinct species from those which they described; I am therefore particularly desirous to correct the mistake.

to enter into minutiæ, but to render my former account more complete, and apply the dissection of this large fish to its proper use in comparative anatomy, which is, by means of it, to illustrate the functions of the organs of fishes of an ordinary size.

In addition to my former description of the fins, I have now annexed a drawing (Pl. XVI.) which shews the structure of the pectoral fin, a beautiful example of the mechanism of the fins of cartilaginous fishes in general.

The stomach was examined in its entire state, and the annexed drawing (Pl. XVII.) is an accurate representation of the appearance of its internal surface, which is exposed in one view, shewing that the pyloric portion is longer and narrower than I had before represented it.

The situation of the pancreas is correctly noticed in my former paper; the gland is oblong, thick and round where it is attached to the duodenum, and becoming thin, flat, and bifid towards its loose extremity.

The ducts of the liver are six in number, and inclosed in a broad flat band, which passes obliquely down before the stomach, till it is connected to the duodenum; each of the ducts opens, by a separate oblique orifice, into a common cavity of an oval form, from which there is a direct opening into the duodenum. This swell or enlargement might be considered as a substitute for the gall-bladder, which is wanting, were it not that a similar enlargement is also met with in fishes which have one. In the cod there is the same dilatation, and the hepatic ducts open into it in the same oblique manner; but there is also a gall-bladder, and the cystic duct, as well as the others, terminates in this dilatation.

The oblique openings of the hepatic ducts in the Squalus

Maximus, being so different from those of quadrupeds, explain the general principle on which the hepatic ducts in fishes, whose livers are loaded with oil, are formed. The substance of their liver is so exceedingly tender, that this contrivance is employed to prevent the bile from being forced back into the liver, which is not found necessary in the solid livers of land animals.

The heart was particularly examined, and the annexed drawing (Pl. XVIII.) shews its internal cavities, and the valves of the branchial artery; more particularly a muscular structure met with in the coats of that vessel, extending for some way after it leaves the ventricle.

The situation of the kidneys is mentioned in my former account; the ureters open into the cavity, common to the urine and semen, by two orifices, three quarters of an inch in diameter.

The structure of the body of the testicles had been destroyed; the epididymis consisted of innumerable convolutions of a tube three-eighths of an inch in diameter, at the upper part coiled up into two or three lobes or masses, which could not be unravelled, from which the vas deferens went off, making irregular convolutions down towards the anus. The lower part for three feet in length is straight, and the canal seven inches in diameter, having broad valvulæ conniventes; the widest are near the termination, and are two inches and a half broad. The contents of this portion, as I have remarked in my former paper, are different from those of the epididymis, and upper portion of the vas deferens, being a substance like starch broken down into rounded portions in a thinner fluid.

This circumstance leads to the idea, that the straight portion

of the vas deferens is analogous to the vesiculæ seminales of other animals, secreting its own fluid with which the semen is to be mixed before it enters the penis, and the valvulæ conniventes form a surface from which this secretion probably takes place.

It is deserving of observation, that the epididymis and vas deferens were loaded with semen, which there is reason to believe is not the case in quadrupeds, unless immediately previous to the act of copulation; but in fishes, where the connexion between the sexes is less complete, the semen appears to be prepared at a more early period.

The openings from the vasa deferentia are situated on each side, four inches higher up than those of the ureters, rounded in form, and kept closed by the pressure of two oviform ligamentous substances; these openings readily admit of dilatation, so that the hand can pass into them.

The penis has an infundibular form, and terminates by an oblique aperture about three inches in circumference.

The holders correspond with those of the dog-fish, which upon another occasion have been described to the Society; the spur bears a striking resemblance to that of the male ornithorhynchus paradoxus. There is a canal in each holder communicating with a corresponding cavity between the skin and muscles of the abdomen, eleven feet long and two wide. The inner surface of this cavity is smooth, almost polished, and of a beautiful white colour; it contained a white mucus, extremely viscid and tenacious.

Opportunities of examining the brain of a fish of such magnitude are of rare occurrence; I have therefore not only given drawings of the brain, (Pl. XIX, XX.) but also one

of the brain of a Squalus Acanthias, (Pl. XXI.) that the two may be compared together, with a view to shew the relative size of the parts, one belonging to a shark of thirty feet, the other to one of three feet long.

In the brains of what we consider the animals of greatest intelligence, there is a cerebrum, cerebellum, and medulla oblongata; beneath the cerebrum there are the tubercula quadrigemina. In fishes, the cerebrum is wanting, and there is no part at all analogous to it, unless we consider the enlargements, from which the olfactory nerves arise, to be of that description.

These enlargements are separated from the other parts of the brain by the optic nerves going off in a transverse line between them and the tubercula quadrigemina. In the present specimen, unfortunately, not only the enlargements from which the olfactory nerves go off, were destroyed; but also a portion of each of the anterior tubercula quadrigemina: the cerebellum was, however, entire, and is represented of the natural size.

The brain does not occupy more than one-third of the cranium. The medulla spinalis is large in proportion to the brain. From the termination of what corresponds to the calamus scriptorius in the human brain, a fissure extends on the upper part of the medulla spinalis, dividing it longitudinally into two portions; there is a similar fissure on the anterior surface; into both of these a thin fold of pia mater extends and adheres with firmness to the surfaces with which it comes in contact.

The dura mater is very dense, and adheres firmly to the inner surface of the cranium and theca vertebralis. The pia

mater nearly resembles that of the human brain; it becomes thicker where it covers the spinal marrow. The space between the dura and pia mater is occupied by a cellular membrane of a very fine texture.

As the different parts of the brain are described in the explanation of the drawing, I shall only remark in this place, that the circumstance most deserving of observation respecting it is, that the cerebellum has an increase of size in the Squalus Maximus in a much greater degree beyond that of the Squalus Acanthias than the tubercula quadrigemina. The protuberances from which the olfactory nerves arise were probably large in the same proportion with the tubercula; at least, in the brain of a shark, preserved in the Hunterian Collection, of a smaller size than that of the Squalus Maximus, but much larger than that of the Squalus Acanthias, that is the case.

The eye is small for the size of the fish; the ball has projections on the sclerotic coat, where the muscles are attached, which make it approach to a quadrangular form; but its internal cavity is circular. The circumference in the widest part is nine inches. The longest diameter three inches, the shortest one inch and three quarters. The sclerotic coat is cartilaginous, one quarter of an inch thick on the posterior part, becoming thinner towards the ciliary processes, where it is only one-sixteenth of an inch.

The cornea is thin, but made up distinctly of three layers, of which the middle one is by much the thinnest. The optic nerve is nearly of the size of the sixth pair, and, where it perforates the sclerotic coat, projects a little before it gives off the retina, which is extremely thin.

The choroid coat is covered with a tapetum lucidum of the

colour of an amalgam of silver broken into small portions. There are ciliary processes, not common to fishes in general; they are about one-third of an inch in extent, and slightly projecting; they are lined with a black pigment.

The vitreous humour is unattached to the choroid coat; it is inclosed in strong cells, and the crystalline lens, which is spherical and one inch in diameter, is imbedded in it for two-thirds of its substance. In the Tetrodon Mola, which, as well as the Squalus Maximus, in common language has been called the Sun-fish, the vitreous humour has a firm attachment to a groove in the choroid coat one-twelfth of an inch in breadth, extending from the entrance of the optic nerve to the termination of the retina, in the shortest line from the one to the other, and there are no ciliary processes; two such remarkable differences in eyes of nearly the same size, appeared to be deserving of being noticed.

The cartilage upon which the ball of the eye rests is attached to the bottom of the orbit, and is seven inches and a half long; its stem is a flattened cylinder, five-eighths of an inch in diameter; it terminates in a broad concave surface in a transverse direction adapted to the bottom of the ball of the eye, and is connected to the sclerotic coat by a ligament long enough to admit of motion.

There are four straight and two oblique muscles; the straight very large, much beyond what can be required merely to move so small an eye: the rectus internus and externus are strongest, they are five inches in circumference, while the superior and inferior are only three and a half.

In the structure of the ear, the only remarkable circumstance is the great capacity of the cavities in which the semi-

circular canals are contained, the canals themselves not being much larger than in the skate. They are shewn in the drawing. In the recent subject they were pellucid, containing a transparent fluid.

On the Structure of the Branchial Artery.

The muscular structure of the branchial artery of the dog-fish, and the direction in which that artery leaves the ventricle, are exactly the same as in the Squalus Maximus, only are seen upon so small a scale, that they do not arrest our attention; but when magnified, to the size which they acquire in this fish, they make a stronger impression on the mind, and force us irresistibly to enquire into their use.

This direction of the artery appears to be common to fishes in general; but the muscular structure is confined to particular tribes. I find it is common to all the sharks, and there is a similar structure in the sturgeon.

In the wolf fish, the Anarchichus Lupus, the muscular structure of the branchial artery is nearly the same; but the valves are placed close to the opening of the ventricle, and are only two in number.

In the turbot there is no muscular structure in this part of the artery; but the coats are extremely elastic, and admit of being very considerably dilated, particularly at its origin, where three valves are placed, and so contrived that the dilatation of the artery makes them shut more closely.

In the Lophius Piscatorius, there is no appearance of muscularity in the coats of the branchial artery, and no lateral valves as in other fishes; but there is a muscular tube half

an inch long, rising from the edge of the opening of the ventricle which projects into the artery.*

These different structures, so very unlike one another, and bearing no resemblance to the mechanism of the same parts in quadrupeds, make it probable, that the circulation through the gills is impeded by the external pressure of the water, in different degrees according to the depth of the fish from the surface: therefore in those fishes which frequent great depths, as the Squalus Maximus and all the shark tribe, there is a muscular structure in the coats of the branchial artery, which, when the fish is deep in the water, by its contraction diminishes the area of the vessel, and makes the valves perform their office; but when the fish is near the surface, this muscular structure, by its relaxation, renders the area of the artery so wide, that regurgitation of the blood takes place into the ventricle, and prevents the small vessels of the gills from being too much loaded.†

In fishes that swim deep, and do not come to the surface, as the wolf fish, the regurgitation does not take place into the ventricle; but the relaxation of this muscular portion of the artery allows it to dilate, and form a reservoir, and the valves remain closed, so as to prevent more blood leaving the ventricle. In fishes residing at moderate depths, as the turbot, elasticity is employed as a substitute for muscular power, there being less variation in the pressure made upon the gills; but in the Lophius Piscatorius, which probably never descends into

* This structure, which it is difficult to describe, will be better understood by a reference to the annexed drawing. (Pl. XXII.)

† That such regurgitation takes place when the muscle is relaxed, is ascertained by the ventricle being readily injected after death with common wax injection from the artery, the valves allowing it to pass.

water of much depth, the ventricle is so weak, that the supply of blood to the gills is regulated by the contraction and relaxation of a muscular valve.

As water, according to the degree of pressure upon it, is capable of containing a greater quantity of atmospherical air, than under ordinary circumstances, such a supersaturated state of the water might compensate, with respect to the respiration of fishes, for the difficulties, which occur at great depths, of forcing the blood through the vessels of the gills: I enquired what evidence could be produced, of the water at great depths containing a more than ordinary quantity of air; my philosophical friends, to whom I proposed this question, said, that it was a point that had not been considered. I therefore resolved to put it to the test of experiment, and as I knew there was a well at Mr. Coutts's in the Strand, which more than twenty-five years ago had been sunk four hundred feet below the surface of the water in the Thames, I requested permission to make the experiment in that well. A cylindrical vessel, with a valve above and below, was let down to the depth of one hundred and eighty-six feet, which is now the depth of the well; it came up full of clear water, which Mr. W. Brande ascertained to contain no greater proportion of atmospherical air, than is met with in common river water. It therefore appears that the supply of air to fishes is nearly the same at whatever depth they are from the surface.

Besides the guards which have been mentioned, to prevent the circulation through the gills from being improperly carried on, in particular tribes of fishes, the ventricle itself is so formed, and is so situated with respect to the auricle, that the blood received is first impelled in a direction nearly at right

angles to that of the artery, and then another set of muscles is employed to force it into the artery.

This mechanism, common to most fishes, and so different from what is met with in land animals, where the blood is forced by the action of the left ventricle into the different parts of the body, appears to be intended to prevent too great a force being employed, at any one time, in impelling the blood through the gills.

Having traced in these different gradations the guards upon the circulation through the gills in fishes, I am led to extend my remarks to the hearts of a lower class of animals. In the Mollusca there is no reason for putting guards upon the action of the heart, as in fishes, because in them the blood first supplies the different parts of the body, and only in its return passes through the gills; but there is a regulation of another kind, by means of which the circulation is increased or diminished, according to the activity or torpor of the animal. In the teredines, where a boring engine, requiring a great muscular power to work it, is almost constantly employed, the heart consists of two auricles and two ventricles; the auricles strong, cylindrical, and having valves between them and the ventricles; the ventricles themselves very strong, so that in fact there is a heart, composed of two auricles and two ventricles, both acting at the same time, and the blood is hurried on by a double power to supply the muscles of the boring shells, and, in this part of its course, has a bright red colour.

In the Oyster, on the other hand, the heart consists of only one auricle and one ventricle, both very weak in their muscular power, when compared with those of the teredines, although belonging to an animal of larger dimensions; but the heart is

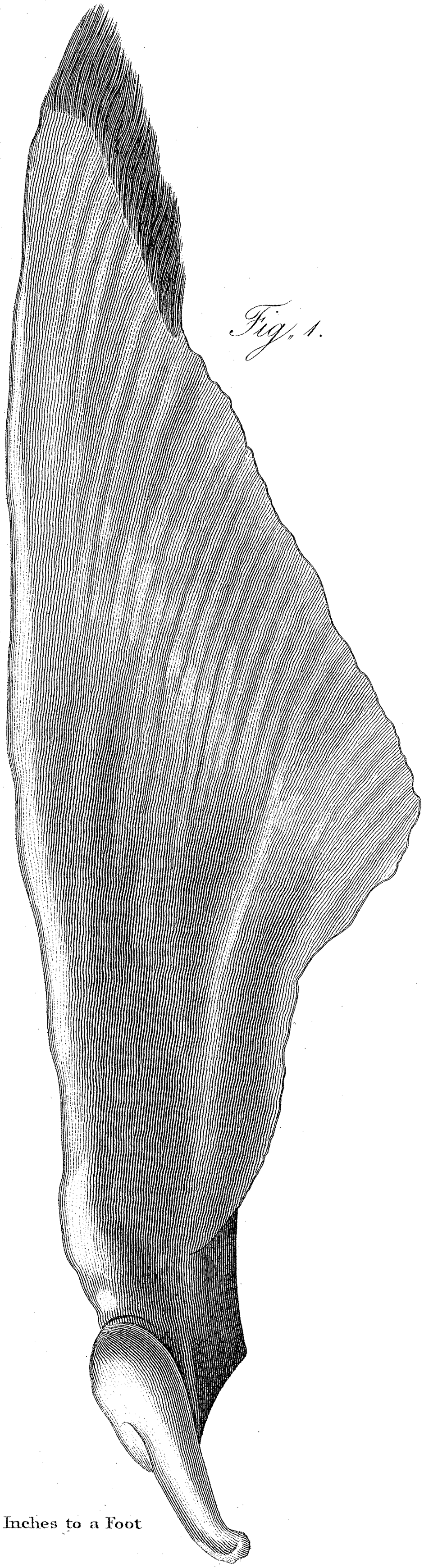
laterally connected to the great muscle that shuts the shell, so that whenever that muscle is actively employed, its lateral swell presses against the heart, and forces out the blood, and by this means gives activity to the circulation, at the only time in which an increased circulation is particularly required.

In the Muscle, the heart can hardly be said to be distinctly divided into auricle and ventricle; but to consist of an oval bag, through the middle of which the lower portion of the intestine passes. Two veins from the gills open into the heart, one on each side, these may be considered as the auricles.

The coats of the ventricle are very thin, so as to have little power of propelling the blood; but this weakness appears to be compensated by the effect of the contraction and relaxation of the intestine contained in their cavity. This circumstance renders it probable, that the circulation goes on with activity while the processes connected with digestion are employed; but when the intestines are empty, there being no supply of nourishment, the circulation is not only very languid, but may possibly be entirely stopped.

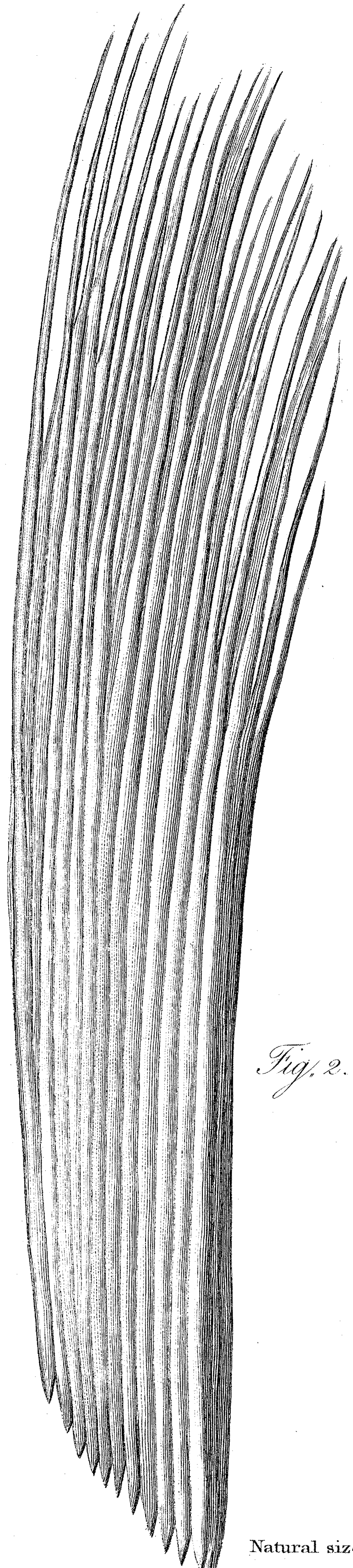
In the caterpillar, the blood cannot be said to circulate, but is carried from one end of the animal to the other, in a tube which may be either called heart or artery, by a species of peristaltic motion. This ebbing and flowing of the blood, if such a term can be admitted, is greatly increased by the pressure upon the different portions of this tube, produced by the action of muscles employed in the progressive motion of the animal, so that the supply of blood to the different parts of the body is proportioned to the demand, which arises out of the bodily exertions.

Fig. 1.



Two Inches to a Foot

Fig. 2.



Natural size

J. Howship del. J. Basire sc.

One Inch to a Foot.

Fig. 1.

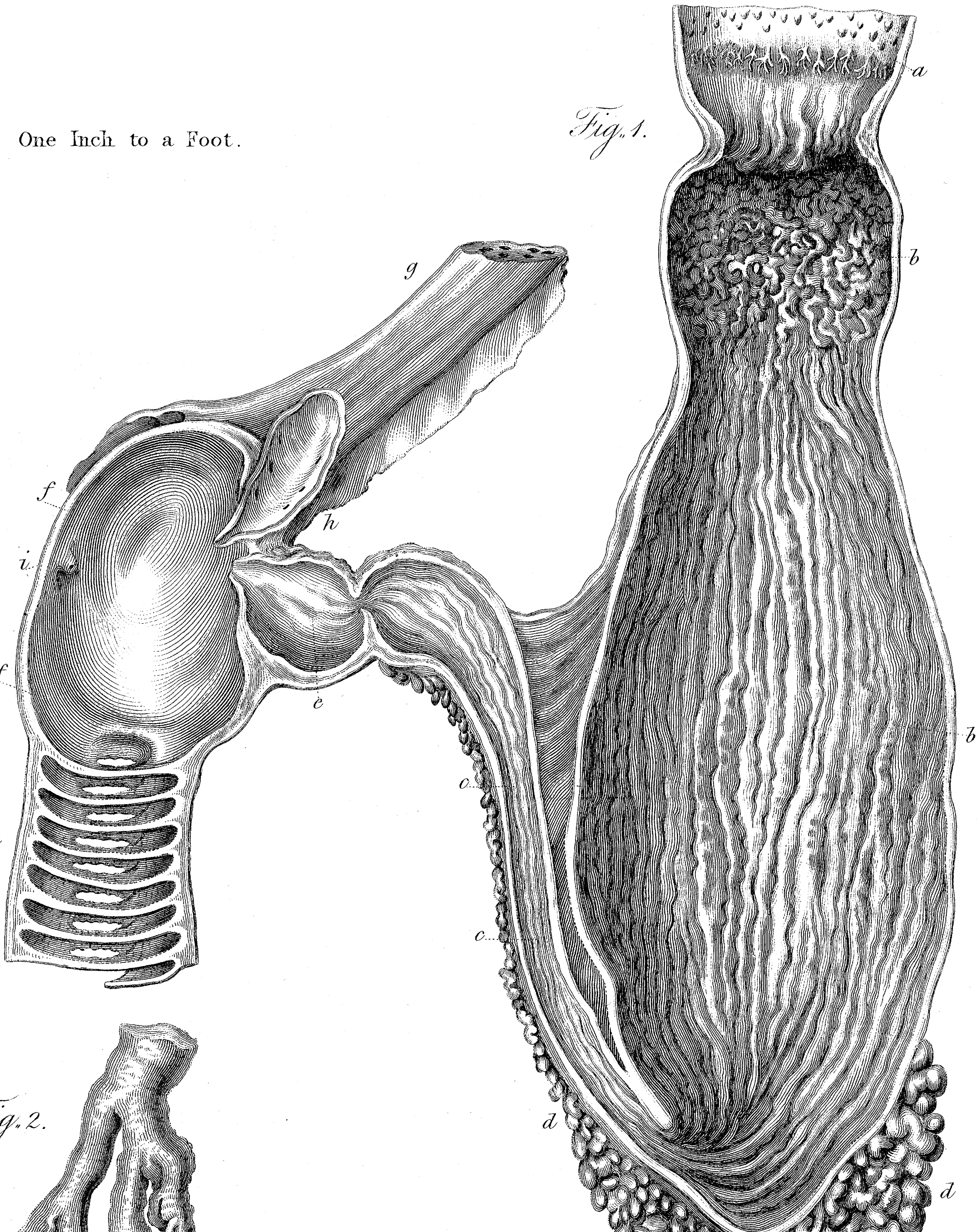
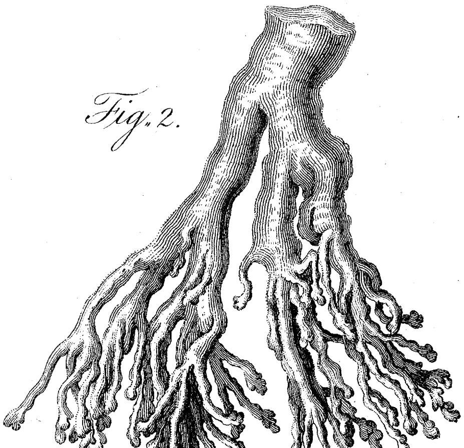


Fig. 2.



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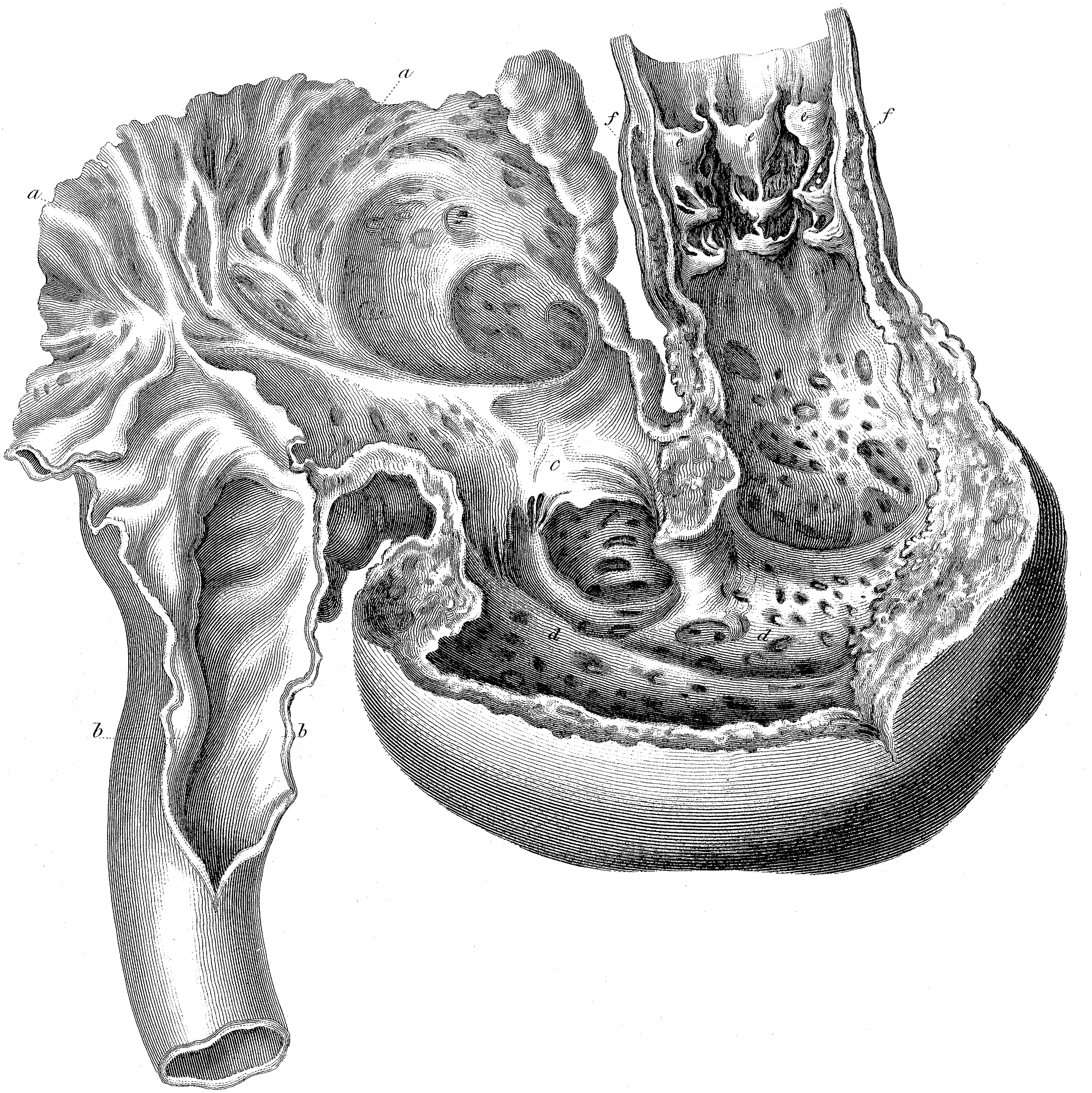

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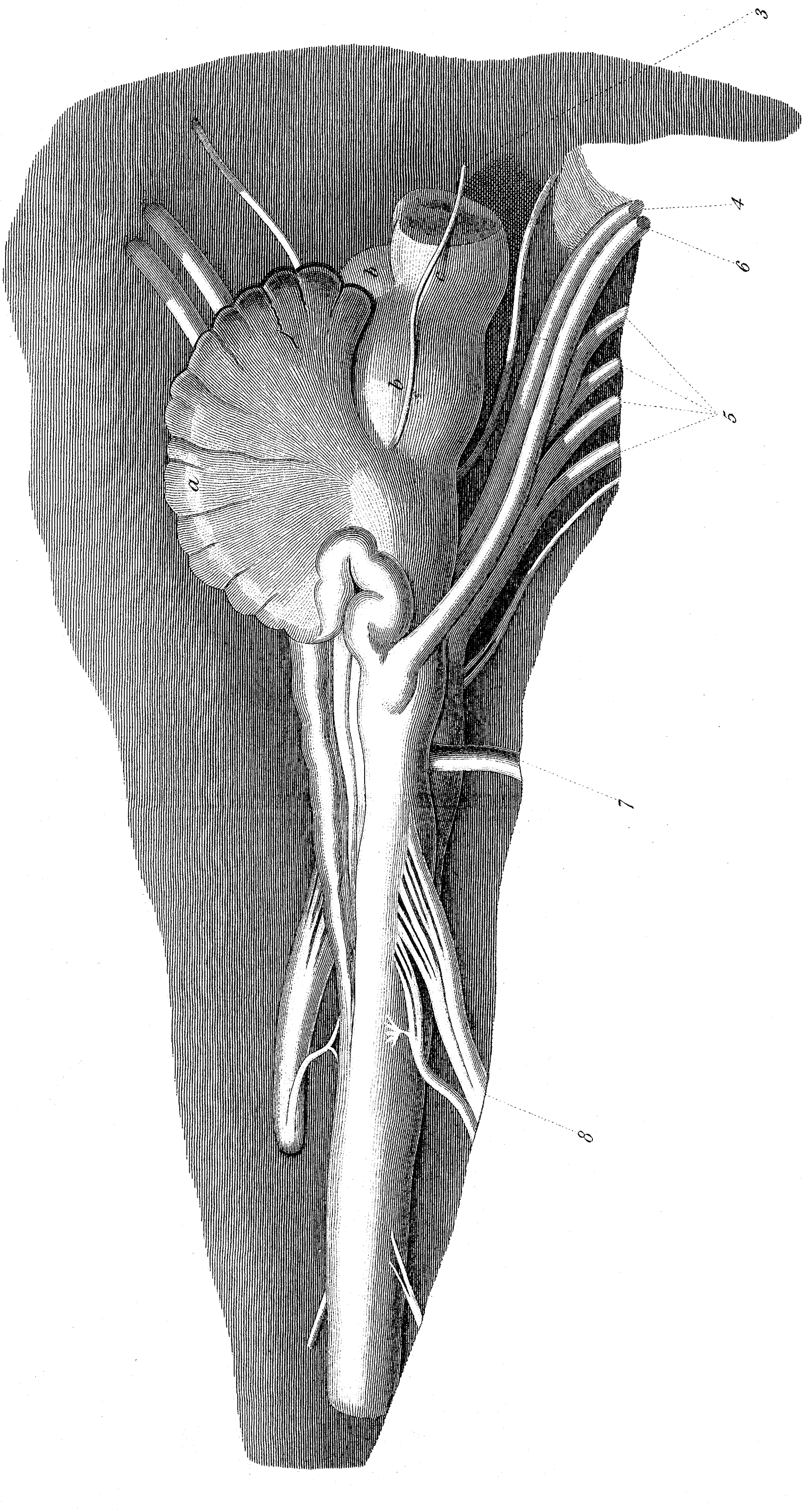

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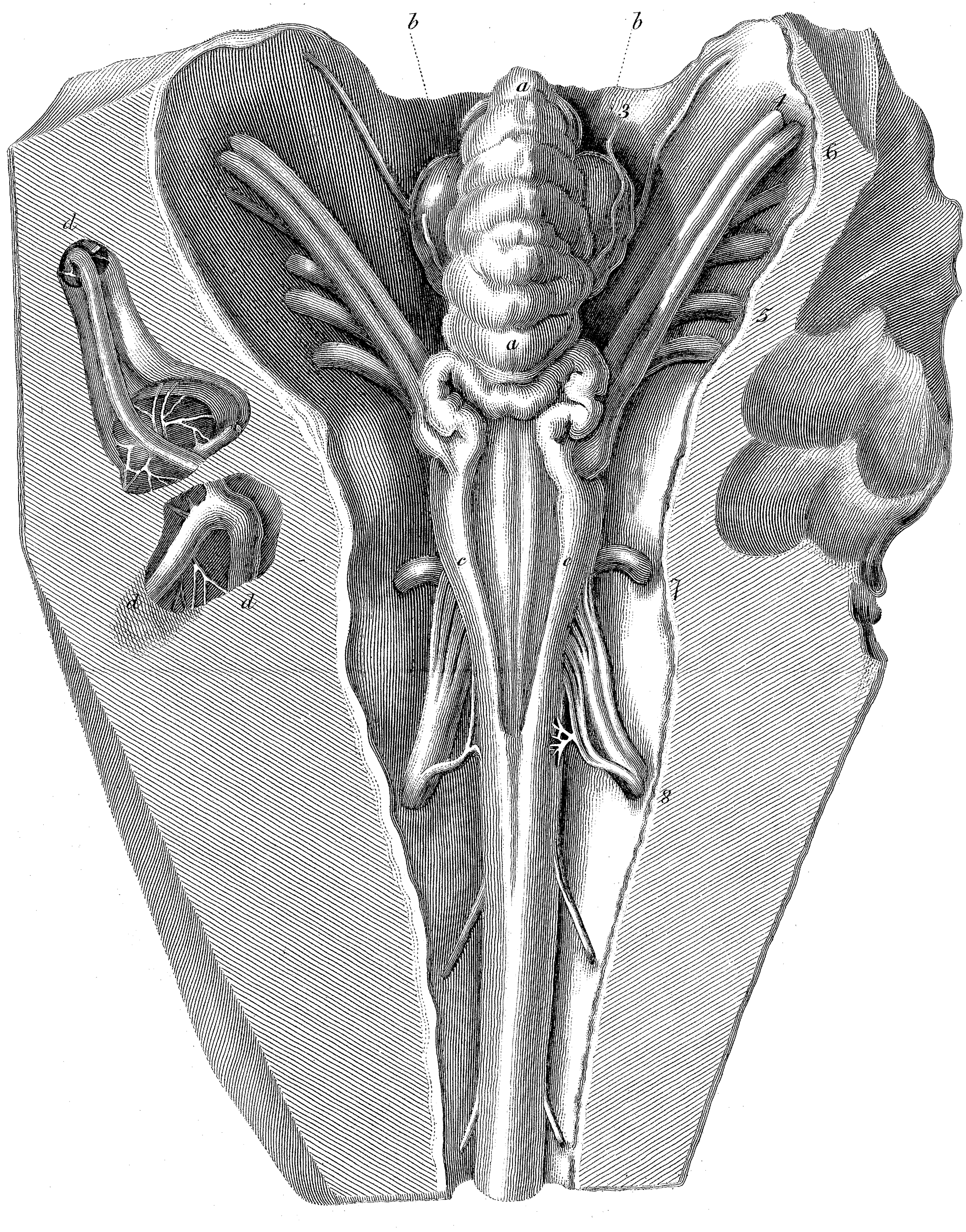

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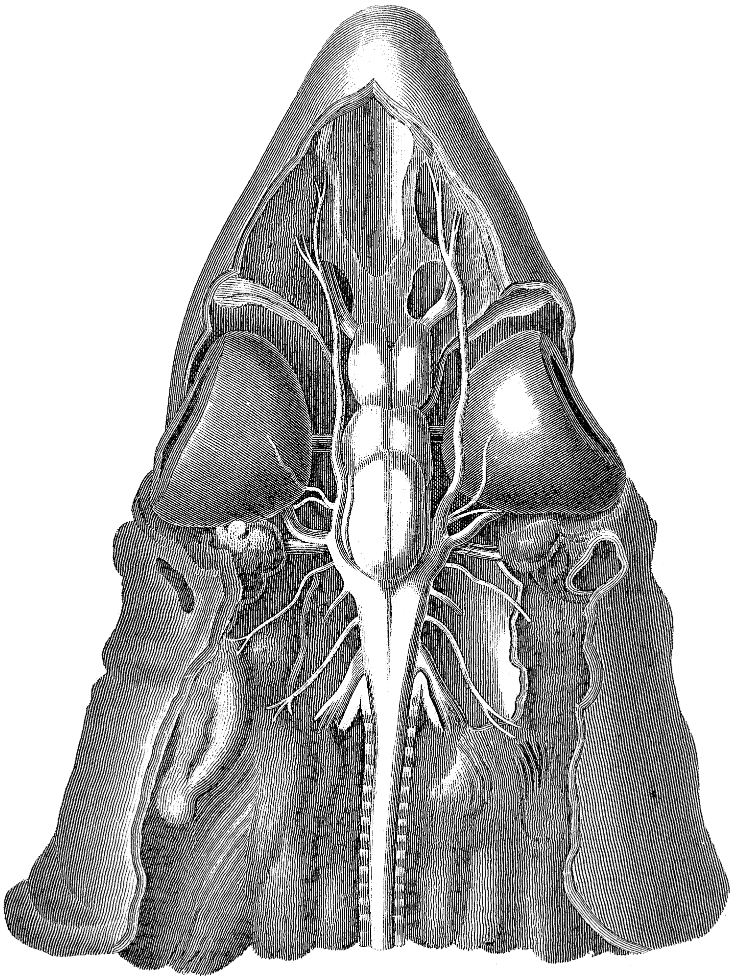

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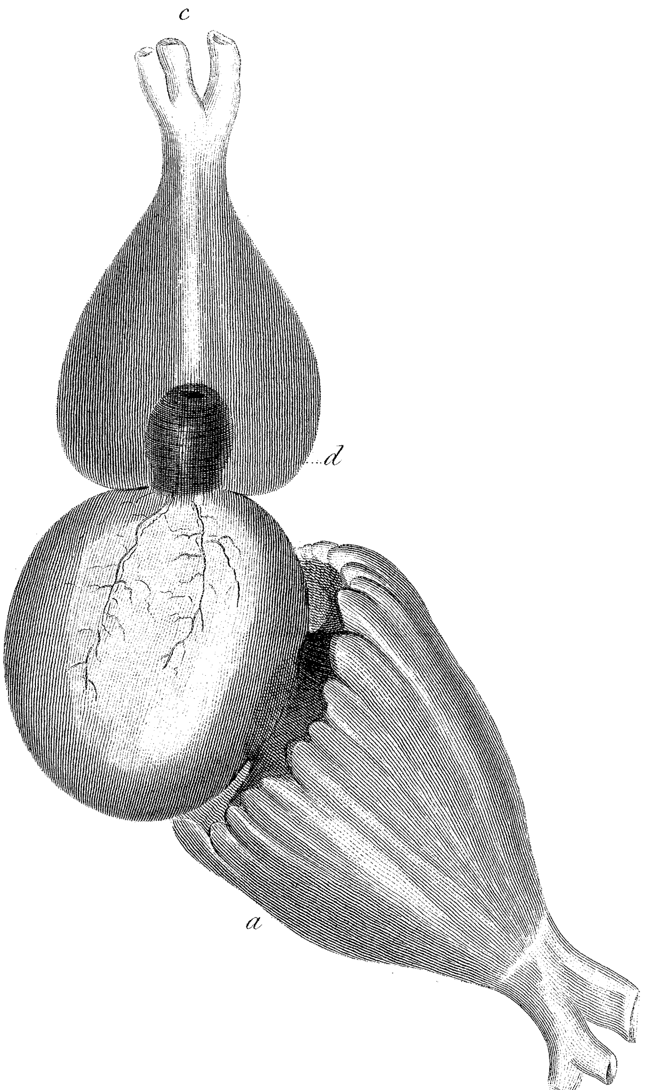

W. Clift del.
J. Basire sc.

EXPLANATION OF THE PLATES.

(See Plates XVI, XVII, XVIII, XIX, XX, XXI, XXII.)

Six of the following Plates are taken from drawings made by Mr. Howship, who very kindly undertook that task, during the indisposition of Mr. Clift, and his knowledge of anatomy, which he has cultivated with much ardour, induced me to solicit his assistance upon this occasion.

Plate XVI.

Fig. 1. A view of the pectoral fin of the Squalus Maximus, from which the skin and cellular membrane are removed, to shew the arrangement of the cartilages of which it is composed.

Fig. 2. A portion of the elastic fibrous structure with which the fin is tipped, of its natural size.

Plate XVII.

Fig. 1. An internal view of the stomach and duodenum of the Squalus Maximus.

a. The œsophagus.

bb. The cardiac portion of the stomach.

cc. The pyloric portion.

dd. The spleen.

e. A small cavity belonging to the stomach.

ff. The duodenum.

g. The band containing the hepatic ducts, six in number.

h. The dilatation in which the gall ducts terminate.

i. The opening of the pancreatic duct.

k. The spiral turns of the intestine.

Fig. 2. The fringe at the termination of the œsophagus of the natural size.

PLATE XVIII.

The heart of the Squalus Maximus laid open.

a a. A portion of the internal surface of the auricle.

b b. One of the venæ cavæ laid open.

c. The valve between the auricle and ventricle.

d d. The cavity of the ventricle.

e e e. The three rows of valves and the three intermediate spaces, along which regurgitation takes place when the canal of the artery is dilated.

f f. The strong muscular covering of the artery.

PLATE XIX.

A side view of the cerebellum, tubercula quadrigemina, and nerves of the brain of the Squalus Maximus.

3, 4, 5, 6, 7, 8. The different nerves going off from the brain corresponding with those in the brain of man.

a. Cerebellum.

b b. Two of the tubercula quadrigemina.

c. A third tuberculum mutilated.

PLATE XX.

A view of the upper surface of the cerebellum and nerves of the Squalus Maximus.

The nerves going off marked, as in the last Plate, beyond which are two pair of nerves belonging to the spinal marrow.

a a. Cerebellum.

b b. Two of the tubercula quadrigemina.

c c. The part which corresponds with the fourth ventricle in the human brain, surrounded by an oval, continued, nervous band, from which the principal nerves go off.

d d d. Portions of the three semicircular canals of the ear in the cartilaginous cavity in which they are contained.

Plate XXI.

A view of the upper surface of the brain of the Squalus Acanthias, taken from a fish three feet long, to shew the difference of appearance and size between it and that of the Squalus Maximus.

The brain is entire, and the eyes are left in their situation, so that when this Plate is compared with that of the large brain, the parts that are wanting in it will be readily distinguished.

Plate XXII.

A view of the heart of the Lophius Piscatorius in a distended state, shewing the transparency of its coats, which are extremely thin.

a. The auricle.

b. The ventricle.

c. The branchial artery.

d. The projecting muscular tube serving as a valve.