XXIV. *Observations on the Torpedo, with an account of some additional Experiments on its Electricity. By* John Davy, *M.D. F.R.S. Assistant Inspector of Army Hospitals. Communicated by Sir* James McGrigor, *Bart. F.R.S. Director General of the Army Medical Department.*

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1. *On the Fœtal Development of the Torpedo.*

The accounts we possess by different naturalists of the mode of generation of this fish are so discordant and perplexing, that I have been induced to investigate the subject afresh, and I now propose to submit to the Society the results of my observations.

It may be advisable to premise a few particulars respecting the generative organs of the Torpedo. The female, like those Rays and Squali which are considered ovo-viviparous, has two ovaria, a common oviduct and two uterine cavities. The ovaria, one on each side of the spine, are attached to and enveloped in a fold of the peritonæum, just above the liver and a very little below the common infundibulum, or opening of the oviduct. The oviduct passes round on each side under the liver, and ends in an enlargement, one over each kidney, which from its function may be called a uterine cavity, formed, like the duct itself, of a villous inner membrane and of a peritonæal outer coat, connected together by loose filamentous tissue, and opening into the lower part of the intestine or cloaca by a common mouth, a little posterior to the minute papilla, the termination of the ureters. In the oviduct, just above its enlargement into the uterine cavity, there is only a slight trace of a glandular structure, in which respect the Torpedo appears equally to differ from the different species of Squalus and of Ray; all those which I have examined of either genus being possessed of a large glandular body in the situation mentioned.

The male generative organs consist of two firm oval testes, occupying the same situation as the ovaria in the female, and not very different in appearance; of vasa deferentia without vesiculæ seminales; and of a papilla in the cloaca, the common termination of the seminal and urinary passages, near the verge of the intestine.

Like the Squali and Rays in general, the male Torpedo is provided with two appendices, one on each side of the anus, composed of articulated bones, of muscles, of cartilages, and a glandular structure.

The eggs of the Torpedo I have never found in the oviduct in their passage, but only in the ovaria, or attached to the ovaria, or in the uterine cavities. When mature and attached to the ovaria, they are covered with a vascular membrane, through which they break to enter the infundibulum. In the uterine cavity they are destitute of white; they are covered, before the appearance of the embryo, with a most delicate membrane or pellicle, and consist entirely of yolk. The number of eggs varies very much with the size of the fish: in the smallest pregnant fish that I have examined, I have never found fewer than four in the two cavities; and in the largest, not more than seventeen. Their size, too, varies;—their average weight is about 182 grains; the largest of eighteen eggs which I have weighed, taken from five different fish, before the embryo appeared, was equal to 210 grains, the smallest to 129. Though without a distinct white, there is, in the uterine cavity common to all of them, a little fluid, generally milky, more rarely glairy, and sometimes bloody, which on evaporation affords crystals of common salt and a very little animal matter, composed chiefly of albumen.

In describing the fœtal development of the Torpedo, I shall confine myself strictly to what I have actually observed.

In the first stage in which I have witnessed the embryo, it appeared as represented in Plate XXII. fig. 1., about seven tenths of an inch long, without fins, or electrical organs, or any distinct appearance of eyes, with very short external branchial filaments*, not yet carrying red blood, and with a red spot in the situation of the heart (probably the heart itself) communicating, by red vessels in the umbilical cord, with the vascular part of the egg.

In the next stage in which I have observed it, it appeared as in Plate XXII. fig. 2., not quite an inch long, nor a quarter of an inch wide; the ventral fins visible, and also the dorsal and the inferior portion of the great pectoral fins; the branchial cartilages distinct and naked, the electrical organs not having yet appeared; the external branchial filaments longer than in the preceding, but still comparatively short; some of them tipped with red blood, others carrying it.

The next stage of advance I have seen is represented by fig. 3. Plate XXII. This embryo was about an inch and one tenth long and four tenths of an inch wide where widest, and it weighed just five grains. Its electrical organs were beginning to appear. The external branchial filaments were about six tenths of an inch long and contained red blood. The heart was distinct and large, as were also the two lobes of the liver. The stomach was small, apparently empty, smaller than the intestine: the intestine was large and white. The vitello-intestinal canal was distinct; it appeared as a very slender thread, connected with the upper part of the intestine, and, like the intestine itself, it contained no yolk. The eyes were apparent. There was a vesicle on the head distended with a colourless fluid, and the cavity of the cranium was full of a similar fluid. The roots of the electrical nerves were visible, but no brain.

The next stage in which I have observed the embryo is represented by fig. 4.

* These filaments, variable in length and appearance, are constant in containing each a blood-vessel, which makes the circuit of the filament.

Plate XXII. It was advanced only a little beyond the preceding; the principal differences were in the electrical organs being a little larger, the branchial filaments considerably longer (about an inch long), and the brain and spinal cord apparent.

In the next stage in which I have seen it, as represented by fig. 5. Plate XXII., there was a very considerable advance. The fœtus was about two inches and a half long, and one inch and three quarters wide. The electrical organs were distinct, the pectoral fins entire, the external branchial filaments very long. The stomach was still small, and empty, whilst the intestine was distended with yolk. The external yolk was covered with a vascular membrane, and not partially, as in the preceding, but entirely. The vitello-intestinal canal freely communicated with the intestine, and was yet very little enlarged where it joins itself to the intestine at the commencement of its valvular portion.

The next stages which have come under my observation are represented by figg. 6 and 7. Plate XXII., and fig. 1. Plate XXIII. The cavity of the abdomen is shown laid open in figg. 6 and 7, in order to exhibit the external yolk in progress of diminution, and the internal yolk contained in a membranous bag, as it were, a lateral extension of the vitello-intestinal canal, in progress of accumulation*. The branchial filaments have almost entirely disappeared.

I shall notice only two stages more of the young Torpedo, represented by fig. 4. Plate XXIII., and fig. 1. Plate XXIV.; the one of a fish six weeks old, in which the internal yolk was considerably diminished in bulk, its connexion with the umbilicus almost absorbed, the intestine full of yolk, the stomach empty but considerably developed: the other of a fish six months old, in which only a very small portion of the internal yolk remained, and the connexion of the inner yolk-bag with the umbilicus was absorbed, a vestige only of the canal of communication remaining.

These fish, at about the full period of utero-gestation, were extracted from a Torpedo just after she had been caught, were instantly put into salt water, and were preserved alive. I shall have occasion to revert to them in another part of my paper.

I may remark generally, that I have never found in any of the gravid Torpedos which I have examined in different stages, any membrane investing the fœtus, as is

* At this period of fœtal development the yolk has two distinct membranes, an external transparent one and an internal vascular one. The former is of great delicacy generally, excepting where the egg joins the abdomen; there it is very thick and strong, and slightly opake, serving in a manner the part of the sheath of the umbilical cord of the Mammalia: it is connected with, and appears to end in the cutis of the abdomen. The latter, the membrana umbilicalis, or chorion, if it may be so called from its great vascularity, passes into the cavity of the abdomen, and terminates in the vitello-intestinal canal, from whence the internal yolk-vesicle proceeds. Two large vessels (the trunks of the vessels of the chorion) enter the cord-like termination of the egg: one of them terminates in the vena portæ; the termination of the other I have not ascertained in a satisfactory manner; I believe it corresponds in function to the umbilical arteries, and brings blood from the fœtus to the egg, the other vessel returning it.

the case with the fœtus of some of the Squali*. Neither have I found any fluid in the uterine cavity at any period, excepting that already mentioned†.

The facts I have stated relative to the development of the fœtus of the Torpedo, though amply sufficient to demonstrate that this fish is not oviparous, are not incompatible with its being ovoviviparous, as it is considered by the naturalists who have paid most attention to the subject; yet I believe it is not strictly so, and that it is more correct to say that it is intermediate between ovoviviparous and viviparous, the fœtus, as I believe, deriving its support in part from the ovum, and in part from the parent. The principal fact on which I found this belief is, that the mature fœtus is very much heavier than the egg. In the three following Tables I shall give the statical results substantiating this fact.

The first Table will relate to the ovum just after it has entered the uterine cavity, or before the appearance of the embryo; the second, to the ovum after the fœtal development has commenced, but has made little progress; and the third, to the fœtus when mature, or nearly mature, indicated by the total disappearance of the external yolk, or its being reduced externally to a very small bulk. In noticing the kind of Torpedo, I shall use the popular names by which they are designated at Rome, reserving for another place the consideration of its species. The exact time when the fish was caught will be given, with a view to endeavour to determine its breeding season and period of utero-gestation.

TABLE I.

Kind.	When caught.	Number of Eggs.	Weight of each Egg tried.
			grains.
Tremola.	March 30.	8	200
			200
Tremola.	May 21.	5	185
			185
			198
			188
			188
Tremola.	May 24.	9	193
			193
			193
			200
			210
Tremola.	April 29.	5	167
			167
Tremola.	May 31.	5	129
			140
			170
			165

* The fœtus of the *Squalus Acanthias*, at a very early period, is contained in a delicate membrane, which at a more advanced period, near the full time, disappears. The fœtus of the *Squalus Squatina* seems to be analogous to that of the Torpedo without a membrane; that of the *Squalus galeus* has a membrane, even in its advanced stage, appearing to be, as it were, a link between the Torpedo and the oviparous Rays, whose eggs, inclosed in a thick strong horny shell (*Mus marinus, Pulvinar marinum* of the older naturalists), are hatched out of the body.

† I have in vain sought in the uterine cavity of the Torpedo for lithic acid, which is so abundantly secreted

Table II.

Kind.	When caught.	Number of Eggs.	Weight of each Egg tried.	Weight of each Embryo attached tried.
			grains.	grains.
Tremola.	June 13.	13	166	2
			140	2·5
			101	2
			156	2
			134	
			111	
			147	2
			174	3
			131	
			164	
			102	
Tremola.	June 26.	14	79	12
			79	14
			115	12
			107	13
			108	11
			77	13
Tremola.	June 28.	9	215	5
Occhiatella.	June 29.	4	120	1
			119	
			114	

Table III.

Kind.	When caught.	Number of fœtal Fish.		Weight of each tried.	
		Male.	Female.	Male.	Female.
				grains.	grains.
Tremola.	September 6.	2	3	540	580
Occhiatella.	September 12.	2	4	503	505
Tremola.	September 15.	1	4	435	457
					420
					460
					471
Tremola.	September 29.	6	7	481	514
				487	495
				464	533
				452	506
				485	521
				428	519
					500

The mean of the results contained in these Tables is, that the weight of the egg before any appearance of the embryo is 182 grains; and after its appearance, in-

by the kidneys of the chick in ovo; nor have I succeeded in detecting urea in the fluid it contains, a substance which I have found in a notable quantity in the fluid of the uterine cavity of the *Squalus Squatina*, and in abundance in the liquor amnii of the Dog about the fifth week of pregnancy, and have also detected in the human liquor amnii at the full period. In the cloaca of very young Torpedos I have sometimes seen a transparent fluid, probably urine, but in too small quantity for examination. The nature of the urinary secretion of the adult Torpedo I have not yet been able to ascertain; I suspect that it is liquid, and that it is voided almost as rapidly as it is secreted, the fish being without a urinary bladder, and its cloaca of narrow dimensions.

cluding the weight of the embryo, about 177 grains; whilst the weight of the mature fœtal fish is about 479 grains; proving an augmentation of weight in the mature fœtus more than double that of the egg, and in this respect differing remarkably from the fœtal chick, which at its full time weighs considerably less than the original yolk and white from which it is formed, owing in part to the evaporation of water through the shell, and in part to the excretions going on, especially of lithic acid derived from the kidneys.

How is this augmentation of weight to be accounted for? Is there, as in the majority of the Mammalia, any connexion between the fœtus of the Torpedo and the parent through the medium of a vascular and cellular structure? Or has the fœtal fish in utero, like the fœtus of the Sepiæ in the egg, the power of feeding by the mouth, and of taking food into the stomach? Or does the uterine cavity of the parent fish secrete or pour out a fluid which is absorbed by and in part nourishes the fœtus?

The first and second query I must answer in the negative. Nothing that I have observed indicates any connexion such as that supposed in the first query, between the parent and fœtus. I have carefully examined the gravid uterus under water, thinking it possible that the villi of the uterine cavity might inosculate with the branchial filaments, but I could not detect the slightest union of them, or even apposition. I have carefully examined, too, the stomach of the fœtus in its different stages, and I have always found it empty. Admitting, then, that the augmentation is effected by absorption (the only way apparently remaining to account for it), another question arises, How is the absorption accomplished? Is the whole surface of the fœtus an absorbing surface, as in the instance of some of the Mammalia which are destitute of a placenta, and whose fœtus do not appear to be connected with the uterus, as that of the Opossum and Kangaroo? Or are the branchial filaments the principal absorbing organs?

It appears not improbable that both the general surface and the filaments are concerned in the operation. The late Dr. Monro, who observed these filaments in the fœtus of the common Skate, supposes that they perform the same function as the gills, and are a substitute for them, like the branchial appendices of the Tadpole; and the same view has been taken by others of analogous filaments belonging to the fœtus of most of the Squali. This function they may perform in common with the surface; and at the same time they may convey nourishment and material for growth. If I may hazard a conjecture, I would suggest that the matter which may be absorbed by the surface, may enter into the composition of the body generally; whilst that which may be absorbed by the branchial filaments, may be chiefly employed in forming the electrical organs, and perhaps the branchiæ and the adjoining mucous glands. I shall notice a few circumstances which appear to me favourable to this conjecture.

1. The branchial filaments are most numerous and of greatest length whilst the electrical organs are forming, appearing just before these organs begin to be deve-

loped, and being removed when they are tolerably complete. Now it seems more reasonable to suppose that this associated progress of the two is in the relation of cause and effect, than to imagine that the filaments are solely designed as a substitute for the branchiæ; especially as the blood in the vessels of the yolk membrane seems to be as well adapted to receive the influence of any little air which may be contained in the fluid in the uterine cavity, as the blood circulating in the vessels of the filaments.

2. In none of the Squali the fœtus of which I have had an opportunity of examining at different periods, have I found the same elaborate apparatus of branchial filaments: they have been less numerous and very much shorter. Does not this greater elaborateness indicate that they are intended, in the Torpedo, for a special purpose? And when we consider the nature of the electrical organs abounding in fluid, as well as their peculiar office, does it not seem accordant that there should be such a peculiar provision as that in question for their formation?

3. In one instance I found a large fasciculus, as represented in Plate XXIV. fig. 2. unconnected with the branchial apertures, attached to the head, anterior to the eyes, in the situation of the principal cluster of mucous glands in the adult fish, between the anterior portions of the two electrical organs. May not this be considered an instantia crucis, both as showing that the branchial filaments are not solely designed as a substitute for the gills, and rendering it highly probable that they are concerned, not only in the development of the electrical organs, but also of the mucous glands?

It is not necessary to discuss the other two modes in which the fœtus of the Torpedo is nourished, analogous to what is witnessed in the chick in ovo, first by means of vessels conveying blood, passing from the yolk membrane, and afterwards, in addition, by the direct passage of the substance of the yolk into the intestine of the fœtus, through the vitello-intestinal canal.

Whether the fœtus of those Squali and Rays which are considered ovoviviparous are only nourished in these two ways, or also in the additional manner of the fœtus of the Torpedo, is a subject for inquiry. From what I have observed, I am rather disposed to think that they are nourished in the latter manner, though in a less degree, and without excepting even those which are contained in a closed membrane.

From the facts given in the preceding tables, and from others which I have observed, it may be inferred that the Torpedo does not bear young more than once a year; that the breeding season is the latter end of autumn and the beginning of winter*; and that the period of utero-gestation is from nine to twelve months †.

I have alluded, some pages back, to the fœtal Torpedo at its full term. Since I

* According to Aristotle, it brings forth in autumn. In my former paper I supposed erroneously that the principal breeding season is the spring, from the circumstance that the fish at that time abound in ova of a large size.

† I say from nine to twelve months, because I suspect the period of utero-gestation is not precisely fixed, but that it varies with circumstances favourable or unfavourable to bringing forth. Thus, I have had young Tor-

have been in Malta, though I have examined more than two hundred Torpedos, I have found five only in which the young were arrived at, or near, this stage. Of these, three were brought alive. I shall give some particulars, chiefly of their broods, as they may not be considered uninteresting in themselves, and as they may tend to illustrate the slow growth and some of the peculiarities of this extraordinary fish.

The first live Torpedo that I obtained in this state was an Occhiatella, on the 12th of September. It was fourteen inches long, and eight inches and a half wide; and after the extraction of the fœtal fish it weighed one pound three ounces. It had been caught rather more than an hour, and was in a small bucket full of salt water. I immediately set about preparing an apparatus to try its electricity, which occupied me about five minutes: but it was too late—the fish was then motionless. As soon as the apparatus was ready, I opened the cavity of the abdomen, hoping that if gravid, as asserted by the fisherman, the young might be still alive. From each uterine cavity three fish were extracted, but they were all dead; neither in air nor in salt water did they show the slightest signs of irritability, though they had no appearance of being bruised or in any way injured. The size of each was nearly the same; the only difference I could perceive was a little variation in the magnitude of the external yolk-bag: in two it had all but disappeared—it was smaller than a barleycorn; in the other two it was a little larger, and in the two others perhaps a little larger still. The internal yolk was very large, and about the same size in all. Their organization generally appeared to be complete, even to their teeth.

The next fish that I obtained near its full time was a Tremola, on the 29th of September. It was eighteen inches long and thirteen wide. It had been caught an hour or two before, and was in a very languid state, having been put into a vessel containing only just sufficient water to cover it. It was tried on the multiplier, but it did not affect the needle. When moribund, the abdomen was opened, and I extracted with the hand, without experiencing any shock, from the two uterine cavities, twelve fœtal fish; and one which had been expelled before, and was alive and swimming about, made thirteen. They were all nearly of the same size; and of all of them, the external yolk-bag had very nearly disappeared, the portion remaining being less than a small pea. Most of them appeared inanimate; two or three only moved their tails very slightly, and the margins of the pectoral fins. They were as soon as possible transferred to fresh sea-water. After about two minutes, one or two of them began to move their water-valves *. I was now called away, and rather more than four hours elapsed before I returned. On my return I found them all freely respiring,

pedos brought me, caught in the sea, in which the internal yolk-vesicle was large; and, in one instance, I found them in utero, with this vesicle greatly reduced in size, so as to suggest the idea, which ARISTOTLE adopted, that the young of the Torpedo, after birth, return at will into the uterus; an idea which cannot be held, on account of its anatomical impossibility. (ARISTOTLE, Hist. Animal., vi. cap. 10.)

* I apply this term to the valves which are situated at the openings behind the eyes, the office of which appears to be, to force water into the gullet, to supply the branchiæ; which water, in regular respiration, passes

and moving about actively. They imparted smart shocks to the fingers or finger pressing the upper surface, and another of the same hand the under surface of the electrical organ: they distinctly affected the galvanometer, and feebly magnetized needles through the medium of a spiral. These trials were made at 2 P.M. At 10 P.M. all the fish were alive and vivacious; an hour after I found them all dead.

The third fish I have to notice was a Tremola, seventeen inches long and twelve and a quarter broad. When brought, on the evening of the 6th of November, in a vessel of salt water, soon after it had been caught, it was tolerably vivacious; yet it did not affect the galvanometer. Before it was quite dead, the abdomen was opened, and the fœtal fish were extracted. They were ten in number, all of them about the same size. In all of them the outer yolk-bag had disappeared, as represented in Plate XXIII. figg. 2, 3, 4. Touching them with the hand, in the act of removing them from the uterine cavity, I received a distinct shock, sharp though not strong. Put into fresh sea-water, as they were extracted, some of them immediately, and in a few seconds all of them, were active and swam about: and making trial of one of them instantly, (the apparatus being in readiness,) it powerfully affected the galvanometer, and made a needle slightly magnetic. To ascertain the state of the internal yolk-vesicle, one of these fish was killed by putting it into fresh water, about half an hour after its extraction. It immediately became very restless, and endeavoured to escape: then, in less than a minute, it became quiet, and its water-valves ceased to act. Two or three times, at intervals, it was again restless: in about twenty minutes it was motionless and dead *. The appearance of its internal yolk-vesicle is represented in Plate XXIII. fig. 3.

Three of these fish remained alive till the 22nd of May, in sea water, which was changed daily, or every second day. Of the others, one only died a natural death; the rest were killed at intervals, for the purpose of examining the size of the internal yolk-vesicle, which very slowly diminished during this period, and, as well as I could judge, in a very regular manner; supposing, when first extracted, that in all, the internal yolk was nearly of the same size. Plate XXIV. fig. 1. shows the diminution it had undergone on the 22nd of May, when the three residual fish died, apparently from the carelessness of a servant giving them turbid salt water, and weaker in salt than they had been accustomed to.

During the whole of this period of five months and more, they ate nothing, though very small fish, both dead and alive, were put into the water. They retained, and indeed increased in activity, and even in their electrical energies, of which I made

out through the branchial apertures, but occasionally is discharged (the latter being closed) in considerable quantity through the superior apertures. BLOCH erroneously supposes that these latter are the normal outlets. He says, "Ils servent à l'animal à rejetter l'eau qu'il avale, soit en prenant sa proie, soit celle qui entre par l'ouverture des ouïes."—Histoire Naturelle des Poissons, tom. iii. p. 667.

* Is it found in the Nile, as asserted by some authors? The above fact would seem to indicate that the Torpedo cannot exist in fresh water.

occasional trials. They also became of rather firmer consistence, and of a darker colour, and perhaps contracted a little in dimensions. The weighing of those first killed was neglected; of the three which died last, two (males) weighed 510 grains each; the other (a female) 560 grains. Their stomachs were pretty largely developed, but empty: in the intestine there was a small quantity of yolk remaining, coloured greenish yellow in the inferior part, from the admixture of bile *.

All these facts seem to show a very slow development, and are in accordance with a long period of utero-gestation; and I may add, in favour of the same, that the ova in the ovaria of all the three parent fish were very small, the largest of them not exceeding a pea, and the majority of their minute vesicles containing a transparent fluid.

Other inferences might be drawn from these details, especially in favour of the branchial filaments being absorbent organs, rather than supplying the place of gills (the gills being apparently useless in utero when formed); but I am afraid of trespassing further on the time of the Society on a subject of limited interest.

In the beginning of this paper, I have alluded to the discrepancy which exists amongst writers on natural history relative to the mode of generation of the Torpedo. Aristotle always describes this fish as viviparous; so does Lorenzini, who wrote in the middle of the seventeenth century. On the contrary, Blumenbach, generally an accurate writer, though he quotes Lorenzini, gives the Torpedo as an example of the oviparous cartilaginous fish, laying a few large eggs, protected by a horny shell. And even Cuvier appears to have fallen into the same error, at least in his Règne Animal he has not corrected it; and from his general account of the generation of the Rays, both in this work and in his Histoire Naturelle des Poissons, it is to be inferred. It is most probable that analogy and want of confidence in Aristotle and Lorenzini were the cause of this mistake. No doubt, had these able men enjoyed an opportunity of investigating the subject themselves, they would not have failed in ascertaining the truth. Even in Malta, the inquiry is of considerable difficulty, requiring much time and patient waiting, owing to the great rareness of the gravid fish. Some idea of this may be formed, when I mention, that after I had begun the pursuit, more than twelve months elapsed before I could procure a fish with young, though I examined a very large number in hope of finding one, and though I offered to pay the fishermen above fifteen times the market price of the fish.

2. *On the Species of Torpedo in the Mediterranean.*

Respecting the number of species of Torpedo found in the Mediterranean, naturalists have been much divided in opinion; some, as Rondelet, followed by Risso, admitting four species; some, as Bellon, and latterly Rudolphi, limiting them to

* I have never found the stomach of the fœtal fish, or of these fish, which were so long without eating, softened or corroded; a change which I have several times observed in the stomach of the adult fish, killed when there was food in it in process of digestion.

two; and others, as LINNÆUS and BLOCH, with WILLOUGHBY, RAY, and ARTEDI, admitting only one*.

That there are two distinct species in the Mediterranean, namely, the Occhiatella and the Tremola, as the two kinds are vulgarly called at Rome, the spotted and non-spotted of BELLON, there does not appear to me to be a doubt. But it appears more than doubtful if any other true species exist in this sea. I draw this conclusion from multiplied observations made both at Rome and in Malta.

That these fish, the Occhiatella and Tremola, are distinct species, admits of satisfactory proof. They differ not only in their colour and general appearance, but also somewhat in their form. The Occhiatella is more gracefully made than the Tremola; its fins are larger, especially its dorsal fins; its water-valves are larger and different in shape, and the openings behind the eyes to which they belong are guarded by much smaller projections than protect those passages in the Tremola†. And, internally, there is a remarkable difference in the structure of the villous coat of the uterine cavity: in the Occhiatella the villi are filamentous and detached, as represented in Plate XXIV. fig. 4.; in the Tremola they are continuous delicate plates or laminæ, as shown in Plate XXIV. fig. 3.‡ These characters are constant in all the different specimens which I have examined.

To these two well characterized species, it appears to me that all the varieties of the Torpedo, at least those known hitherto in the Mediterranean, may be referred: the *T. unimaculata* of RISSO, and the second species of RONDELET§, to the Occhiatella; and the varieties with dark irregular spots, or without spots, to the Tremola.

CUVIER, in the last edition of his Règne Animal, and RUDOLPHI, have so considered the first-mentioned variety, the *T. unimaculata*, as it differs only in having one eye-spot instead of five, the most common number. But it is not more uncommon to meet with it having three or four spots than one; and that this is purely accidental

* Both those who have adopted four species and those who have allowed only one, appear to have followed RONDELET, in the latter instance critically, in the former literally, in proof of which the following passage may be adduced. "Torpedinum genera quatuor facimus, tria earum quæ maculis notatæ sunt, quartum ejus quæ maculis caret. Quæ genera omnia viribus et corporis specie non differunt, sed maculis tantum. Quare quæ de unius facultatibus et partium tum internarum tum externarum descriptione dicuntur, eadem etiam reliquis convenire existimato." (G. RONDELETII Libri de Piscibus, &c., p. 358. fol. Lugduni, 1554.)

† CUVIER, in the edition of his Règne Animal of 1830, (for an extract from which, as well as for one from RUDOLPHI's Grundriss der Physiologie, relative to the Torpedo, I am indebted to my friend Dr. ALLEN THOMSON,) distinguishes the Occhiatella by its spots, and by the absence "de dentelures charnues au bord de ses évents." This does not hold good of any of the specimens which I have examined. The cartilaginous projections (which they really are) covered with cutis, I have found only smaller in the Occhiatella, not absent.

‡ The villi increase in size during the period of pregnancy, and then contain a large quantity of blood. In each filament, in the instance of the uterus of the Occhiatella, there is a blood-vessel reflected on itself, circulating blood of a bright scarlet hue; and in the lamellar structure of the uterus of the Tremola there is a similar appearance of blood-vessels in loops.

§ "Secunda Torpedinis species à primâ differt, quòd maculas nigras, rotundas, circulis non distinctas habeat, sed eadem pentagoni figurâ dispositas. Est etiam primæ concolor."—RONDELET, p. 362.

is proved by the circumstance, that in a brood of several fœtal fish, of which all but one resembled the parent in having five spots, the exception had three. The Occhiatella has been seen even with seven eye-spots.

The varieties of the Tremola are the *T. marmorata* of Risso and the *T. Galvanii*, which Rudolphi, and, I believe, latterly Cuvier, has considered identical in species. This appears to me to be proved by their general character being the same, their water-valves, fins, and uterine structure; and further, by the circumstance, that between the two varieties (the former marked with black spots or patches irregularly distributed, the latter without spots,) there is a complete gradation or intermixture, both the spotting and colouring varying infinitely, so that it is difficult to find two fish exactly similar in either respect. How much this variation is owing to locality and other circumstances, it is difficult to decide. As the spotted fish is most frequently caught where the bottom is sandy, and the other variety where it is muddy, light may be concerned in the difference, and the spots may be produced like freckles, by the action of light: and in process of time they may become hereditary, the fœtuses generally, even of these varieties, resembling in appearance the parent fish.

Rudolphi has given to the Occhiatella species the Italian name of *T. ocellata*; perhaps the Latin word *oculata** may be preferable. The other species he designates as the *T. marmorata*, for which might be substituted the term *diversicolor*, being applicable to all the varieties of it, and descriptive of its quality of variableness of appearance.

For the information of travellers who may visit Malta, and wish to investigate the electricity of the Torpedo, I may mention that this fish (both the *T. oculata* and *diversicolor*) is called by the Maltese Haddayla, derived from a verb in their language signifying to benumb or paralyze, and consequently that it should be inquired for by this name, not by that of Torpedo, which is generally unknown here. I may add further, by way of caution, that the Torpedo in Malta is often difficult to be procured, partly owing to its being little sought after for the table, being used as an article of food only by the indigent, and partly, I believe, from the uncertainty and irregularity of its coming into shallow water. However, by paying well the fishermen, it may be obtained at all seasons; and the longest time to wait may be a fortnight or three weeks.

3. *An account of some additional Experiments on the Electricity of the Torpedo.*

Mr. Faraday in the Third Series of his Experimental Researches on Electricity, states that he has little or no doubt, were Harris's electrometer applied to the Torpedo, the evolution of heat would be observed†. I have made very many experiments

* Pliny, by Bloch and others, is supposed to have applied this term to the Torpedo. As in the only passage in which I am aware he has used it (Hist. Nat., lib. xxxii. cap. ii.—the passage is little more than a list of fish,) the word Torpedo is also employed, as if applied to a different fish, the justness of their supposition is doubtful.

† Philosophical Transactions, 1833, p. 46.

on this subject, completely establishing Mr. FARADAY's anticipation. The instrument employed was similar to that described by Mr. HARRIS in the Philosophical Transactions of 1827, differing merely in the wire passed through the small globe being exceedingly fine, and of platina, formed after Dr. WOLLASTON's method*; in having a small stop-cock for regulating the height of the spirit in the stem; and in using as small a quantity of spirit as possible†. The delicacy of this instrument was so great, that the spirit was not only moved by a single spark of the electrical machine, but even very distinctly by the electricity of a single voltaic combination, composed of a copper and zinc wire, the former $\frac{1}{25}$th of an inch in diameter, the latter $\frac{1}{50}$, excited by dilute sulphuric acid.

This instrument was strongly affected by active fish, and even distinctly by weak ones; indeed, occasionally, when it has formed part of a circle in connexion with a galvanometer, I have seen it affected alone, the galvanometer affording no indication of the passage of the electricity. Using two air thermometers of the same construction, each connected with the wires for contact at one end, and with a galvanometer at the other, the heating effect of the electricity of the Torpedo has been apparently diminished, and even more distinctly diminished on adding to the circle another link of very fine platina wire. And at the same time its influence on the galvanometer has been diminished, and its power of imparting permanent magnetism to a needle placed in a spiral, both forming part of the circle.

When heat has been applied to the extra link of platina by means of a spirit lamp, so as to render it red hot, the diminution of effect has disappeared; and equally so, as well as I could judge from many experiments, whether acting on the thermometer, the galvanometer, or the needle in the spiral.

It appeared not improbable that a short portion of a very fine platina wire might be ignited in the passage of the electricity of the Torpedo. I have made several experiments to ascertain this, but have never witnessed the effect, even in perfect darkness, and using fish, the discharge of whose electricity at the same time converted a needle into a tolerably powerful magnet, the needle having been put into a spiral connected with the fine wire, so as to afford a test of the strength of the electricity. This want of ignition may at first view seem contrary to the effect on the thermometer; but perhaps it ought not to be considered so, taking into account the rapid manner in which the heat evolved in the fine platina wire must be carried off by the adjoining compound wire of platina and silver.

The experiments detailed in my former paper were demonstrative that the electricity of the Torpedo is capable of acting like voltaic electricity in effecting chemical

* Philosophical Transactions, 1813, p. 114.

† I mention these circumstances because I have not been able to refer to Mr. HARRIS's later account of his instrument, published in the Philosophical Transactions of the Royal Society of Edinburgh. I should add that the bulb of the thermometer was defended from the variable temperature of the surrounding air by being included in a wooden box.

decompositions; and several other trials which I have made are amply confirmatory of this. In these latter experiments I have not, as in the former, coated the wires introduced into the fluids with sealing-wax, leaving the points only exposed. Though the wires were naked, and in every instance introduced more than a quarter of an inch into the fluid, and the distance between them was at least a tenth of an inch, yet satisfactory results were obtained. Using either a saturated solution of common salt, or a mixture of equal parts of sulphuric acid of commerce and water, and platina or gold wires, gas was given off round each wire under the influence of the discharge of the electricity of an active fish, one contact wire being applied to the under surface, and the other to the upper surface of the Torpedo. When steel needles were used with the salt water, then gas was disengaged only from the one in connexion with the under surface of the fish, the other needle becoming oxidated. Using a strong solution of nitrate of silver and gold wires, silver was precipitated only on that in connexion with the under surface; employing strong nitric acid and platina wires, gas was given off from one only, that in connexion with the upper surface; and using a solution of iodide of potassium and starch*, the iodine in combination with the starch, as indicated by the discolouration, was precipitated round the same wire.

Even the decomposition of water has been effected when the circle has been interrupted by four portions of the solution of common salt, contained in small tubes with two needles in each, the needles in one connected with those in the other, and at the same time with the galvanometer, a spiral holding an unmagnetized needle and an air thermometer. And simultaneous with the chemical decomposition, the needle in the galvanometer has been moved, and the spirit in the air thermometer has been raised, and the needle in the spiral has been magnetized.

The tests or indications of the electricity of the Torpedo at present known are six in number, namely, the physiological effect, as the sensation it imparts is sometimes called; the chemical effects, as the precipitation of iodine, the decomposition of water, &c.; its effect on the thermometer, on the galvanometer, and on steel in the spiral. These different tests, in point of delicacy, I am inclined to believe are in the order in which they are enumerated. That the two first should be placed highest, and that sensation should have the precedence, the experiments which I have made appear to prove, independently of all analogy.

When the human body has formed part of a circle of communication between the two opposite surfaces of a Torpedo, and also a chemical apparatus with platina wires and the solution of iodide of potassium and starch, the shock experienced by the hands has been strong, and the chemical effect either null or slight, no gas appearing when a strong solution of salt has been used, and no precipitation of iodine occurring unless the platina points were very nearly in contact, and the fish energetic.

* When starch in powder is added to a saturated or nearly saturated solution of the iodide of potassium, a transparent gelatinous mass is formed. This I have used in my experiments; a single combination of copper and zinc wire, acted on by a very dilute acid, occasions in this compound a precipitation of iodine.

When besides the human body and the chemical apparatus the galvanometer has been introduced into the circle with the air thermometer and spiral, the shock has been experienced as if it had been received direct from the fish, but I have never witnessed at the same time any other effect.

Not taking the human body into the circle in trials on fish of very feeble electricity, I have witnessed the precipitation of iodine when neither the air thermometer, nor a delicate galvanometer with a double needle, has been affected.

The same kind of evidence has been obtained of the thermometrical test being next in point of delicacy, in as much as I have seen the air thermometer affected by a fish which had no influence on the galvanometer in connexion with the wire of the thermometer.

That the needle in the spiral is the least delicate test, does not require to be insisted on. The electricity of a Torpedo, of almost feeble energy, has been equal to produce all the effects alluded to at once, excepting sensation, as already explained, and excepting the imparting permanent magnetism to the steel needle. The last effect, as might be expected, has required greater force; a moderate force, however, has been sufficient when a very slender needle has been used, and a spiral of fine wire closely coiled, only just capable of receiving the needle*.

It having been stated on high authority that a spark has been obtained from the *Gymnotus electricus*†, I have thought it right to renew the attempt to procure a spark from the Torpedo. I have tried the method which it is said succeeded with Mr. WALSH in the instance of the Gymnotus, namely, dividing with a pen-knife gold-leaf attached to glass, and connecting the divided parts with the contact wires. Using an active fish in this way I could neither observe a spark in the dark, nor in the light detect the slightest indications of the passage of electricity, either by the galvanometer or the more delicate test of the sensation or shock. I have been equally unsuccessful using an electroscope formed on the principle of COULOMB's, which displayed sparks when touched either by a small rod of glass slightly excited, or of sealing-wax; even when the Torpedo was taken out of water and all adhering moisture removed, no effect could be obtained, not even the slightest indications of attraction. I have varied the trials, using highly rarefied air at ordinary temperatures, and also condensed air deprived of moisture, with the same negative result. And I have been equally unsuccessful in substituting flame: unless the metallic points were in contact in the flame of the spirit-lamp, the passage of the electricity

* The spiral I have latterly used is of fine copper wire gilt, having about 300 convolutions to the inch: an inch of it weighs four tenths of a grain.

† Mr. WALSH is said to have written to M. LE ROI to the above effect; and also that Sir JOHN PRINGLE and M. MAGELLAN assured M. LE ROI they had witnessed the result repeatedly. Vide BLOCH's Ichthyologie, p. 1020. BLOCH refers for his information to ROZIER's Journal, Ann. 1774. M. DE HUMBOLDT (Annales de Chimie et de Physique, tom. xi. 427.) states that the same result has been observed by M. FAHLBERG. He refers to Vetensk. Acad. ny. quart. 2. (1801.)

appeared to be completely interrupted. In very many experiments, employing the most active fish, if there were any visible space between the ends of the red-hot platina wire, I never witnessed the galvanometer in connexion with one wire affected, nor could obtain a shock. Reasoning on the subject, this perhaps is what might be expected, considering that the surface of the fish is a better conductor than air. One fact, however, which I had observed, afforded some encouragement to persist in the trials, the fact that the torpedinal electricity passes through distilled water, which is a worse conductor of it than its own skin.

I thought it possible that by insulating the Torpedo on a plate of dry glass, and wiping its circumference dry and smearing it with oil, that either a spark might be procured, or that the galvanometer might be affected. But in this, too, I have been disappointed; not even in flame, when the interruption of the circle has been only just visible, has any effect on the instrument been produced, or any chemical effect, using the delicate test of solution of iodide of potassium and starch.

In a few experiments on metallic conductors, the effect of the electricity of the Torpedo on the galvanometer appeared to be much the same, whatever metals were used, and whether rusty or bright, provided the junctions were bright. The mass of metal appeared to have more influence; the effect, as might have been expected, diminishing with the increase of the mass; thus, when a poker weighing about two pounds formed a part of the circle, the effect on the electrometer, though distinct, was less powerful than when it was omitted; and when a large copper coal-scuttle was substituted for it, the effect was still more diminished, the deviation of the needle being only just visible. Extension of surface, as in the instance of increased length of wire, had a sensible modifying effect; thus, in an experiment in which about 1000 feet of wire were used (formed of three pieces, two about $\frac{1}{50}$th of an inch in diameter, the third piece considerably finer), the motion of the needle was decidedly slower than when a short length of wire was employed, though the space traversed was not perceptibly different.

The few experiments which I have made on the Torpedo, analogous to those instituted by Mr. Todd, described by him in the Philosophical Transactions for 1816, have afforded very similar results. When the brain has been divided longitudinally, the fish has continued to give shocks; when the brain has been entirely extracted, the fish instantly lost this power, though the muscles generally continued to act powerfully; nor could any shock be procured in this instance, either by puncturing with a sharp instrument the electrical nerves, where they quit the cavity of the cranium, or where they enter the electrical organs, just after passing between the branchial cartilages. On one occasion, however, it may be mentioned, that when a small portion of brain was accidentally left, contiguous to the electrical nerves of one side, and with which they were connected, then the fish, on being irritated, gave a shock to an assistant who grasped the corresponding electrical organ.

M. de Humboldt states that the shock of the Torpedo may be procured by touching, with the finger or hand, one surface only of the fish *. The experiments which I have made expressly on this point have led me to a different conclusion, namely, that it is requisite to touch the opposite surfaces of the electrical organs or organ, or a conductor or conductors connected with them, to receive a shock. In very many instances that I have irritated Torpedos by pressing with the finger on different parts of the back, as the upper surface of the electrical organs, and on the margin of the pectoral fins, however much the fish were irritated, I never had any sensation excited by the electricity, which there was reason to believe was discharged; though immediately after, on touching the two surfaces, irritating only the upper, shocks were received. On some few occasions, I have perceived a shock, when apparently only one surface of the fish was touched; but I believe in these instances the discharge took place through the water †. In corroboration, I may mention, that in experiments in which one surface only has been touched and irritated, the fish themselves appear to make an effort to bring, by muscular contraction, the border of the under surface (the upper being pressed on) in contact with the offending body. And this I have witnessed as distinctly in the fœtal fish as in the adult; clearly showing that the effort is instinctive ‡.

The conductor, which I suppose to be necessary for conveying the electricity when a shock is felt without immediate contact, exists in salt water. The galvanometer has been affected when the two extremities of it have been brought in contact, one with the back of the fish, and the other with the water, two or three inches from the fish. And in one instance I experienced a shock, although I touched the water alone, close to a Torpedo; it was in removing an active fish, by means of an earthenware dish, from one vessel into another: the hand that received the shock grasped the wet margin of the dish just as the Torpedo entered it.

I believe that the Torpedo has the power of discharging its electricity in any direction it chooses. This inference is drawn from finding that when one hand, in contact with the opposite surfaces of the fish, is receiving shocks, the other hand, immersed in the water close by, has received no shock. And, in confirmation of this, I may mention, (and at the same time to show how the discharge is connected with the volition of the animal,) that when I have applied to the opposite surfaces of a Torpedo copper plates, merely gently touching, joined together by a copper wire, and

* Annales de Chimie et de Physique, tom. xi. p. 430.

† The most remarkable example of the kind of which I have any note, was that of a young Torpedo, which gave slight shocks to the hand on which it was supported, whether just under the surface of the water, or just after it was taken out of the water into the air.

‡ In my former paper, I have supposed that the mucus with which the Torpedo is lubricated may be a conducting medium between the two opposite surfaces. This was an erroneous view; it may serve that purpose to the surfaces individually. Seeing the error theoretically, I was led to examine the margins of the fins, and they have appeared to me to have less mucus adhering to them than any other part of the fish, as if intended partially to insulate the electrical organs.

then irritated the fish with the contact wires in the usual manner, the galvanometer attached to the contact wires has been distinctly affected.

In my former paper I have stated my inability to account for my brother, the late Sir Humphry Davy, not having obtained any positive results in his experiments on the Torpedo. After reconsidering the subject, I am disposed to think it might have been owing to his using large fish, without the means of ascertaining their electrical activity, excepting by the shock. And we have seen, that when the human body forms part of the circle of communication with a galvanometer, the latter is not affected in the passage of the electricity producing the shock, which may serve to explain his not having witnessed any effect on the instrument at Trieste. As regards the electrical energies of large Torpedos, nothing is more uncertain. There appears to be no relation between the muscular and electrical power. I have seen strong vivacious fish, which made great muscular exertions in the water, almost or entirely destitute of electrical power; and, on the contrary, I have seen others languid and moribund, which have exerted considerable electrical power. Small fish are almost always active electrically, and they are greatly to be preferred as subjects for experiment. Mr. Walsh noticed, in the fish on which he experimented at Rochelle and the Isle of Ré, a retraction of the eyes of the Torpedo at the instant it exercised its electrical function. This I have not witnessed in the Torpedos of the Mediterranean; nor, indeed, have I been able to associate any visible sign, any apparent movement of the fish, with the electrical discharge.

The electricity of the Torpedo, theoretically considered, offers a wide field for speculation. Is it, it may be asked, merely a form or variety of common electricity, or a distinct kind, or not a single power, but a combination of many powers?

The first opinion, which is commonly received, and which has been ably advocated recently by Mr. Faraday, is supported by the majority of the facts adduced in this paper. The circumstance principally hostile to it, at least in appearance, is the interruption of the torpedinal electricity by the smallest quantity of air, and its want of the power of attraction and repulsion in the air.

These peculiarities are seemingly in favour of the second opinion, that the electricity of the Torpedo is specific and peculiar. But, till the opposite surfaces of the electrical organs can be perfectly insulated, so that no easier mode of communication is afforded than through air, they can hardly be considered as deserving of much weight*. The origin of the electricity of this fish perhaps offers a stronger argument in favour of its specific nature; being, apparently, peculiar and distinct from any known mode of electrical excitement, independent, as far as we can judge, of chemical action, or change of temperature, or change of form. But this argument may be

* In the experiments in which I attempted to insulate the surfaces by means of oil, the probability is, that I failed, and that a communication continued, if not by the outer surface of the skin, at least by its inner; indeed, the attempt to insulate these organs in the manner desired seems to be almost hopeless.

Fig: 1.

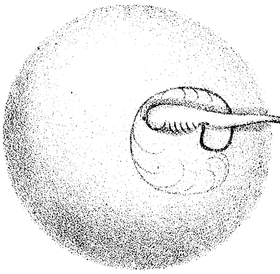


Fig: 2.

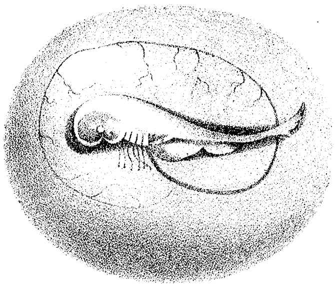


Fig: 3.

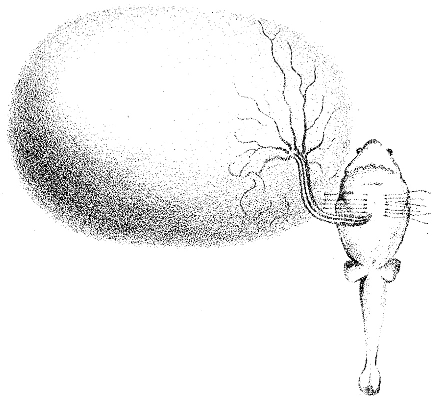


Fig: 4.

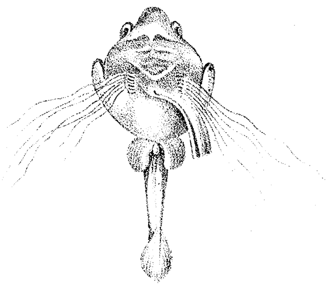


Fig: 5.

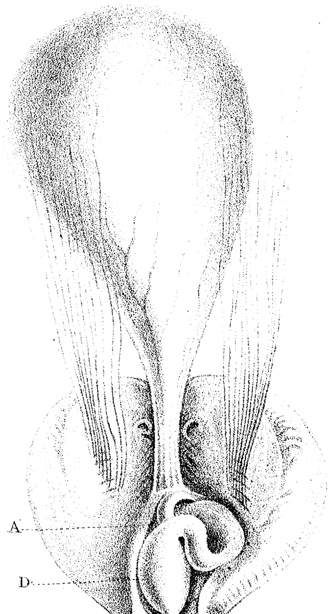


Fig: 6.

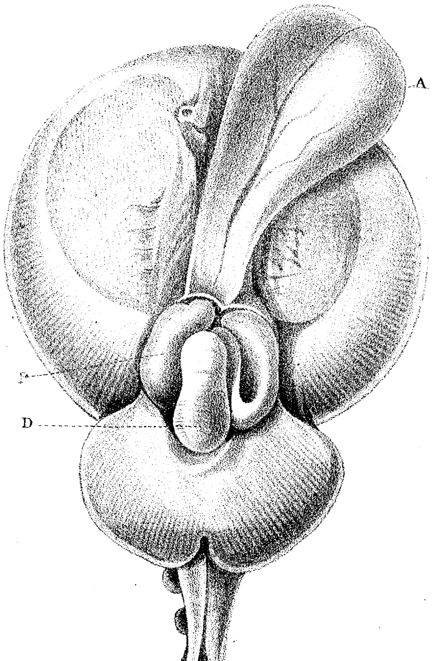
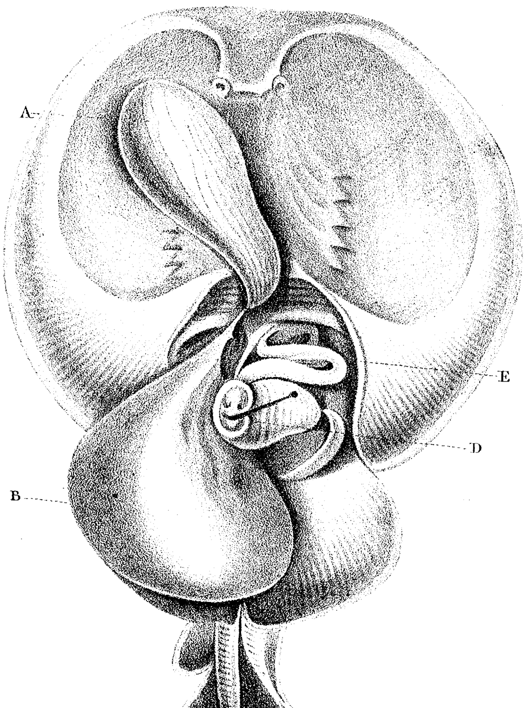


Fig: 7.



J. Basire lithog.

put aside by referring torpedinal electricity to animal secretion, the cause and nature of which are still a mystery *.

The third opinion may be indulged in as an hypothesis, and, as a guide to research, it may not be useless. It applies, however, almost as much to other varieties of electricity as to that of the Torpedo; all of which, it is possible, may be compounded, or owe their various effects to the union of several powers or ethereal fluids, and their peculiarities, compared one with another, to the predominance in various degrees of these fluids. What is known of the solar ray is not unfavourable to such an opinion; and the history of physical science, in relation to elementary ponderable matter, may rather give encouragement to the notion.

Malta,
March 4th, 1834.

Explanation of the Plates.

Plate XXII.

The figures in this plate are intended to show the progress of the embryo, the increase and decrease of the branchial filaments, and the decrease of the external and increase of the internal yolk-vesicle.

Fig. 1. Fœtal Torpedo and yolk-bag, at the period when the branchial filaments are very short, and do not carry red blood.

Fig. 2. Fœtal Torpedo and yolk-bag, at the period when the branchial filaments are beginning to carry red blood.

Fig. 3. Front view of the fœtal Torpedo, with the yolk-bag, showing the further increase of the branchial filaments, and the commencement of the development of the electrical organs.

* In examining the structure of the Torpedo, I have found that the skin covering the electrical organs above is not only more coloured, but also thicker than below, and more vascular, and surrounded by more powerful muscles, and supplied with a greater quantity of mucus; whilst the under surface appears to have a larger proportion of subcutaneous nerves. This difference of structure in the two surfaces of the electrical organs is probably somehow connected with their opposite electrical states.

I may here notice another peculiarity of organization common to both species of Torpedo, which came under my observation in seeking, though unsuccessfully, for the great sympathetic or the analogous ganglionic nerves, which Cuvier asserts exist in the cartilaginous fish (Histoire Naturelle de Poissons, tom. i. p. 438.). The peculiarity alluded to is represented by Plate XXIV. fig. 5. It has very much the appearance of a nervous ganglion, but is in reality a blood-vessel, enlarged into a little bulb, lined with a reddish substance like muscular fibre, giving the idea of a small heart. It is situated one on each side of the aorta, from whence it proceeds, just below the great plexus of nerves which supplies the pectoral fin; and the arterial branch derived from it is lost in this fin. If it be muscular, as it appears, its function may be to aid in propelling the blood into the pectoral fin, and perhaps into the electrical organ.

Fig. 4. Front view of the fœtal Torpedo, showing a more advanced stage in the development of the branchial filaments and electrical organs.

Fig. 5. Front view of the fœtal Torpedo at a more advanced stage, with the abdomen laid open to show,

A. The vitello-intestinal canal, connecting the yolk and intestine previous to the appearance of the internal yolk-vesicle;

D. The intestine distended with yolk.

Figg. 6 and 7. Fœtal Torpedos further advanced, with the cavity of the abdomen laid open, showing the internal yolk-bag, B, progressively augmenting, as the external yolk-bag, A, is diminishing.

Fig. 7. D. The intestine laid open below the stomach, E, showing the entrance of the vitello-intestinal canal.

Plate XXIII.

The figures in this plate are intended to show the diminution and disappearance of the external yolk-vesicle, and, with fig. 1. Plate XXIV., the diminution of the internal yolk-vesicle.

Fig. 1. Front view of a young Torpedo, showing a further diminution of the external yolk-bag.

Fig. 2. Ditto, showing the total disappearance of the external yolk-bag.

Fig. 3. Ditto, with the abdomen laid open, showing,

B. The internal yolk-bag, of large size.

Fig. 4. A young Torpedo, six weeks old; the cavity of the abdomen laid open, to show,

B. The internal yolk-bag, considerably diminished in bulk, and its connexion with the umbilicus almost absorbed;

D. The intestine, full of yolk;

E. The stomach considerably developed, but empty.

Plate XXIV.

Fig. 1. A Torpedo, six months old; the cavity of the abdomen laid open to show the internal yolk-bag, B, almost entirely absorbed, and with a mere vestige of the canal of communication remaining; D, the intestine; E, the stomach.

Fig. 2. Back view of a fœtal Torpedo, showing the accessory fasciculus of branchial filaments, described at p. 537.

Fig. 3. A. The glandular structure in the oviduct, just above the uterine cavity of the *T. diversicolor*.

Fig. 4. The uterine organs of the *T. oculata*, the infundibulum, ovaries, oviducts, uterine cavities (one laid open), and their common aperture in the cloaca.

Fig. 5. The bulbous vessels (supposed to be auxiliary hearts) connected with the aorta.

Fig. 1.

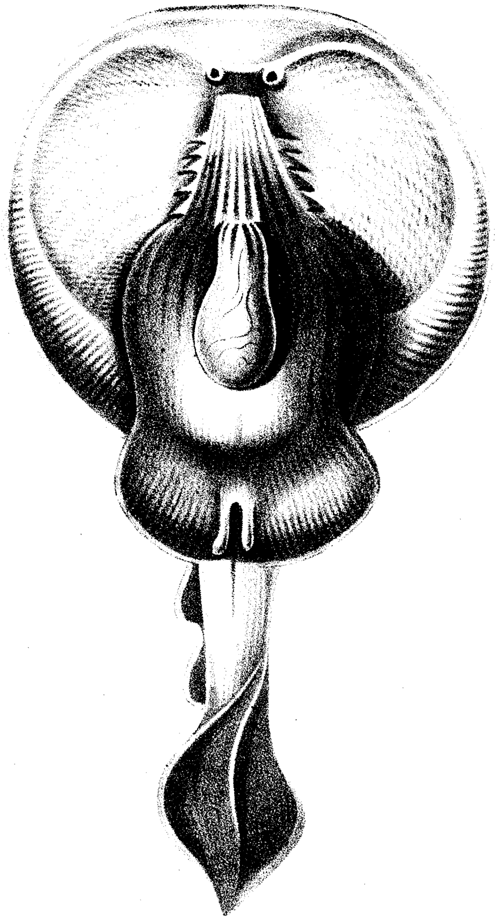
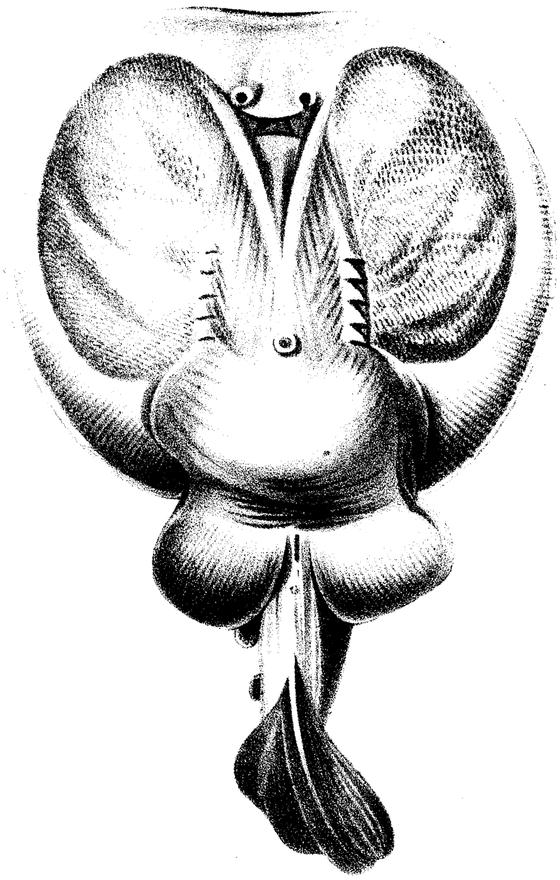


Fig. 2.



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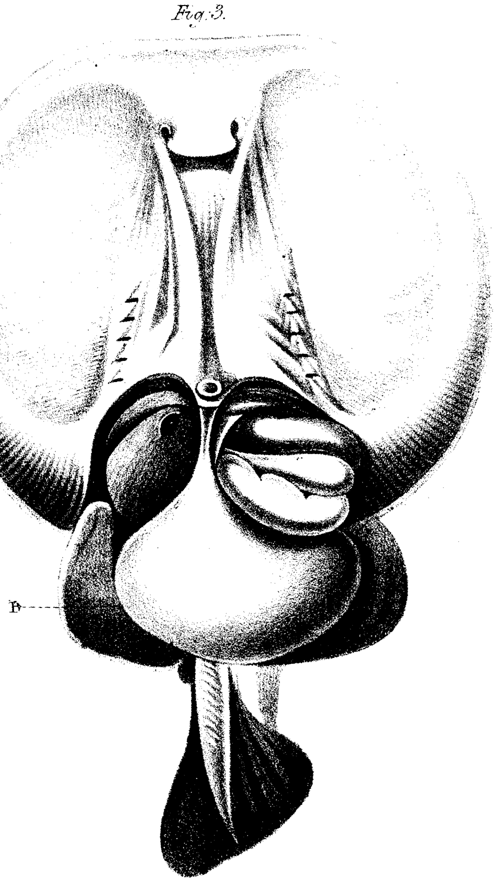

Fig. 4.

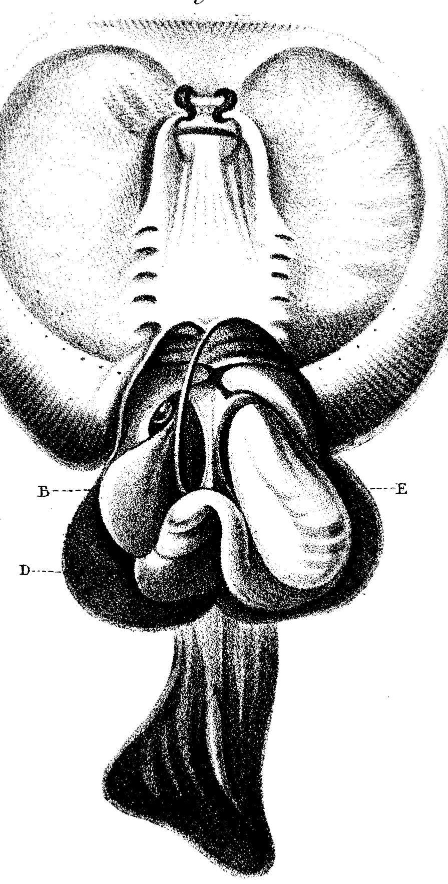

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Fig. 1.

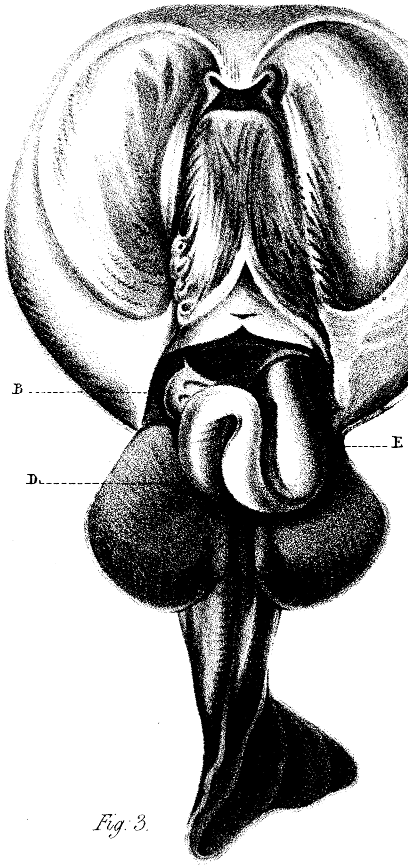
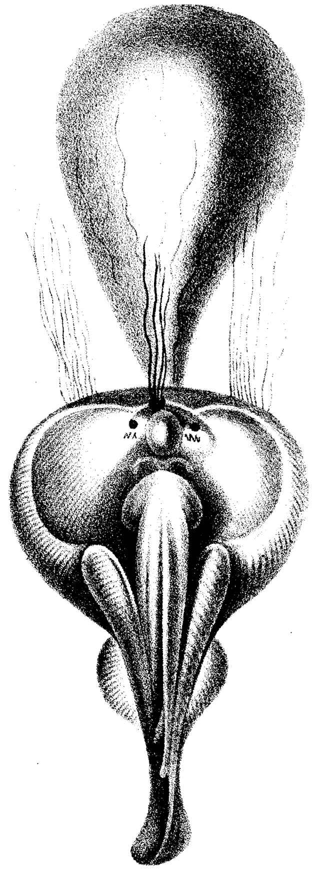


Fig. 2.



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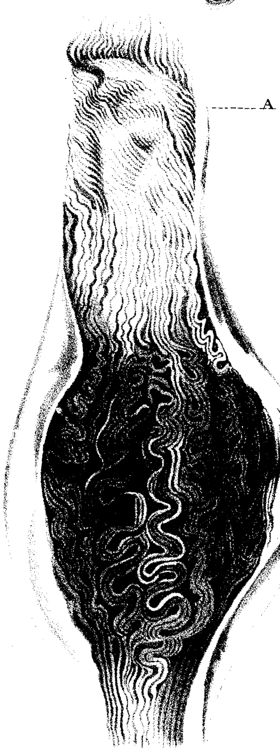


Fig. 5.

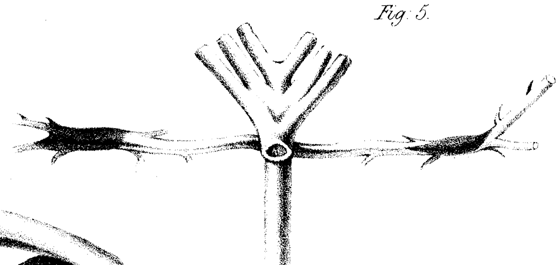
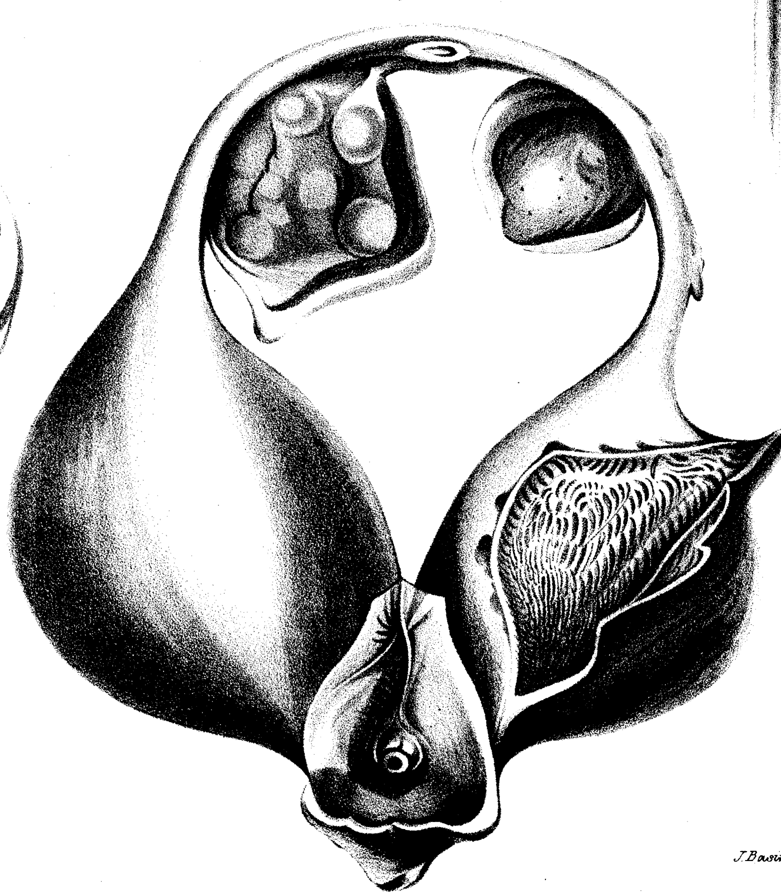


Fig. 4.



J. Basire lithog.