XXXIX. *Of the electric Property of the Torpedo. In a Letter from* John Walſh, *Eſq*; *F. R. S. to* Benjamin Franklin, *Eſq*; *LL. D., F. R. S., Ac. R.* Par. *Soc. Ext.*, &c.

Cheſterfield-Street, July 1, 1773.

DEAR SIR,

Read July 1, 1773. I Am concerned that other engagements have prevented me from giving to the Royal Society, before their receſs, a complete account of my experiments on the electricity of the Torpedo; a ſubject not only curious in itſelf, but opening a large field for intereſting inquiry, both to the electrician in his walk of phyſics, and to all who conſider, particularly or generally, the animal œconomy.

To ſupply the deficiency in the beſt manner I am now able, I will requeſt the favour of you to lay before the Society my letter from la Rochelle, of the 12th July 1772, and ſuch part of the letter I afterwards wrote from Paris, as relates to this ſubject. Looſe and imperfect as theſe informations are, for they were never intended for the public eye, they are ſtill the moſt authentic, and ſo far the moſt

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ſatisfactory I can at preſent offer, ſince the notes I made of the experiments themſelves remain nearly, I am ſorry to ſay it, in that crude and bulky ſtate in which you had the trouble to read them.

Letter from Mr. WALSH to Dr. FRANKLIN, dated la Rochelle, 12th July 1772.

" It is with particular ſatisfaction I make to you " my firſt communication, that the effect of the " Torpedo appears to be abſolutely electrical; by " forming its circuit through the ſame conductors " with electricity, for inſtance metals, and water; " and by being intercepted by the ſame non-con- " ductors, for inſtance glaſs, and ſealing-wax. I " will not at preſent trouble you with the detail of " our experiments, eſpecially as we are daily ad- " vancing in them; but only obſerve, that we have " diſcovered the back and breaſt of the animal to be " in different ſtates of electricity: I mean in par- " ticular the upper and lower ſurfaces of thoſe two " aſſemblages of pliant cylinders, of which you " have ſeen engravings in Lorenzini *. By the " knowledge of this circumſtance we have been " able to direct his ſhocks, though they were very " ſmall, through a circuit of four perſons, all feel- " ing them; likewiſe through a conſiderable length " of wire held by two inſulated perſons, one touching " his lower ſurface, and the other his upper. When

* Obſervazioni intorno alle Torpedini di Stef. Lorenzini 1678.

Redi appears to be the firſt who remarked theſe ſingular parts of the Torpedo in 1666. Franc. Redi, Exper. Nat.

" the

" the wire was exchanged for glaſs, or ſealing-wax,
" no effect could be obtained: but as ſoon as it was
" reſumed, the two perſons became liable to the
" ſhock. Theſe experiments have been varied many
" ways, and repeated times without number, and
" they all determined the choice of conductors
" to be the ſame in the Torpedo as in the Ley-
" den Phial. The ſenſations likewiſe, occaſioned
" by the one and the other in the human frame, are
" preciſely ſimilar. Not only the ſhock, but the
" numbing ſenſation which the animal ſometimes
" diſpenſes, expreſſed in French by the words *en-*
" *gourdiſſement* and *fourmillement*, may be exactly imi-
" tated with the Phial, by means of Lane's Electro-
" meter; the regulating rod of which, to produce the
" latter effect, muſt be brought almoſt into contact
" with the prime conductor which joins the Phial.
" We have not yet perceived any ſpark to accompany
" the ſhock, nor the pith balls to be ever affected.
" Indeed all our trials have been on very feeble
" ſubjects, whoſe ſhock was ſeldom ſenſible beyond
" the touching finger: I remember but one, of at
" leaſt two hundred, that I myſelf muſt have re-
" ceived, to have extended above the elbow. Per-
" haps the Iſle of Ké, which we are about to viſit,
" may furniſh us with Torpedos freſher taken and of
" more vigour, by which a farther inſight into theſe
" matters may be had. Our experiments have been
" chiefly in the air, where the animal was more
" open to our examination than in water. It is a
" ſingularity that the Torpedo, when inſulated,
" ſhould be able to give to us, inſulated likewiſe,
" forty or fifty ſucceſſive ſhocks from nearly the

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" ſame part; and theſe with little, if any diminu-
" tion in their force: indeed they were all very
" minute. Each effort in the animal to give the
" ſhock is conveniently accompanied with a de-
" preſſion of his eyes, by which even his attempts
" to give it to non-conductors can be obſerved.
" The animal, with reſpect to the reſt of his body,
" is in a great degree motionleſs, but not wholly ſo.
" You will pleaſe to acquaint Dr. Bancroft, of our
" having thus verified his ſuſpicion concerning the
" Torpedo *, and make any other communication
" of this matter you may judge proper. Here I
" ſhall be glad to excite, as far as I am able, both
" electricians and naturaliſts, to puſh their inquiries
" concerning this extraordinary animal, whilſt the
" ſummer affords them the opportunity."

Extracts of a Letter from Mr. WALSH to Dr. FRANKLIN, dated Paris, 27th Auguſt, 1772.

——— " I ſpent a complete week in my ex-
" periments at the Iſle of Ré, and had there every
" convenience for proſecuting them to their extent,
" except that I was reſtrained by the jealouſy of
" the government from making them where the
" animal was caught. At my return to la Ro-
" chelle, I communicated to the members of the
" Academy of that place, and to many of the prin-
" cipal inhabitants, all that I had obſerved con-
" cerning the Torpedo, in the intention of ſtirring

* Bancroft's Natural Hiſtory of Guiana, p. 194.

" up

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" up a ſpirit of inquiry, both as to its electricity and " general œconomy.

——— " The vigour of the freſh taken Tor- " pedos at the Iſle of Ré, was not able to force the " torpedinal fluid acroſs the minuteſt tract of air; " not from one link of a ſmall chain, ſuſpended " freely, to another; not through an almoſt in- " viſible ſeparation, made by the edge of a penknife, " in a ſlip of tinfoil paſted on ſealing-wax. The " ſpark therefore (of courſe the attendant ſnapping " noiſe) was denied to all our attempts to diſcover " it, not only in day-light, but in complete dark- " neſs. I obſerved to you, in my laſt, the ſingu- " larity of the Torpedo being able, when inſulated, " to give to an inſulated perſon a great number of " ſucceſſive ſhocks: in this ſituation I have taken " no leſs than fifty from him in the ſpace of a " minute and an half. All our experiments con- " firmed, that his electricity was condenſed, in " the inſtant of its exploſion, by a ſudden energy " of the animal; and as there was no gradual " accumulation, nor retention of it, as in the caſe " of charged glaſs, it is not at all ſurprizing that " no ſigns of attraction or repulſion were perceived " in the pith balls. In ſhort, the effect of the Tor- " pedo appears to ariſe from a compreſſed elaſtic " fluid, reſtoring itſelf to its equilibrium in the ſame " way, and by the ſame mediums, as the elaſtic fluid " compreſſed in charged glaſs. The ſkin of the " animal, bad conductor as it is, ſeems to be a " better conductor of his electricity, than the " thineſt plate of elaſtic air. Notwithſtanding the " weak ſpring of the torpedinal electricity, I was " able

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" able, in the public exhibitions of my experiments " at la Rochelle, to convey it through a circuit, " formed from one ſurface of the animal to the " other, by two long braſs wires, and four perſons, " which number, at times, was increaſed even to " eight. The ſeveral perſons were made to com- " municate with each other, and the two outermoſt " with the wires, by means of water contained in " baſins, properly diſpoſed between them for the " purpoſe; each perſon dipping his hands in the " neareſt baſins, connectively with his neigbour on " either ſide. ——

" The effect produced by the Torpedo, when " in air, appeared, on many repeated experiments, " to be about four times as ſtrong as when in " water."

A clear and ſuccinct narrative of what paſſed at one of the public exhibitions, alluded to in the laſt letter, appeared in the French Gazette of the 30th October 1772. As it came from a very reſpectable quarter, not leſs ſo from the private character of the gentleman, than from the public offices he held, I muſt deſire leave of the Society to avail myſelf of ſuch a teſtimony to the facts I have advanced, by giving a tranſlation of that narrative.

Extract of a Letter from the Sieur SEIGNETTE, Mayor of la Rochelle, and ſecond perpetual Secretary of the Academy of that City, to the publiſher of the French Gazette.

" In the Gazette of the 14th Auguſt, you men- " tioned the diſcovery made by Mr. Walſh, Mem- " ber

" ber of the parliament of England, and of the " Royal Society of London. The experiment, of " which I am going to give you an account, was " made in the preſence of the Academy of this " city. A live Torpedo was placed on a table. " Round another table ſtood five perſons inſulated. " Two braſs wires, each thirteen feet long, were " ſuſpended to the ceiling by ſilken ſtrings. One " of theſe wires reſted by one end on the wet " napkin on which the fiſh lay; the other end " was immerſed in a baſin full of water placed " on the ſecond table, on which ſtood four other " baſins likewiſe full of water. The firſt perſon " put a finger of one hand in the baſin in which " the wire was immerſed, and a finger of the " other hand in the ſecond baſin. The ſecond " perſon put a finger of one hand in this laſt " baſin, and a finger of the other hand in the " third; and ſo on ſucceſſively, till the five per- " ſons communicated with one another by the " water in the baſins. In the laſt baſin one end " of the ſecond wire was immerſed; and with " the other end Mr. Walſh touched the back of " the Torpedo, when the five perſons felt a com- " motion which differed in nothing from that of " the Leyden experiment, except in the degree of " force. Mr. Walſh, who was not in the circle " of conduction, received no ſhock. This expe- " riment was repeated ſeveral times, even with " eight perſons; and always with the ſame ſuc- " ceſs. The action of the Torpedo is commu- " nicated by the ſame mediums as that of the " electric fluid. The bodies which intercept the

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" action of the one, intercept likewiſe the action " of the other. The effects produced by the " Torpedo reſemble in every reſpect a weak elec- " tricity."

This exhibition of the electric powers of the Torpedo, before the Academy of La Rochelle, was at a meeting, held for the purpoſe in my apartments, on the 22d July 1772, and ſtands regiſtered in the journals of the Academy.

The effect of the animal was, in theſe experiments, tranſmitted through as great an extent and variety of conductors as almoſt at any time we had been able to obtain it, and the experiments included, nearly, all the points, in which its analogy with the effect of the Leyden Phial had been obſerved. Theſe points were ſtated to the gentlemen preſent, as were the circumſtances in which the two effects appeared to vary. It was likewiſe repreſented to them, That our experiments had been almoſt wholly with the animal in air: That its action in water was a capital deſideratum: That indeed all as yet done was little more than opening the door to inquiry: That much remained to be examined by the Electrician as well as by the Anatomiſt: That as artificial electricity had thrown light on the natural operation of the Torpedo, this might in return, if well conſidered, throw light on artificial electricity, particularly in thoſe reſpects in which they now ſeemed to differ: That for me, I was about to take leave of the animal, as nature had denied it to the Britiſh ſeas; and that the proſecution of theſe reſearches

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reſted in a particular manner with them, whoſe ſhores abounded with it.

The Torpedo, on this occaſion, diſpenſed only the diſtinct, inſtantaneous ſtroke, ſo well known by the name of the electric ſhock. That protracted but lighter ſenſation, that Torpor or Numbneſs which he at times induces, and from which he takes his name, was not then experienced from the animal; but it was imitated with artificial electricity, and ſhewn to be producible by a quick conſecution of minute ſhocks. This, in the Torpedo, may perhaps be effected by the ſucceſſive diſcharge of his numerous cylinders, in the nature of a running fire of muſketry: the ſtrong ſingle ſhock may be his general volley. In the continued effect, as well as in the inſtantaneous, his eyes, uſually prominent, are withdrawn into their ſockets.

The ſame experiments, performed with the ſame Torpedos, were on the two ſucceeding days repeated before numerous companies of the principal inhabitants of La Rochelle. Beſides the pleaſure of gratifying the curioſity of ſuch as entertained any on the ſubject, and the deſire I had to excite a proſecution of the inquiry, I certainly wiſhed to give all poſſible notoriety to facts, which might otherwiſe be deemed improbable, perhaps by ſome of the firſt rank in ſcience. Great authorities had given a ſanction to other ſolutions of the phœnomena of the Torpedo; and even the Electrician might not readily liſten to aſſertions, which ſeemed, in ſome reſpects, to combat the general principles of electricity. I had reaſon to

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make ſuch concluſions from different converſations I had held on the ſubject with eminent perſons both at London and Paris. It is but juſtice to ſay, that of all in that claſs you gave me the greateſt encouragement to look for ſucceſs in this reſearch, and even aſſiſted me in forming hypotheſes, how the Torpedo, ſuppoſed to be endued with electric properties, might uſe them in ſo conducting an element as water.

After generally recommending to others an examination of the electric powers of theſe animals when acting in water, I determined, before I took my final leave of them, to make ſome farther experiments myſelf with that particular view; ſince, notwithſtanding the familiarity in which we may be ſaid to have lived with them for near a month, we had never detected them in the immediate exerciſe of their electric faculties againſt other fiſh, confined with them in the ſame water, either in the circumſtance of attacking their prey, or defending themſelves from annoyance: and yet that they poſſeſſed ſuch a power, and exerciſed it in a ſtate of liberty, could not be doubted.

A large Torpedo, very liberal of his ſhocks, being held with both hands by his electric organs above and below, was briſkly plunged into water to the depth of a foot, and inſtantly raiſed an equal height into air; and was thus continually plunged and raiſed, as quick as poſſible, for the ſpace of a minute. In the inſtant his lower ſurface touched the water in his deſcent, he always gave a violent ſhock, and another ſtill more violent in the inſtant of quitting the water in his aſcent;

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aſcent; both which ſhocks, but particularly the laſt, were accompanied with a writhing in his body, as if meant to force an eſcape: Beſides theſe two ſhocks from the ſurface of the water, which may yet be conſidered as delivered in the air, he conſtantly gave at leaſt two, when wholly in the air, and conſtantly one and ſometimes two, when wholly in the water. The ſhocks in water appeared, as far as ſenſation could decide, not to have near a fourth of the force of thoſe at the ſurface of the water, nor much more than a fourth of thoſe intirely in air.

The ſhocks received in a certain time were not, on this occaſion, counted by a watch, as they had been on a former, when fifty were delivered, in a minute and a half, by the animal in an inſulated and unagitated ſtate: But from the quickneſs, with which the immerſions were made, it may be preſumed there were full twenty of theſe in a minute; from whence the number of ſhocks, in that time, muſt have amounted to above an hundred. This experiment, therefore, while it diſcovered the comparative force between a ſhock in water and one in air, and between a ſhock delivered with greater exertion on the part of the animal and one with leſs, ſeemed to determine, that the charge of his organs with electricity was effected in an inſtant, as well as the diſcharge.

The Torpedo was then put into a flat baſket, open at top, but ſecured by a net with wide meſhes, and, in this confinement, was let down into the water, about a foot below the ſurface; being

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being there touched, through the meſhes, with only a ſingle finger, on one of his electric organs, while the other hand was held, at a diſtance, in the water, he gave ſhocks, which were diſtinctly felt in both hands.

The circuit for the paſſage of the effect being contracted to the finger and thumb of one hand, applied above and below to a ſingle organ, produced a ſhock, to our ſenſation, of twice the force of that in the larger circuit by the arms.

The Torpedo, ſtill confined in the baſket, being raiſed to within three inches of the ſurface of the water, was there touched with a ſhort iron bolt, which was held, half above and half in the water, by one hand, while the other hand was dipped, as before, at a diſtance in the water; and ſtrong ſhocks, felt in both hands, were thus obtained through the iron.

A wet hempen cord being faſtened to the iron bolt, was held in the hand above water, while the bolt touched the Torpedo; and ſhocks were obtained through both thoſe ſubſtances.

A leſs powerful Torpedo, ſuſpended in a ſmall net, being frequently dipped into water and raiſed again, gave, from the ſurface of the water, ſlight ſhocks through the net to the perſon holding it.

Theſe experiments in water manifeſted, That bodies, immerſed in that element, might be affected by immediate contact with the Torpedo; That the ſhorter the circuit in which the electricity

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tricity moved, the greater would be the effect; And that the ſhock was communicable, from the animal in water, to perſons in air, through ſome ſubſtances.

How far harpoons and nets, conſiſting of wood and hemp, could in like circumſtances, as it has been frequently aſſerted, convey the effect, was not ſo particularly tried as to enable us to confirm it. I mention the omiſſion in the hope that ſome one may be induced to determine the point by expreſs trial.

We convinced ourſelves, on former occaſions, that the accurate Kæmpfer *, who ſo well deſcribes the effect of the Torpedo, and happily compares it with lightning, was deceived in the circumſtance, that it could be avoided by holding in the breath, which we found no more to prevent the ſhock of the Torpedo, when he was diſpoſed to give it, than it would prevent the ſhock of the Leyden Phial.

Several perſons, forming as many diſtinct circuits, can be affected by one ſtroke of the animal, as well as when joined in a ſingle circuit. For inſtance, four perſons, touching ſeparately his upper and lower ſurfaces, were all affected; two perſons likewiſe, after the electricity had paſſed through a wire into a baſin of water, tranſmitted it from thence, in two diſtinct channels, as their ſenſation convinced them, into another baſin of water, from whence it was conducted, probably in an united ſtate, by a ſingle wire. How

* Kæmpf. Amœn. Exot. 1712, p. 514.

much

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on the organ of the other, was ſenſible of ſhocks, ſometimes delivered by one fiſh, and ſometimes by the other, as might be diſcovered by the reſpective winking of their eyes. That the organs, uncharged, ſerved ſome way or other as conductors, was confirmed with artificial electricity, in paſſing ſhocks by them; and in taking ſparks from them, when electrified.

The electric effect was never perceived by us to be attended with any motion or alteration in the organs themſelves, but was frequently accompanied with a little tranſient agitation along the cartilages which ſurround both organs: this is not diſcernible in the plump and turgid ſtate of the animal, while he is freſh and vigorous; but as his force decays, from the relaxation of his muſcles, his cartilages appear through the ſkin, and then the ſlight action along them is diſcovered.

May we not from all theſe premiſes conclude, that the effect of the Torpedo proceeds from a modification of the electric fluid? The Torpedo reſembles the charged Phial in that characteriſtic point of a reciprocation between its two ſurfaces. Their effects are tranſmitted by the ſame mediums; than which there is not perhaps a ſurer criterion to determine the identity of ſubtile matter: They, beſides, occaſion the ſame impreſſion on our nerves. Like effects have like cauſes. But it may be objected, that the effects of the Torpedo, and of the charged Phial, are not ſimilar in all their circumſtances; that the charged Phial occaſions attractive or repulſive diſpoſitions in

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in neighbouring bodies; and that its diſcharge is obtained through a portion of air, and is accompanied with light and ſound; nothing of which occurs with reſpect to the Torpedo.

The inaction of the electricity of the animal in theſe particulars, whilſt its elaſtic force is ſo great as to tranſmit the effect through an extenſive circuit and in its courſe to communicate a ſhock, may be a new phænomenon, but is no ways repugnant to the laws of electricity; for here too, the operations of the animal may be imitated by art.

The ſame quantity of electric matter, according as it is uſed in a denſe or rare ſtate, will produce the different conſequences. For example, a ſmall Phial, whoſe coated ſurface meaſures only ſix ſquare inches, will, on being highly charged, contain a denſe electricity capable of forcing a paſſage through an inch of air, and afford the phænomena of light, ſound, attraction, and repulſion. But if the quantity condenſed in this Phial, be made rare by communicating it to three large connected jars, whoſe coated ſurfaces ſhall form together an area 400 times larger than that of the Phial (I inſtance theſe jars becauſe they are ſuch as I uſe); it will, thus dilated, yield all the negative phænomena, if I may ſo call them, of the Torpedo; it will not now paſs the hundredth part of that inch of air, which in its condenſed ſtate it ſprung through with eaſe; it will now refuſe the minute interſection in the ſtrip of tinfoil; the ſpark and its attendant ſound, even the attraction or repulſion of light bodies, will now

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be wanting; nor will a point brought however near, if not in contact, be able to draw off the charge: and yet, with this diminiſhed elaſticity, the electric matter will, to effect its equilibrium, inſtantly run through a conſiderable circuit of different conductors, perfectly continuous, and make us ſenſible of an impulſe in its paſſage.

Let me here remark, that the ſagacity of Mr. Cavendiſh in deviſing and his addreſs in executing electrical experiments, led him the firſt to experience with artificial electricity, that a ſhock could be received from a charge which was unable to force a paſſage through the leaſt ſpace of air.

But, after the diſcovery that a large area of rare electricity would imitate the effect of the Torpedo, it may be inquired, where is this large area to be found in the animal? We here approach to that veil of nature, which man cannot remove. This, however, we know, that from infinite diviſion of parts infinite ſurface may ariſe, and even our groſs optics tell us, that thoſe ſingular organs, ſo often mentioned, conſiſt like our electric batteries of many veſſels, call them cylinders or hexagonal priſms, whoſe ſuperficies taken together furniſh a conſiderable area.

I rejoice in addreſſing theſe communications to You. He, who predicted and ſhewed that electricity wings the formidable bolt of the atmoſphere, will hear with attention, that in the deep it ſpeeds an humbler bolt, ſilent and inviſible: He, who analyſed the electrified Phial, will hear with

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pleaſure that its laws prevail in animate Phials: He, who by Reaſon became an electrician, will hear with reverence of an inſtinctive electrician, gifted in his birth with a wonderful apparatus, and with the ſkill to uſe it.

However I may reſpect your talents as an electrician, it is certainly for knowledge of more general import, that I am impreſſed with that high eſteem, with which I remain,

Dear Sir,

Your affectionate

and obedient ſervant,

John Walſh.

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EXPLANATION of the PLATE

OF THE

Male and Female Torpedo, or Electric Ray.

TAB. XIX.

FIG. I.

A view of the under ſurface of the female.

a. An expoſure, on flaying off the ſkin, of the right electric organ, which conſiſts of white pliant columns, in a cloſe and for the moſt part hexagonal arrangement, giving the general appearance of a honey-comb in miniature. Theſe columns have been ſometimes denominated cylinders; but, having no interſtices, they are all angular, and chiefly ſix-cornered.

b. The ſkin which covered the organ, ſhewing on its inward ſide an hexagonal net work.

c. The noſtrils in the form of a creſcent.

d. The mouth in a creſcent contrary to that of the noſtrils, furniſhed with ſeveral rows of very ſmall hooked teeth.

e. The

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e. The branchial apertures, five on each ſide.

f. The place of the heart.

g. g. g. The place of the two anterior tranſverſe cartilages, which, paſſing one above and the other below the ſpine, ſupport the diaphragm, and uniting towards their extremities, form on either ſide a kind of clavicle and ſcapula.

h. h. The outward margin of the great lateral fin.

i. i. Its inner margin, confining with the electric organ.

k. The articulation of the great lateral fin with the ſcapula.

l. The abdomen.

m. m. m. The place of the poſterior tranſverſe cartilage which is ſingle, united with the ſpine, and ſupports on each ſide the ſmaller lateral fins.

n. n.
n. n. } The two ſmaller lateral fins.

o. The anus.

p. The fin of the tail.

FIG.

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FIG. II.

A view of the upper ſurface of the female.

a. a. An expoſure of the upper part of the right electric organ.

b. The ſkin which covered the organ.

c. The eyes, prominent and looking horizontally outwards, but capable of being occaſionally withdrawn into their ſockets.

d. Two circular apertures communicating with the mouth, and furniſhed each with a membrane, which in air, as well as in water, plays regularly backwards and forwards acroſs the aperture in the office of inſpiration.

e. The place of the right branchia.

f. The two fins of the back.

g. g. The place of the anterior tranſverſe cartilages.

FIG. III.

A view of the under ſurface of the male, whoſe ſize, as here repreſented, is, in general, ſmaller than that of the female.

a. a. Two appendices, diſtinguiſhing the male ſpecies.

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The Male & Female TORPEDO or ELECTRIC RAY,
frequenting the Sea Shores in the Neighbourhood of LA ROCHELLE.

Philos Trans. Vol. LXIII. Tab. XIX. p. 480.

Fig. 1.
Under Surface of the Female.

Fig. 3.
Under Surface of the Male, which is generally smaller than the Female.

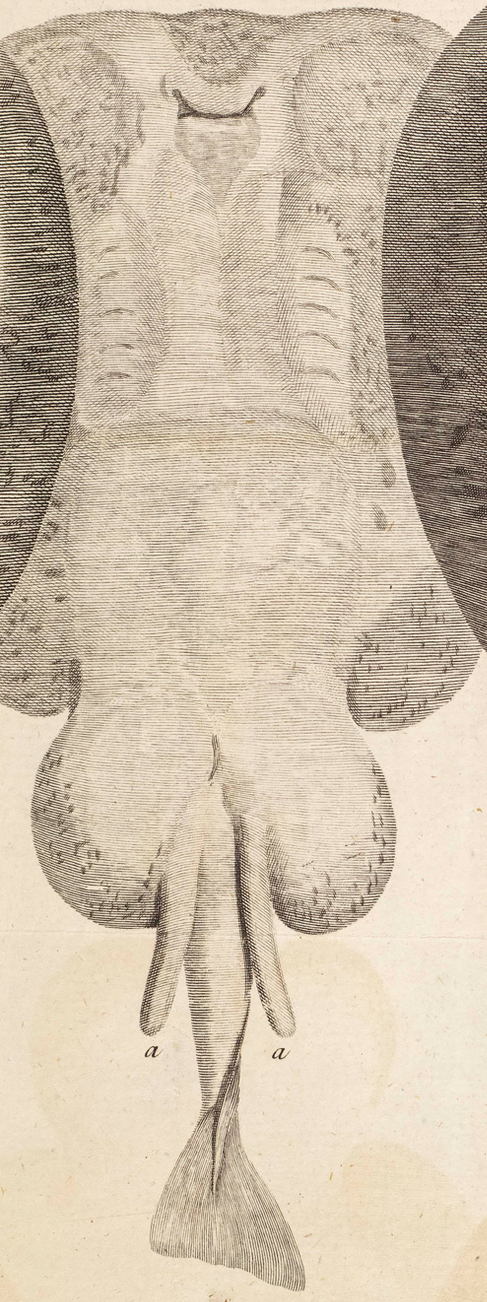

Fig. 2.
Upper Surface of the Female.

J^s. Stuart delin.

J^s. Roberts sculpsit.

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