IX.—*On the System of the "Lateral Line" in Fishes.* *By* ROBERT M'DONNELL, M. D.

Read May 26, 1862.

SOME of those persons who have examined most carefully the system of the lateral line consider it a doubtful matter whether it should be classed with the electric organs, or with those of sensation. I believe there is sufficient evidence to show that it is distinct from either. In order to make this clear, it will first be necessary to define precisely what is meant by the "system of the lateral line," and to examine its peculiarities in certain fishes; and subsequently to compare it with the tactile organs, and those which are either electrical, or are supposed to be the homological representatives of the true electric organs.

By the system of the lateral line is meant that system of which the straight or curved lines seen in most fishes by the naked eye, running from the external opening of the gills to the tail, forms the most prominent, if not always the most important, feature. The so-called mucous tubes and pores on the head, which are distinctly visible in many fish even of small size, about the snout, on the under-jaw, and gill-covers, constitute a part of the same system. A simple inspection of some of our common fish, which may be examined during life in an aquarium (for example, the common eel), will satisfy the observer that the mucous tubes and pores about the head are but a part of the same system met with on the sides all the way along the body to the tail. The mucous pores visible about the jaws, on the gill-covers, and across the occiput of most fishes, constitute the *cephalic portion of the system of the lateral line.* But in many fishes, as the sharks and rays, this portion is developed to a peculiar degree;

yet around the mouth no apertures exist, although they are very numerous on the back of the head, and over the surface of the body.

The *lateral lines proper* are the portions of the system which run longitudinally from the head to the tail, sometimes nearly quite straight, as in the salmon; or curved upwards, as in the sea bream; or in the reverse direction, as in the fresh-water bream. Generally speaking, the scales which are found along the course of these lines are distinguished by their form and their size; often, but by no means invariably, these lines correspond with the interval between the dorsal and ventral muscles, and their colouring is not unfrequently different from other parts of the surface. Apertures similar to, but not so large as those about the head, are in many fishes visible to the naked eye along the entire course of the lateral line; and if, after death, the skin is cut along this line, a canal is opened, into which a probe or bristle may be passed. This is the *lateral canal*, or, more correctly, the canal of the lateral line system; and it occasionally extends as an uninterrupted tube through the ramifications of the cephalic portion, as well as along the lateral lines proper, having its tubular outlets on the skin, varying in size, form, and number, in different localities. The cephalic ramifications of this canal were designated by De Blainville, in the sharks, rays, and chimæras, the "systeme lacunaire." The system of the lateral line exists, more or less completely developed, in all fish, without exception,* which I have had an opportunity of examining; its modifications, however, met with in different species, are very varied. Before attempting to describe the principal modifications which have come under my notice, it may be well, in order to avoid misapprehension, to point out certain structures which may be, or have been, confounded with different parts of the lateral line system:—

1st. The lateral vessel described so well by Hyrtl† must be regarded as essentially distinct from the canal of the system of the lateral line. This vessel (*vaisseau lateral*) is found in the subcutaneous cellular tissue, following nearly

* In the lancelet alone I have not yet found any trace of it: I have, as yet, only had an opportunity of examining one specimen, and not a fresh one.

† "Sur les sinus caudal et céphalique des poissons et sur le systéme de vaisseaux lateraux avec lesquels ils sont en connexion."—An. des Sciences Nat., Seconde Serie, tom. 20, p. 215, 1843; and Müller's Archiv, 1843, p. 224.

the same direction as the lateral line; it communicates with the caudal sinus, and contains a clear fluid, resembling the fluid contained in that sinus.

2nd. The tubes to which Professor Agassiz has drawn attention, opening externally, "which have hitherto been considered mucous tubes, but which, he is convinced, are tubes for the introduction of water into the body."*

3rd. The organs connected with the fifth pair of nerves in the sharks and rays, by some called muciferous tubes, on account of the clear jelly they contain; but these organs appear to be true tactile organs, and, at all events, will be considered subsequently, as something quite distinct from the lateral line system.

4th. The papillæ delineated by Leydig† as occurring in the lips of many fresh-water fishes, which are also probably tactile organs, and at present can hardly be regarded as in any way connected with the system about to be described.

5th. The bodies discovered by Savi in the torpedo (*appareil folliculaire nerveux*)—which last, however, may be related to the lateral line system, as I shall afterwards attempt to show.

OF THE SYSTEM OF THE LATERAL LINE IN THE RAYS.

The portion of this system in the rays which corresponds with the cephalic portion in other fishes is largely and very peculiarly developed: it, for the most part, is displayed so as to form a curious outline on the ventral aspect of the fish, external to the gills, and anterior to the mouth. The tube, which by its windings and branchings, follows the course represented in Plate V., Fig. 1, *d*, is easily injected, not only on account of its large calibre, but because, on this aspect of the fish, it has few openings on the skin to allow of the escape of the injected material. Monro‡ has delineated this portion of the system of the lateral line in the skate very correctly; and he describes it as consisting of "large and picturesque canals, which naturally contain mucus, and which are

* "Proc. of Boston Soc. of Nat. Hist." (1848), p. 27; and the "American Journal of Science and Art," Silliman (1848), p. 431.

† Dr. Franz Leydig's "Lehrbuch der Histologie," p. 197: Frankfort, 1857.

‡ "The Structure and Physiology of Fishes," &c., by Alexander Monro, M. D., plate vi.

so distinctly seen, that it is needless to be very particular in the description of them." Turning round the snout, the canal of the system of the lateral line passes from the ventral to the dorsal aspect of the fish, and over the back of the body, and along the entire length of the tail, it, although much diminished in calibre, follows a course as much resembling that of the lateral line proper in other fish, as the unusual form of the ray will allow. This portion of the canal, which is represented in Plate IV., *a*, *a*, *a*, cannot be injected, owing to the rapid escape of the material thrown in from the numerous orifices opening upon the surface from this part of the system. The accompanying Figures (Plates IV. and V.) make more clear than any description could the course followed by the canal of the system of the lateral line on the upper and under aspects of the ray; the outline does not materially differ in any of the varieties which I have examined. In the torpedo, the dorsal part of the system is well developed (Plate VI., Fig. 1, *i*, *i*, *i*), and is merely modified in its outline by the large size of the electrical organs of that animal; but the ventral portion I have been unable to discover. In the rays, the canal of the system of the lateral line lies principally in the substance of the skin itself; but the dilated portion towards the front of the snout is embedded in the gelatinous structure underneath the skin. In the sting-ray, the whole of the cephalic portion seems to lie *under*, not in, the skin. Monro* has very imperfectly represented this system on the back of the skate, having evidently only traced it a short way on the back of the snout and head. And Leydig,† who has investigated the subject with great care, has not examined whether the lateral line proper in the rays gives off side branches on its way backwards; this, however, is shown perfectly to be the case in the figure.

When in a recently taken fish the canal on the ventral surface is examined, it is found to be moderately filled with a kind of mucus, which is not of a very viscid consistence. This may, by pressure with the finger, be readily made to move along the inside of the tube, and thus, even without injection, the outline of the canal can be traced. If the canal is opened in fish which have just been taken from the water, and this fluid allowed to have exit, it appears that it is not sufficiently abundant to exude of itself in any quantity from the open-

* Loc. cit., plate vii.

† "Beitrage zur Mikroscopischen Anatomie und Entwickelungsgeschichte der Rochen und Haie; Von Dr. Franz Leydig," p. 361: Leipzig, 1852.

ing; but if the finger be run along the tube, it is easily squeezed out with a very slight pressure; it is quite transparent, and consists of thinnish mucus, containing flakes of delicate epithelium. When the canal itself is laid open for some extent by the introduction of a director, on which a sharp-pointed knife is run so as to slit it up, its walls are found to be very tough and strong. This firm cylinder lies for the most part in, and indeed is formed by, the corion; in the snout, where the canal in most species lies deeper than the skin, and in the gelatinous subcutaneous tissue, this cylinder, however, does not lose its strength, although its walls have a greater transparency. Inside of this strong-walled cylinder there lies an internal tube of very delicate membrane, which, at least in those places where the canal is widest, seems to lie loose within the cylinder, or floating in the mucous contents of the canal. The inner tube is composed of a fine basement membrane, covered with epithelium; and in the snout one may easily follow filaments of the trigeminal nerve, which, perforating the strong wall of the cylinder, are displayed upon the inner tubular membrane, and there terminate in gangliform bodies, mostly communicating with each other by connecting filaments (Plate V., Fig. 5). Even in the snout, the nerve-filaments which perforate the cylinder, and end on the membrane inside of it, are not very numerous. In those parts of the canal which lie outside of the gills on the ventral surface, they are few in number; and on the back, and along the tail, still fewer. The nerve going to this latter portion of the lateral line system in the rays receives its nerve-filaments, as in other fish, from the lateral nerve—a branch of the pneumogastric.

The foregoing description of the structure of the canal of the system of the lateral line will be found to agree, in most respects, with that given by Leydig.

In attempting to inject any material into this canal, one often finds that the inner delicate tube, being doubled-in by the injection, prevents it from filling completely even the ventral portion; and I have more than once found that when this had happened, and the pressure on the syringe was increased, the injection had passed (by rupture ?) into the blood-vessels of the lateral fins, filling them beautifully. Upon the back of the head, body, lateral-fin rays, and all along the tail, the canal of the lateral line lies in the skin, except at one or two points, where it for a short space becomes imbedded in the cartilage of the skeleton. The skin of the torpedo is easily raised from the subjacent parts,

and the course of the lateral line then readily followed, being seen from the deep aspect of the skin; the numerous tubules leading to the orifices on the surface are distinctly seen.

The dissection necessary to show the ramifications of the system of the lateral line on the dorsal aspect of the skate (as seen in Plate IV.) is a more troublesome undertaking, but shows a similar disposition of the system. Nowhere in this portion have I been able to discover nerves terminating in knobs. The nerve-filaments are few in number; and when examined in pieces of the lateral canal, which have been previously placed in acetic acid, they are merely to be seen as well-defined fibres. When an injection is thrown into the canal of the lateral line from an opening made in the middle of the back, the material injected gushes from the numerous openings in the skin; but sometimes, by a bold push, the entire outline of the cephalic portion on the ventral aspect may be injected from the back.

The slimy mucus which is so abundant over the surface of the skate is quite different, both in consistence and appearance, from that obtained from the canal of the lateral line; one can at once distinguish the one from the other by the character of the flakes of epithelium in each. The external mucus contains the ordinary epidermic scales of epithelium, such as may be scraped off any part of the surface.

It has been already noticed, that in the torpedo there is not to be found on the ventral aspect of the fish anything at all corresponding with the "picturesque canals" constituting the cephalic portion of the lateral line in the skate. On the other hand, the bodies described by Savi as forming the "appareil folliculaire nerveux" are found only in the torpedo. Hence arises the question, to be reverted to afterwards,—Do the gangliform nerve terminations met with in the canals of the head of the skate correspond with the round bodies of which the "appareil folliculaire nerveux" is composed?

OF THE SYSTEM OF THE LATERAL LINE IN THE SHARKS.

Among the squalidæ, I have had opportunities of examining the system of the lateral line in the blue shark (*Carcharias glaucus*), the varieties of dog-fish common in our seas (*Squalus canicula*, *Squalus galeus*, *Squalus mustelus*, *Squalus*

acanthias), and in the angel-fish (*Squalus squatina*) ; in all, the examinations have been made in fish quite recently taken. The cephalic portion of the system in outline resembles, on a much smaller scale, the "picturesque" form of the canal in the corresponding part in the rays, as in that group few or no openings lead from the canal to the surface on the ventral aspect of the head. Tracing the canal round the front of the snout, it is found to diminish in calibre, to have its anastomosis with the opposite side, and continue its course so as to run into the lateral line proper behind the eye, and above the gill apertures. From this on to the tail, it continues having nearly the same calibre all the way, and having numerous small ducts, at tolerably regular intervals, which pass from the main canal obliquely, and open on the surface by minute orifices, generally invisible among the rough scaly coating of the animal. The forcible injection of water into any part of the main canal makes these orifices plain, as the water springs from them in small jets. In making attempts to inject the system with coloured materials (gelatine and bichromate of lead), I have observed the fluid which necessarily escapes from these orifices rapidly become diffused over the surface surrounding them, by the capillary attraction between the small scales. I have never found the injection to pass from the lateral line proper into the blood-vessels, but from the cephalic part of the canal this has taken place by rupture. The skin of the dog-fish is naturally clean, and free from mucus.

The outline of the system of the lateral line, as seen by dissection on the dorsal aspect of the angel-fish, lies in the skin, except the branches internal and external to the eye, which, like the anastomosing branch are embedded in cartilage. The canal of the cephalic portion, if opened when the fish are freshly taken from the water, is found to contain a thin watery mucus. The structure of this system does not differ materially from that of the rays. The cylinder is perforated by nerve-fibres, few in number, which are lost upon an internal membrane of great delicacy ; this internal membrane exists only in the cephalic portion, and its nerves are twigs from the fifth pair. The lateral line proper receives branches from the nervus lateralis of the pneumogastric ; minute twigs of this nerve may be traced to the canal of the lateral line, but what may be their precise mode of termination I cannot at present say.

In the *Chimæra monstrosa* and sturgeon, the lateral line system is of a

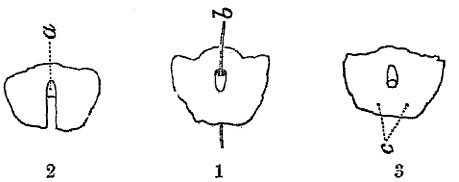
transitional character; in the latter, I have as yet had no opportunity of examining it with accuracy; in the former I have observed nothing which can be added to the description given of it by Leydig.* The outline of the cephalic portion is easily seen, embracing the eye between two branches, which in front join into one towards the tip of the snout, and behind uniting with the occipital anastomosing branch, are all three in one continued into the lateral line proper. The rings which surround the canal of the lateral line of the chimæra are like the half rings of the trachea. There are many openings on the surface from the cephalic portion of the system in this fish, and the fluid contents of the canal have ready exit. The large boss-like scales of the sturgeons are neither confined to the lateral line, nor are they perforated by its canal; in the sterlet *(Accipenser ruthenus)* they are smaller along that line than elsewhere, but are very numerous; while in the *Accipenser brevirostris* there is a large interspace between the scales, in which the lateral line canal may be seen running along beneath the skin, or rather through it.

OF THE SYSTEM OF THE LATERAL LINE IN THE SPARIDÆ.

In the fish hitherto described the canal of the system of the lateral line is one continuous tube, forming the tortuous convolutions of the cephalic portion, and, as it goes backwards, constituting the lateral line proper on the sides of the trunk and tail. In many of the bony fishes, however, these elements of the system do not form one continuous whole, in which the same canal is traceable throughout. The cephalic portion of the tube is, as it were, cut up into pieces of various length—sometimes long enough to unite many of the tubules leading to the orifices on the surface—sometimes so short as to be nothing more than shallow follicles embedded in the skin, or dipping into the bony structure of the gill-covers, or jaws. The lateral line itself is rarely cut up in this way; it, generally speaking, runs along from the upper part of the gill aperture to the tail as one tube all the way, and in the vast majority of cases has numerous openings on the surface at regular intervals. On account of the large size of scales, the structure of this portion may be well seen in the marine breams. If

* "Lehrbuch der Histologie." Frankfurt, 1857: p. 200.

a scale be taken from the lateral line proper of the sea bream *(Pagellus centrodontus)*, it is seen to be perforated by a tunnel; this tunnel begins on the upper surface of the scale, and towards the head; it passes obliquely through the scale, and ends on the under surface, where the overlapping of the scale on the next one makes the point of exit correspond with the entrance of the tunnel into the next scale. Thus the canal of the lateral line proper tunnels its way through the scales all the way along. That part of each scale which overlaps the one



. SCALES FROM THE LATERAL LINE OF THE SEA BREAM (*Pagellus centrodontus*).

1 Shows the canal, having a bristle passed in a direction from the head (*b*) towards the tail; 2, The canal opened—*a*, the minute opening in the floor for the passage of a nerve-fibre; 3, At *c* are marked the orifices in that part of the scale which overlaps the one next below, and from which anything injected into the canal escapes.

next below is seen to have two or three minute openings in it—the orifices which open on the surface, and from which anything injected into the canal escapes. The floor of the tunnel of each scale has also a small opening in it, through which a filament of nerve enters; this nerve-filament is lost in minute fibres on the lining membrane of the canal. The mode in which these filaments make their way to each scale may be seen, if the scales of the lateral line proper be plucked off; the subjacent corion dissected off at the upper part, and thus the nervus lateralis brought into view. From this nerve a filament passes off to each scale, first perforates the fibrous matrix in which each scale is embedded, and then enters the canal of the lateral line through the little orifice in the floor of the tunnel already mentioned. In fish which were perfectly fresh I have never found an injection enter from this canal into the lateral vessel, and so into the caudal sinus: when this has happened, I have attributed it to the accident of rupture; but at the time I was not aware of Vogt's observations, to be alluded to subsequently.

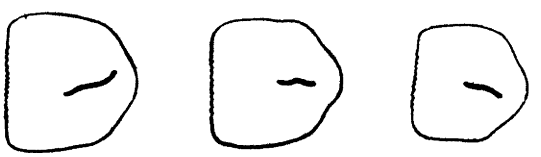
In a great number of families the arrangement of the lateral line proper does not differ materially from that described in the sea-bream. In the perches, gurnards, cods, &c., there is the same general disposition, although the size

and form of the scale varies: thus in the grey gurnard the scale is thick, raised above the surface, and tunnelled by a canal which barely admits a bristle; while in the hake the tunnelling of the scale is incomplete; it would be without a roof were not this part closed in by the epiderm. Again, in many fish the small openings described either do not exist, or are too minute to be discovered. But the filaments of the lateral nerve can, and sometimes do, arrive at the canal by passing between the scales, not by perforating them. The very large scales of the mosal carp (*Barbus mosal*) show very well the oblique perforation of the tunnel through the scale.

As regards the peculiar mode in which the nerve terminates in the interior of the canal, I have always found it to end in a simple filament, which is gradually lost on the membrane which lines the canal. I have never yet been able to discover anything corresponding with the nerve-knob figured by Leydig:* as, however, he does not state from what kind of fish the scale represented in the woodcut is taken, I am unable to deny the existence of such endings for the nerves in question.

OF THE SYSTEM OF THE LATERAL LINE IN THE MULLETS.

In the mullets the system of the lateral line is found to consist of a number of distinct lines, running along the sides of the fish from the head to the tail. Thus, in the grey mullet (*Mugil cephalus*) as many as nine or ten distinct lines may be observed. The large scales of this fish are not perforated by the canal of these lines; a canal runs some way through the substance of each scale, but a fine bristle or hair cannot be passed through this canal, which is often bifurcated at its extremity. No nerve-terminations exist in connexion with these canals.



THREE SCALES, TAKEN FROM AS MANY DISTINCT LINES ON THE SIDE OF THE GREY MULLET (*Mugil cephalus*). The largest is from near the middle of the body; the others, from near the back and belly.

* "Lehrbuch der Histologie," von Dr. F Leydig, p. 203, fig. 108.

OF THE SYSTEM OF THE LATERAL LINE IN THE PIPE FISHES (*syngnathidæ*).

It would at first sight appear that the system of the lateral line was entirely absent in the pipe fishes. It has been suggested to me that the peculiar appendages forming the "false belly" of the male, for the reception of the roe, may be a remarkable development of a lateral line system. This view appears a mere fancy, without any sufficient ground to rest on. It is more probable that the ridge commencing close to and immediately above the small branchial aperture, and running so far as the dorsal fin, when it, as it were, shifts upwards to the dorsal aspect, and so is continued to the tail, is the true lateral line modified. There are no openings connected with it; neither are any pores to be found either on the head or body of the pipe fishes.

OF THE SYSTEM OF THE LATERAL LINE IN THE PERCHES (*percidæ.*)

Among the perches, the ruffe or pope (*Acerina vulgaris*, Cuv.) alone presents a striking appearance as to the system of the lateral line. The bones of the head, especially the preopercular and inferior maxillary bones, are excavated, and present large cavities in connexion with the cephalic portion. Through these excavations the canal of the lateral line runs. Leydig has figured the head of this fish, and also a very striking nervous arrangement met with in the excavations just alluded to.* Without wishing to question the accuracy of so truthful an observer as F. Leydig, I would say that I have only been able to find the knob he has described and figured as a nerve-termination in the

PREOPERCULAR BONE OF THE RUFFE (*Acerina vulgaris*),
Showing the channel through it, and the openings into this channel.

head of the ruffe (Kaulbarsch), in the excavation just above the eye of this fish; in the cavities in the preopercular and inferior maxillary bones I failed

* "Lehrbuch der Histologie, von Dr. Franz Leydig, Professor an der Universitat zu Wurzburg," p. 201, Fig. 104–5, being head of a ruffe (magnified), and a nerve-knob from the ruffe (much magnified).

to find any such nerve-terminations. The ruffe, however, is not a fish found in any Irish river; and those which I have examined having been sent me from the Thames, I may have failed to verify Leydig's observations, in consequence of the specimens being no longer perfectly fresh when they arrived in my hands.

OF THE SYSTEM OF THE LATERAL LINE IN THE SCOMBERIDÆ.

In this family, or rather in some members of it, the ducts from the canal of the lateral line proper which lead to the surface, and there open, are of considerable length: the openings are thus scattered over the body, and not confined—indeed, do not occur along the track of the lateral line itself. This arrangement is remarkable in the dory, and better still in the opah (*Zeus luna*), in which the secondary tubes which run vertically downwards towards the ventral aspect are numerous, occurring at tolerably regular distances from each other, and varying from two to four or six inches in length in large fish. No nerves are to be discovered in connexion with these secondary tubes of the opah.

OF THE SYSTEM OF THE LATERAL LINE IN THE EELS.

It is not possible to determine with certainty whether in the eels there is one continuous tube for the cephalic part as well as the lateral line proper. The tube is too small to be traced, and has too many openings, both about the head and along the body, to be injected. The eel proves, beyond question, that the slimy mucus which in them so abundantly lubricates the body is not a secretion emanating from the pores of the system of the lateral line. If a common fresh-water eel be put in a tube, the mucus may be seen forming on it, and thrown off gradually as it is formed from the surface, just as the mucus of the bronchi or intestines is formed on the general surface.

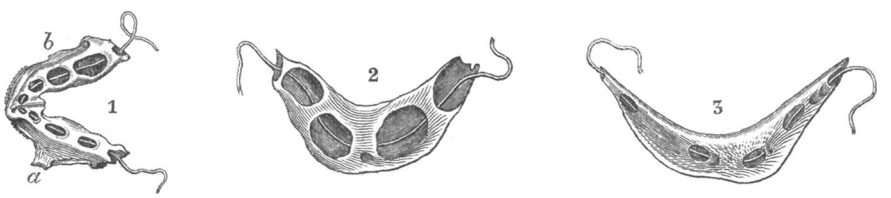
The most careful examination of the skin along the lateral line of the eel does not show any of the knobbed or beaded disposition of the nerve-terminations, such as are observed in the tactile nerves of the lips.

Although it still appears to me doubtful, owing to the difficulty of examining with the microscope the dark opaque skins of these fish, whether in salt-water eels the cephalic portion and the lateral line proper have a common con-

tinuous canal throughout, yet I believe I may state with certainty that in the fresh-water eels the entire system of the lateral line consists of a series of distinct follicles, or crypts, in the tissue of the skin, arranged in linear series, but no one of them connected with another by any common tube or canal. After the most repeated and careful examination, I have been unable to find in these follicles of the lateral line any nerve-terminations which could possibly be regarded as tactile organs. A very rich network of nerves, derived from branches of the fifth pair, is to be found in the lips, more particularly the upper lip of all eels : it is here, probably, that the tactile function principally resides.

OF THE SYSTEM OF THE LATERAL LINE IN THE FLAT FISHES.

In a considerable number of fishes, the cephalic portion of the system of the lateral line forms deep indentations in some of the bones of the head, or makes grooves of variable length in those bones. It is not, however, common to find the canal of the system running through excavations in the bones, and, without its continuity being interrupted, following its course also along the lateral line proper. This peculiarity is not found in all the pleuronectidæ , yet in some it is well marked, and also presents other features worth special notice: thus, in the white sole the inferior maxillæ and the opercular bones will be found to have channels running through them, and openings into the channel :



THE INFERIOR MAXILLARY AND PREOPERCULAR BONES OF THE WHITE SOLE (*Platessa pola*),

Showing the channels through which pass the canal of the system of the lateral line: 1, The inferior maxillary bones—*a*, the upper, and *b*, the under bone, of this unsymmetrical portion of the skeleton; 2, The preopercular bone from the under side; 3, The preopercular bone from the dorsal aspect of the fish.

if into one of these openings, or rather the integument which closes it, a slit be made, and a tube introduced, air may be blown in, so as to inflate the entire system of the lateral line, which in the white sole occupies a number of cham-

bers composed of cartilage, besides the channels through the bones on the under side of the head of this fish.

In the black sole, scattered among the velvety processes which cover the under part of the head, are to be seen a multitude of pores, which I take to be the pores of the lateral line system of this fish, while the velvety processes just spoken of, I conceive, are truly tactile organs.

I have not found any nerves which I think can justly lead to the conclusion that the remarkable arrangement of the lateral line system in the white sole (Plate VII., Fig. 1) is of the nature of an organ of touch. One or two nerves are found crossing the cartilaginous and bony cavities already mentioned, but no nerve-knobs or other arrangement resembling true organs of touch.*

The lateral line of many flat fishes has a continuation, which runs at right angles across the root of the tail. The cephalic portion of the system in the white sole is much larger on the under side of the head (see wood-cuts, showing the canals in the jaws and preopercular bones). The cavities in these bones, when opened in fresh fish, are found to have reticulated bands passing from one side to the other; their walls are lined by a delicate membrane, in which are found a few nerve-filaments. It is a remarkable fact that in these curiously formed, non-symmetrical fishes, the cephalic portion of the system of the lateral line should be most largely developed on the under side

* The white sole (*Platessa pola*, Cuv.), or pole, is described by Yarrel, at page 616 of the first volume of his work on British fishes. He speaks of it as rare on our coasts; it is, however, quite common in the Dublin market, and is a fish much less prized than the black sole (*Solea vulgaris*), from which it differs considerably in form, as well as in colour.

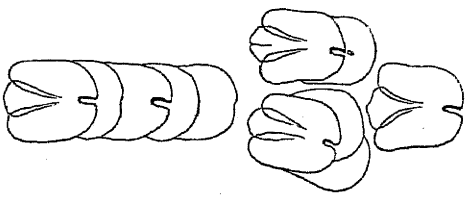
It is thus described by Yarrel:—"The head is small; its length, compared to that of the whole fish, is as one to six. The greatest breadth of the body, dorsal and anal fins excluded, is to the whole length rather more than a third; including the dorsal and anal fins, rather less than a half. The form of the body is an elongated oval, pointed at each end; the mouth is small, and the lips thin; a single row of teeth exists in each jaw, close-set, smooth, incisor-like, with thin and even edges; the eyes are rather large, the upper one ranging vertically behind the line of the lower, with the usual intervening bony ridge; the irides are orange; the pectoral and ventral fins, the dorsal and anal fins, extend very nearly the whole length of the body, and both end on the same plane; the rays about the middle of each are the longest, those at the extreme ends before and behind being very short; the tail is rather long, and is rounded."

See also the account of the pole, or craig fluke, called the white sole in Ireland, p. 197 of the fourth volume of the "Natural History of Ireland," by William Thompson, Esq.

of the head. Of the lateral line proper it is to be observed that its scales are on the upper side, generally speaking, tunnelled as in many other fish, while on the under side the tunnel is incomplete, being finished by the epiderm.

OF THE SYSTEM OF THE LATERAL LINE IN THE ESOCIDÆ.

In the common pike (*Esox lucius*) the cephalic portion of the system of the lateral line consists of openings, some of which, especially on the under jaw, are large, and sink in the bone. There is no continuity between the cephalic portion and the lateral line proper.



SCALES FROM THE LATERAL LINE AND OTHER PARTS OF THE BODY OF THE PIKE (*Esox lucius*).

All over the body of this fish there are to be seen scales with small slits in them; these are much more numerous towards the tail, and are identical with the slits along the lateral line. The tube of the canal of the lateral line is not continuous; it consists of a number of follicles, each distinct from its fellows, and similar to those found over the rest of the body.

In the flying fish (*Exocetus volitans*) the lateral lines on each side, after running close over the root of each pectoral fin, converge towards a point near the middle, and between the gill-flaps. All along the line the scales are smaller than elsewhere, and are tunnelled, &c., as in the scales of other fish.

In the broad-nosed bony pike (*Lepidosteus spatula*) the ivory-like scales are rough and notched along the lateral line, and this notching is much better marked in the young or small specimens than in those of greater size.

Other fish which, so far as their ivory plates are concerned, have a tegumentary structure similar to the lepidosteus, have the scales similarly notched. The hassar (*Callichthys subulata*), at the point of divergence of the dorsal and ventral plates which form its scales, has the marks of the lateral line along the

greater part of the body, but approaching the head these notches mount up so as to indent the dorsal plate. The slits seen in some of these scales of the pike, not confined to the lateral line, are likewise found in the *Polypterus bichir*, in which the scales of the lateral line are marked by longitudinal slits, while those over the other parts of the body are vertical.

The openings about the head of the common pike are large; and if water be injected into one of them, it emanates from the others. The channel of continuity runs through the bones of the head.

The nerve-fibres which make their way to the follicles of the lateral line, as well as those scattered over the surface of the pike, do not perforate the scales; they run obliquely backwards between the scales, and are accompanied by blood-vessels.

OF THE SYSTEM OF THE LATERAL LINE IN THE LEPIDOSIREN ANNECTENS.

The system of the lateral line in this animal is well marked, both in its cephalic portion and in the lateral line proper; and as it is one of the features of this curious creature which gives to it a decidedly piscine character, it is worthy of close investigation. I have examined it in both living and recently dead specimens. The lateral line proper is sufficiently visible all along the body, but no openings are to be seen by the naked eye. The scales are cleft at the margin, not tunnelled.

The outline of the lateral line canal, as it runs on into the cephalic portion, is shown in Plate VI., Fig. 3. One branch arches over the eye, and goes on to the tip of the nose; a second turns towards the angle of the mouth; while a grooved continuation passes under the lower jaw. The branches above and beneath the eye have numerous openings. A bristle passed in at one of these comes out at any of the others. The canal through which the bristle is passed is formed by the epidermis. After the most careful examination, I have been unable to find any knobbed or beaded appearances on the minute nerve-fibres which terminate in this canal; but in the upper lip of the lepidosiren I have found what I take to be tactile papillæ.

OF THE SYSTEM OF THE LATERAL LINE IN THE LAMPREYS.

In the lampreys the system of the lateral line seems to be reduced almost to its minimum of development.

In the lampern I have not been able to find any well-marked lateral line proper; neither in this fish (*Petromyzon fluviatilis*) are there any openings along the sides of the body, but about the eyes are to be discovered the orifices which alone indicate the existence of the system in this animal. The same is the case in the sea-lamprey (*Petromyzon marinus*).

The glutinous hag (*Myxine glutinosa*) I have not had an opportunity of examining in the fresh state; but I should venture to doubt whether the sacs described by Joh. Müller along its body really appertain to the system of the lateral line. According to him, the myxinoids have these sacs only on the side of the trunk, and each sac is enclosed in a peculiar muscular skin, the contents being composed of oval bodies, consisting of one thread rolled up in countless twists. These threads, sticking to anything that comes in contact with the animal, are unwound in the long viscous adhesions which obtain for the fish the name *glutinosa*.

In the Anglesey morris (*Leptocephalus morrisii*) (by some considered a larval lamprey) a lateral line is discernible for some way along the trunk, and the pores of the cephalic portion are visible with a lens.

No system of the lateral line have I been able to discover in the lancelet (*Amphioxus lanceolatus*); neither does Professor Goodsir describe any in his observations on the tegumentary system of this fish; but I have never had an opportunity of examining a fresh specimen.

In the lampern (*Petromyzon fluviatilis*) a branch of the fifth nerve becomes superficial a little in front of the eye, and runs forward to terminate in a very rich network of nerve-fibres, which terminate in the skin round the sucker disk surrounding the mouth. It is a very beautiful arrangement of nerves, and corresponds, I fancy, to the tactile organs of the rays and sharks on the fifth pair. No nerve-knobs were discoverable in the *pores* on the head of the lamperns.

Much confusion has arisen, and still exists, concerning the system which

the foregoing notes show to exist so very generally among fishes as to be an important characteristic of them. This confusion is in great part due to the terms "mucous pores," "muciferous system," "mucous tubes," "schleimcanäle," "glandes muqueuses," &c. &c., which involve a theory with regard to the function of the system of the lateral line which, in the present state of science, we have no sufficient ground to adopt. Further confusion on the same subject has arisen from the fact that the organs found in connexion with the fifth pair of nerves in the sharks and rays having connected with them tubes filled with clear jelly-like mucus, they and other tactile organs have been by some placed in the same category with the system of the lateral line.

The designation, "system of the lateral line," embraces no theoretic view as to function, and leaves the question quite open as to whether this organization belongs to the secretive system, or is more truly to be regarded as placed with organs of sensation, electric organs, or the water-pores of Vogt and Agassiz.

For my own part, I regard it as an organ which secretes some fluid which is poured forth from the skin as an excretion. Yet it is certain that the slimy mucus which lubricates the body of many fishes is not formed by this system. This I have repeatedly proved by direct experiments on living eels and skates, and on the *Lepidosiren annectens*, which lives long enough out of water to watch the process of the mucous formation over the surface. Besides this, if other proof were wanting, is the fact that the microscopic appearance of the mucus and its contained epithelium is different from fluid and epithelial scales obtained from the tubes of the system of the lateral line, when any such fluid exists; also, that there is no mucus met with in the bodies of some fish, in which, nevertheless, the system of the lateral line is much developed (e. g. dog-fish).

I cannot by any means agree with Vogt that "the system of mucous canals, as they have been hitherto named, is only a system of absorbent vessels, which contain lymph coming from the body and intestines, and water forced in from without." Assuredly, in the great majority of fishes, fluid injected into the system of the lateral line does not pass into the lymphatic or venous system. I should indeed venture to suspect that Vogt had confounded the lateral vessel

described by Hyrtl* with the system of the lateral line, did not the well-known reputation of this distinguished anatomist almost preclude such a notion. "If," says Vogt,† "we place before us the entire system of the mucous canals, then we see that two principal lines of direction of these canals are met with, of which one follows the outer part of the head and the lateral line, the other the spinal column, even to the base of the skull and fastenings of the gill-arches; that these two lines are united together through several reservoirs which lie at the base of the skull, and under the shoulder-girdle (*schulter-gürtel*); that they have numerous openings into the venous system through the veins of Duvernoy, the Cuvierian sinus, and the cardinal veins; that the lymphatic vessels of the body open into the inner line; and that, finally, the outer line has numerous openings externally, and consequently stands in relation to the surrounding water through the holes on the head, and probably also through the small canals which perforate the scales of the lateral line. Concerning this last point, viz. the relation of the scale-canals to the side canal, we would gladly have sought to reach greater certainty; but we avow that there are still many doubts to clear away concerning it. We have never been able to find a second canal which would lie inside of the skin itself, and unite all the small canals of the scales in itself. The mucus which covers the bodies of fish is certainly not, as some have hitherto believed, and as Hyrtl still maintains, a secretion of those small canals and the mucous canals of the head. This mucus is the product of the skin at all points; it is the true epiderm of fishes, composed of nucleated cells, which at all events do not differ from the epithelium which coats the inner surface of the intestine. These cells would certainly become of horny texture, like the cells of the epidermis of animals living in air, if the fish did not live in water, where the cells are constantly soaked with fluid."

* "The lateral vessel is in relation with a multitude of neighbouring vessels, which at regular intervals of from a line to a line and a half come from the trunk, and are directed towards the dorsal or ventral surface of the animal; they do not plunge in deeply, but run under the skin, and constitute a sort of vascular armour, embracing the muscular system of the body. In the *Esox lucius* I have reckoned 48 pairs of lateral branches; in the *Actinon fluviatilis*, 36; in the *Accipenser ruthenus*, 50; in the *Lenciscus dobula*, 30; in the *Salmo fario*, 40."—Annales des Sciences Naturelles, 1843, tom. xx. p. 223.

† "Anatomie des Salmones," Neuchatel, 1845, p. 138, and quoted by himself in "Zeitschrift für Wissenschaftliche Zoologie, von Siebold und Kölliker," bund vii. p. 328, 1855.

"If one proceeds from these facts, one easily perceives that the system of the mucous vessels, as they have been hitherto named, is only a system of absorbent vessels containing lymph which comes from the body and intestines, and water which is forced in from without." . . . .

In reply to this I have only to say, that after repeated attempts to inject the system of the lateral line, and that too when the outlets on the surface had been stopped by coating over the body of the fish with collodion, I have failed to prove to my satisfaction that any such communication with the lymphatics or veins exists. It is easy, by injecting the *lateral vessel*, to show the connexions which exist between the lateral vessels and the veins of the body and caudal sinus; but I have never found any evidence that these vessels communicate with the canal of the lateral line. Agassiz, I presume more correctly, seems to regard the water-pores of fish as distinct from the system of the lateral line, probably related to the water-vessel-system of mollusks. In a letter* to von Siebold on this subject, he thus clearly regards the two systems as distinct: "Moreover, I am surprised that no one has directed their attention to the water-pores of fish: I have for six years past recognised them as quite a peculiar formation in a number of families, distinct from the lateral line and the large pores about the head. Examine yourself the opercular flaps and temporal region of the clupeidæ. I know no more beautiful *rete mirabile* (Wundernetz) than that of the water-pores of this region in some of our commonest fishes. Still more deserving of attention is the *Rhombus cryptosus*, or North American scomberoid, which on each side of the dorsal lateral line, and at some distance from it, possesses a row of widely open water-pores, which can be easily injected, and which open through a common passage into the Cuvierian sinus, and thereby are able to convey, and really do convey, water to the blood. What say you to that? Salt water in the blood! It sounds strange, but is not the less true."†

* Concluding paragraph of a letter from L. Agassiz to C. Th. von Siebold on the water-vessel of mollusks. "Zeitschrift für Wissenschaftliche Zoologie, von Siebold und Kölliker," bund vii. p. 180, 1855.

† The following note on the above is added by von Siebold:—"Should not these mucous canals of fish be placed along with those of which Carl Vogt says that connexions may, by means of injections, be shown to exist between them and the lymphatic vessels and veins; and that fluids can pass from the mucous canals by means of a valvular apparatus into the veins and lymphatics, but

It certainly does sound strange—so strange, that I am obliged to confess that I am too sceptical to accept it, even on the assertion of so distinguished a naturalist as Agassiz, without more precise and stringent proof than I have hitherto been able to discover. The water-pores which I have observed do not appear to communicate with the deeper vessels. I had indeed regarded them as subservient to some function of cutaneous respiration, and possibly homologous with the air-cavities described in the skin of the frog, and newt by Ascherson* and Harley;† but the circumstantial statement of Agassiz shows that the matter still requires investigation. All that one can at present feel justified in concluding is, that the water-pore system is different from that of the lateral line.

There does not appear to be any sufficient ground for the supposition that the system of the lateral line is related homologically or otherwise to the electric organs. Indeed, this notion seems to have arisen from the confusion already alluded to, resulting from the designation of different organs by a common name. Geoffroy St. Hilaire, and after him C. Mayer, adopted the opinion (now known to be groundless) that the tactile organs situated on the fifth pair of nerves in the rays were the homological representatives of the electric batteries of the torpedo. These tactile organs being frequently spoken of as "mucous tubes," "canals of the muciferous system," &c., and thus by nomenclature confounded with the system of the lateral line, St. Hilaire's view became extended to organs which he probably never fancied to be related to the electric organs at all. It is certain that the system of the lateral line exists in all the electric fishes, although the smooth, scaleless skin of these fishes makes it less observable at first sight. In the torpedo this system is remarkably well developed, and does not very notably differ in its arrangement from that met with in the other rays. It also is found well marked in the gymnotus and silurus. In the common skate it has no intimate connexion with the body near the head which I at one time supposed to be the homologue of the torpedo's batteries (Plate IV., *c*); nor with

cannot pass from the latter to the former ?" (Compare the official report of the 20th meeting of the Society of German Naturalists and Physicians at Maintz, Sept. 1842, p. 220.)

* "Müller's Archiv," 1840, p. 15.

† "Quarterly Journal of Microscopical Science," vol. v., 1857. "Transactions of Microscopical Society, London," p. 148.

the tail electric organ of Stark.* This tail electric organ, which is found largest in the common skate, is seen to be smaller in the more spiny rays (Plate VII., Figs. 4, 5, 6); and at last in the angel fish (*Squatina angelus*), the dog-fish (*Squalus galeus*), the porbeagle shark (*Squalus cornubicus*), the basking shark (*Squalus maximus*), it exists merely as a ridge along the sides of the tail, which in transverse section shows more or less of a structureless substance between the layers of the corion. As the tail electric organ diminishes in bulk, and gradually disappears, there is not a corresponding change found in the system of the lateral line, which appears to be a totally independent organization. Its coexistence, however, in the same fish with the electric organs, is conclusive proof that they are not the homological representatives of each other (Plate VI., Fig. 1, *i* and *b*).

The view so ably advocated by Leydig, that the system of the lateral line (Seitenkanalsystem) is an organization appertaining to special organs of touch, has unquestionably more evidence in its favour than any of the theories already mentioned. Nevertheless, a careful examination of the subject does not lead me to adopt this view. I admit that occasionally the relations of the nerve-terminations to this system make it probable that it is made secondarily subservient to this purpose; but this, I fancy, is not even generally the case.

It seems to be undisputed that under the head of tactile organs may be classed—1. The peculiar organs found on the trigeminal nerve in sharks, rays, and chimæra (the jelly-tubes); 2. the "appareil folliculaire nerveux" of Savi in the torpedo; 3. the tactile papillæ in the lips of fresh-water fish described and figured by Leydig; 4. the somewhat analogous bodies met with in the head of the sturgeon; and, 5. the barbules which exist about the head of many fish, as the loach (*Cobitis barbatulata*), and the fringe-like appendages near the lips, as in the *Lophius piscatorius* (to which may be added the nerve-terminations on the sucker disk of the lampern, &c. &c.). These organs, however, one and all, appear to be distinct from the system of the lateral line, which, if viewed in its integrity in the ray, for example, has, it must be confessed, much more the appearance of a cutaneous excretive organ than of one of sensation.

* "Proceedings of Royal Society of Edinburgh," vol. ii. p. 1, Session 1844–5; also page 8; also "An. and Mag. of Natural History," vol. xv. p. 121.

One of the most interesting features of the system of the lateral line seems to be, that it is an apparatus peculiar to the skin of fish; and as it is possessed by almost all, if not all, animals of this class, it becomes an important means of determining, for purposes of classification, the piscine characteristics of a doubtful animal such as the *Lepidosiren annectens.* I have sought in vain for any trace of a system of the kind in the water-newt or frog, or the larvæ of these animals, and I cannot help thinking that the organs described and figured by Franz E. Schultze,* in his paper published last year in Müller's Archiv, are in reality related to the tactile organs found on the fifth pair of nerves in the skate, &c.

* "Ueber der Nervenendigung in den so Genannten Schleimkanälen der Fische und Uber Entspreschende Organe durch Kiemen athmenden Amphibien."—Müller's Archiv, 1861, heft vi. p. 759.

EXPLANATION OF THE PLATES.

Plate IV.

This Plate represents the dorsal aspect of the common skate, on which the skin of one side only has been dissected off. The system of the lateral line, with its many openings on the surface, and the numerous jelly-tubes connected with the fifth pair of nerves, are brought into view, besides other parts.

a, *a*, *a*.—The canal of the system of the lateral line as displayed on the dorsal aspect: in front are two tubes, which turn upwards from the ventral surface; of the two, that which is nearer to the middle line lies deeper, and is of larger calibre; it is continued backwards, above, and internal to the eye, behind which it anastomoses with a branch from its fellow, which, having passed backwards below and external to the eye, first gives a lash of small branches, which reuniting form the part of the canal which ramifies over the lateral fin, and later divides into two branches, one passing inwards behind the eye, between it and the temporal orifice; the other going outwards lies at some depth, but goes on to anastomose externally. The branch of communication between the opposite sides is seen a little behind the temporal orifices. Every where the small tubes and orifices opening on the surface are distinctly seen.

b.—One of the organs (tactile) within which a large branch of the fifth pair of nerves terminates, and from which numerous jelly-tubes lead to open on the surface of the skin.

b'.—The jelly-tubes leading from the former.

c.—Glandular organ, which, until it was also found to exist in the torpedo, was regarded as the homological representative of the batteries of the torpedo.

d.—The upper surface of the branchial chambers.

f.—The upper surface of the mass of muscles of the jaws.

g, *g*.—The snout-muscle, consisting behind of a fleshy belly, anteriorly of a long delicate tendon passing forward to the snout

h.—The eye.

j.—The temporal orifice.

Plate V.

Fig. 1.—The system of the lateral line as seen on the ventral aspect of the common skate. The canal has been injected, so as to make windings more distinct; and on both sides a part of the skin has been dissected off, so as to show not only the system of the lateral line, but the organs on the fifth pair of nerves, and their jelly-tubes.

a, *b*, *c*.—The organs (tactile) to which branches of the fifth pair of nerves go, and from which a multitude of jelly-tubes radiate in all directions, opening in the skin. *a*, indicates the under surface of the mass, the upper surface of which is marked *b* in Plate IV.

d, *d*, *d*.—The canal of the lateral line: of the branches running forward to the snout, two only turn up on the dorsal aspect; the other two appear to terminate in *cul-de-sacs*.

d', *d'*.—These tubes lead to the only openings on the surface met with on the ventral aspect; occasionally there are two more tubes of the same kind.

e, *e*, *e*.—Spaces between the branchial apertures.

f, *f*.—The openings of the olfactory sacs.

Fig. 2.—Represents the organ (tactile) (*b*, in Plate IV.; *a*, in Plate V. Fig. 1) connected with the largest branch of the fifth pair, dissected out and laid open so as to show the structure as visible to the naked eye.

a.—Large branch of fifth nerve.

b, *b*, *b*.—The jelly-tubes.

c, *c*.—White fibrous capsule, inside of which the nerve terminates in a number of knobs, each of which lies in the commencement of a jelly-tube.

Fig. 3.—Vertical section made through the snout of a skate, a little external to the median line.

a, *a*.—A probe passed into the canal of system of the lateral line.

b.—Branch of the fifth pair cut off on its way to the organ marked *c* in Fig. 1.

c.—Bundle of jelly-tubes.

d.—The cartilage of the head.

Fig. 4.—Jelly-tubes with nerve-terminations in the flask-shaped ampulla at their commencement, slightly magnified.

a.—Nerve-branches.

b, *b*.—Dilated extremities of jelly-tubes, containing the remarkable masses in which the nerve-fibres seem to terminate.

c, *c*.—Membrane of the tube itself.

d.—Epithelium which lines the tube. (This is magnified in a higher proportion than the other parts.)

Fig. 5.—Terminations of the nerves found in the larger portions of the canal of the system of the lateral line. The portion here represented is taken from the dilated portion in the snout, into which the probe, *a*, is introduced in Fig. 3, Plate V. (slightly magnified).

a, *a*.—Nerve-twigs (also derived from the fifth pair).

b, *b*.—Delicate internal tube of membrane found inside of the tough outer wall of the canal of the system of the lateral line. The nerves terminate after this fashion at tolerably regular intervals.

Plate VI.

Fig. 1.—This Figure represents the dorsal aspect of a young torpedo, natural size; on one side a dissection is made so as to expose the electrical organ, &c.; on the other the outline of the course followed by the system of the lateral line in this fish is traced.

a.—The bodies described by Savi as the "appareil folliculaire nerveux."

b.—The electric organ.

c.—The organ (tactile) on the large branch of the fifth pair, with its jelly-tubes radiating from it. *c'*.—The same on a smaller branch.

d.—Upper surface of the gill-chambers.

e.—Glandular body corresponding with *c*, Plate IV.

f.—The snout-muscle.

g.—The eye.

h.—The temporal orifice.

i, *i*, *i*, *i*.—Outline of the course of the lateral line, with its numerous tubes opening on the surface.

Fig. 2.—The under surface of the head of the black sole, showing the velvety processes with which it is covered, and which apparently constitute the organ of touch of this animal; scattered among these processses are the follicular crypts which form the cephalic portion of the lateral line system in this fish.

a.—Openings of the olfactory sac.

b.—The mouth.

Fig. 3.—The head of the *Lepidosiren annectens*, showing the outline of the system of the lateral line.

Plate VII.

Fig. 1.—This Figure represents the under surface of the white sole. It shows the very remarkable development of the cephalic portion of the system of the lateral line in this fish. The probe, *a*, is seen entering the lateral line proper, the canal of which, at the point where the probe enters, opens into the first of a series of chambers, either formed of cartilaginous cells, or excavated in the bones of the head.

Fig. 2.—A portion of the skin from the under surface of the head of the black sole, treated with dilute acetic acid, and magnified with a pocket lens.

Fig. 3.—Two of the velvety processes from the foregoing, more considerably magnified.

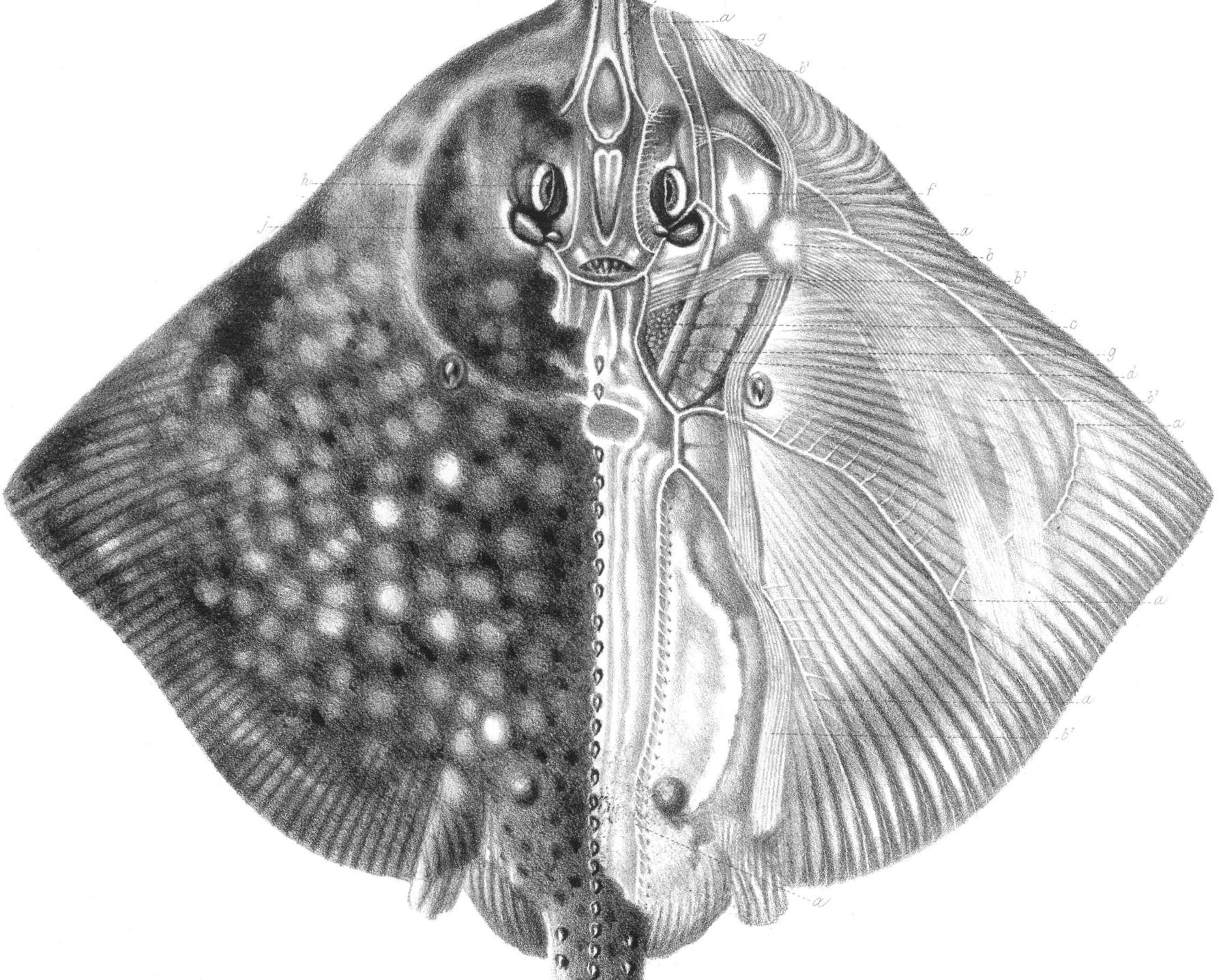
a, *a*.—The nerve-filaments from the branches of the fifth pair which enter these processes.

Fig. 4.—A transverse section of the tail of the common skate (*Raia batis*).

Fig. 5.—The same of the thornback ray (*Raia clavata*).

Fig. 6.—The same of the angel fish (*Squatina angelus*). The transverse sections are made in each at precisely corresponding localities, in order to show the relative size of the tail electric organ in each. The same letters are applicable to each.

a, *a*.—The tail electric organ.
b, *b*; *c*, *c*.—The muscle masses of the tail.
d.—The cartilaginous vertebra of the tail.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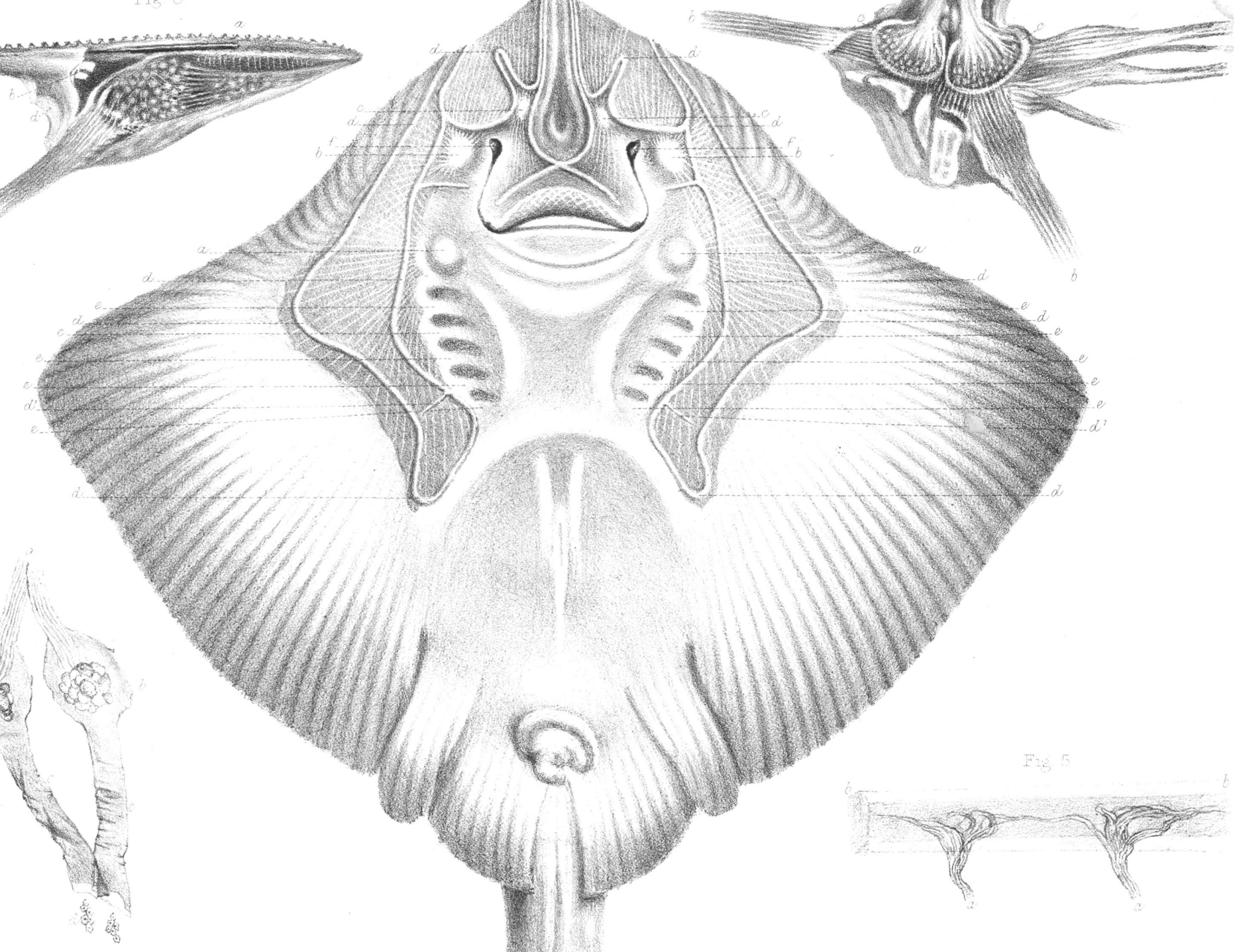
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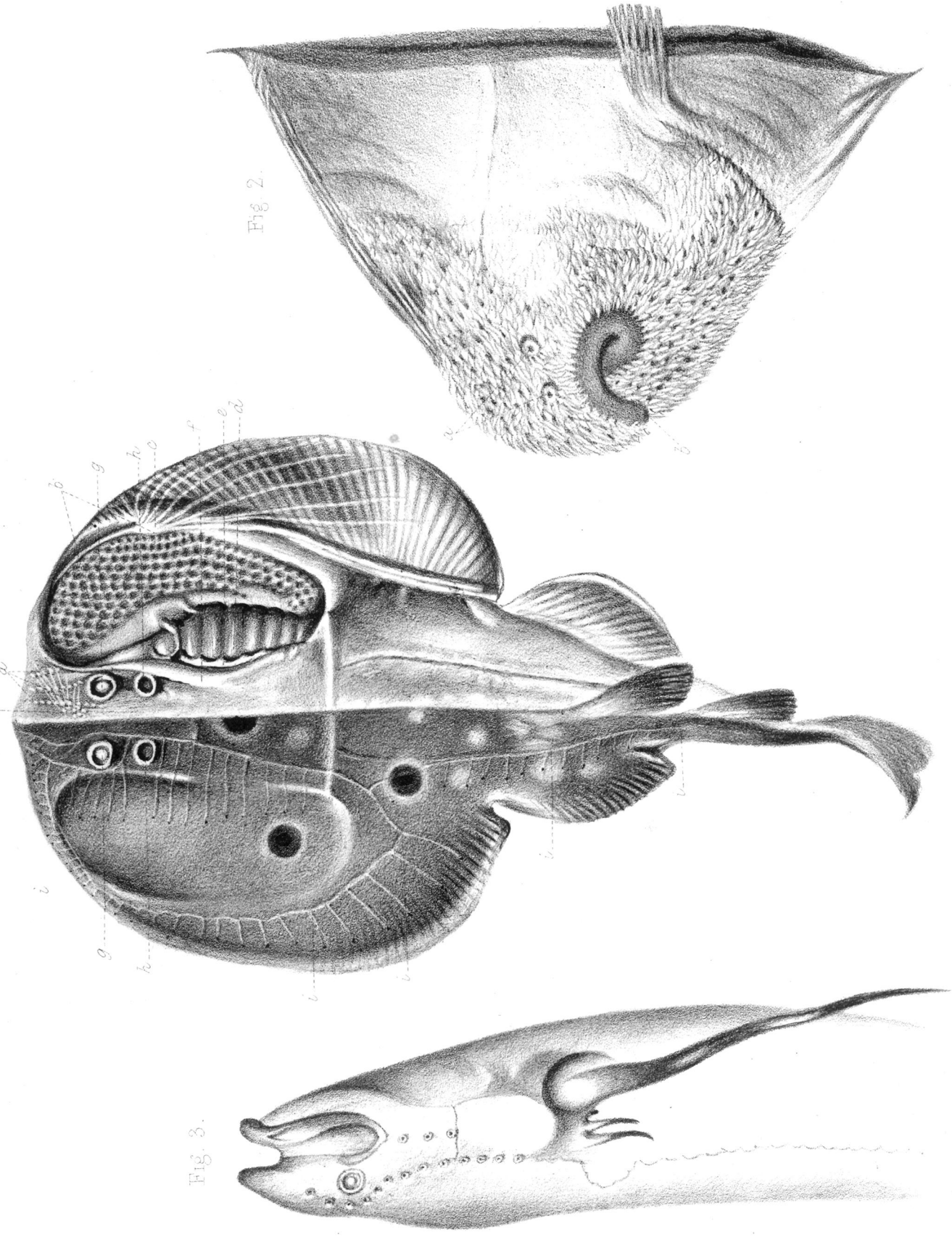
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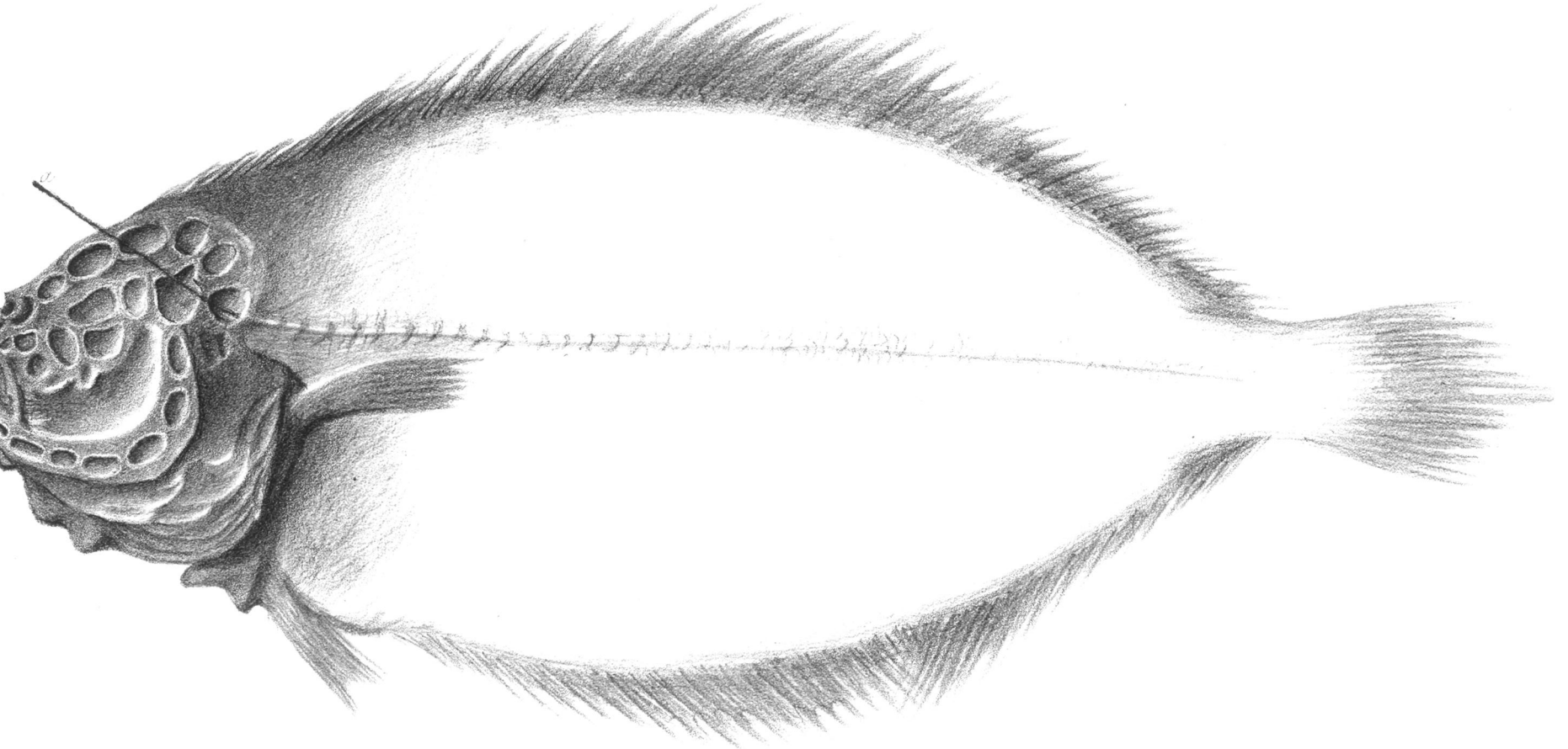

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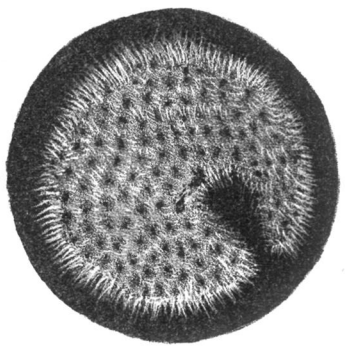

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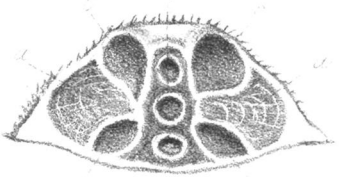

Fig. 5

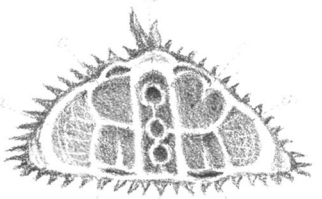

Fig. 6