LXXI. On lightning conductors, and on certain principles in electrical science; being an investigation of Mr. Sturgeon's experimental and theoretical researches in electricity, published by him in the "Annals of Electricity,"

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$$\frac{S^3}{(m\alpha)^3} \left\{ \left(\frac{\sin m\beta}{m\beta} \right)^2 + \left(\frac{\sin m\gamma}{m\gamma} \right)^2 - 2 \frac{\sin m\beta}{m\beta} \frac{\sin m\gamma}{m\gamma} \cos m\alpha \right\},$$

or by

$$\frac{S^3}{(m\beta)^2} \left\{ \left(\frac{\sin m\gamma}{m\gamma} \right)^2 + \left(\frac{\sin m\alpha}{m\alpha} \right)^2 - 2 \frac{\sin m\gamma}{m\gamma} \frac{\sin m\alpha}{m\alpha} \cos m\beta \right\},$$

or by

$$\frac{S^3}{(m\gamma)^2} \left\{ \left(\frac{\sin m\alpha}{m\alpha} \right)^2 + \left(\frac{\sin m\beta}{m\beta} \right)^2 - 2 \frac{\sin m\alpha}{m\alpha} \frac{\sin m\beta}{m\beta} \cos m\gamma \right\}.$$

The sum of the squares of the coefficients of $\sin \phi$ and $\cos \phi$ may be put in another form.

$$\begin{aligned} & \{ \beta (1 - \cos 2m\gamma) - \gamma (1 - \cos 2m\beta) \}^2 \\ & + \{ \beta \sin 2m\gamma - \gamma \sin 2m\beta \}^2 \\ & = 2\beta^2 + 2\gamma^2 - 2\beta\gamma - 2\beta\gamma \cos 2m(\gamma - \beta) + 2(\beta\gamma - \gamma^2) \cos 2m\beta \\ & + 2(\beta\gamma - \beta^2) \cos 2m\gamma \\ & = 4\beta\gamma (\sin m\alpha)^2 + 4\gamma\alpha (\sin m\beta)^2 \\ & + 4\alpha\beta (\sin m\gamma)^2. \end{aligned}$$

Hence the intensity of the light at M

$$= \frac{S^3}{m\alpha \cdot m\beta \cdot m\gamma} \left\{ \frac{(\sin m\alpha)^2}{m\alpha} + \frac{(\sin m\beta)^2}{m\beta} - \frac{(\sin m\gamma)^2}{m\gamma} \right\},$$

γ being that projection which is equal to the sum of the other two.

St. John's College, Nov. 2, 1839.

LXXI. *On Lightning Conductors, and on certain Principles in Electrical Science; being an investigation of Mr. Sturgeon's Experimental and Theoretical Researches in Electricity, published by him in the "Annals of Electricity," &c.* By W. SNOW HARRIS, Esq., F.R.S.

(Illustrated by Plate II.)

To the Editors of the *Philosophical Magazine and Journal*.
GENTLEMEN,

IN the *Annals of Electricity* for October last, will be found a memoir on Marine Lightning Conductors. This memoir is addressed to the British Association, and is considered by Mr. Sturgeon, the author of it, to merit in a high degree the especial consideration of all the learned scientific bodies in Europe and America.

The author endeavours to show, that a metallic rod whilst transmitting a charge of electricity, is always productive of

powerful lateral explosions, not only on near bodies, but on bodies at very great distances. This effect, he thinks, in the case of a lightning rod, is a very fearful circumstance.

2. If this deduction be worth anything, it is altogether subversive of the use of such rods as a means of protection from lightning. I have thought it right, therefore, to examine carefully the experiments and reasonings, which have led the author to this conclusion; and since the inquiry bears materially on a question of great public interest, and contains many new phenomena of electrical action, I hope it may not be considered unworthy a place in your very valuable Journal.

3. Although Mr. Sturgeon has spoken in a slighting way of me and my experiments, and has laboured hard to invalidate them, I still feel, that any personal consideration is comparatively of minor consequence. I will not therefore trouble your readers on the subject. I merely wish to have it understood, that this is not a reply to that large part of the memoir levelled at myself, but is simply an investigation of the author's "Theoretical and Experimental Researches," and of his claims to our confidence as a writer on Electrical Science.

4. So long since as the years 1728 and 1729, Mr. Grey observed the phenomena of electrical conduction and insulation.

(a). Thus a metallic ball, J, fig. 1, (Plate II.) supported on the glass rod *g*, is said to be insulated, and if electrified, will cause a spark in the opening between the metallic body B and the ball J.

(b). If we connect the ball J with any distant body *c*, by means of a metallic wire as in fig. 2, and electrify it as before, the spark will still occur in the opening at the distant body *c*, the electricity being conducted by the intermediate wire.

(c). The distance at which this effect may ensue, is very considerable. Mr. Grey succeeded in making it sensible at a distance of 765 feet*.

(d). The effect is most sensible when the body B is connected with the ground, which places it, by a law of electrical action, in the most favourable state for receiving the spark.

5. I am desirous to call especial attention to these results, notwithstanding their elementary character, because, as we shall presently see, they are really nothing more or less than the essence of Mr. Sturgeon's *new researches*, and which he claims to have considered by all the learned societies of Europe and America.

* Priestley's History of Electricity.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 6.

Fig. 7.

6. When we attempt to charge an electrical jar, J, fig. 3, it is observable, that as the charge accumulates on the inner surface, a corresponding quantity of electricity is forced off from the outer, and without this double effect takes place we fail to accumulate a charge.

(e). To render this evident, we have only to place the jar on an insulator, as in fig. 3; we shall then find, that for every spark we send into the jar, a similar spark will leave its outside, either from the coating directly, or from any distant body *c* connected with it as in fig. 4.

The outer coating J, therefore, and distant body *c*, may be considered in their insulated state as being insulated conductors under the conditions represented in fig. 2.

(f). Suppose the jar charged, and that it remains insulated; then we may discharge it, either by one dense shock through the rod *t*, fig. 4, or gradually, in the reverse way of charging; viz. by continuing to draw sparks from the knob *m*, and add them to the coating J: the circumstance however of our being enabled to take a finite spark, from either side alternately, whilst the jar rests on an insulator, is sufficient to show, that the accumulated electricity is never exactly balanced between the opposed coatings, so that there will always be an excess of either positive or negative electricity over the neutralizing quantities themselves, disposed on the coatings of the jar.

(g). When therefore we discharge the jar, this excess of free electricity will speedily expand itself over the outer surface J, the discharging rod *t*, the knob of the jar *m*, or any other body, *c*, fig. 4, connected with it, which, as in the case of the simply electrified conductor, J, fig. 2, will cause a spark to occur in either of those places. The intensity of this spark however will depend on the capacity of the jar. It is *less* with a large jar, and *greater* with a small one, the quantity of electricity discharged being the same.

(h). When the jar has been discharged, the knob, the outer coating, and all the bodies connected with it, will be found in the same electrical state. We may make this state either positive or negative, by taking a spark either from the knob or coating previously to discharging the jar.

(i). This small spark caused by the excess of free electricity, may be obtained even though the jar be connected with the earth, provided we seize it before the conductors have had time to operate in carrying off the residuary accumulation; Professor Wheatstone having shown by his unrivalled experiments on electrical conduction, that some portion of time elapses in the passage of electricity through wires,

By bringing a metallic ball, B, fig. 3 and 4, therefore in a free state, either very near the discharging rod *c c*, fig. 3, the outer coating J, or any body, *c*, fig. 4, in connexion with it, previously to making the discharge, we seize as it were some of the residuary electricity before it has time to pass off, and hence it becomes evident in this particular direction. The effect, however, will be necessarily greatest when the jar and its appendages are quite insulated. After this spark has taken place, the jar will be found again slightly charged, with what has been called a residuary charge, so that the phenomenon itself is actually the *same as that already* observed in charging the jar originally (*e*).

7. Now these simple experiments (*g*), (*h*), (*i*), are just the experiments described by Mr. Sturgeon, in which he imagines that the small spark above described, is produced by a lateral action of the rod carrying off the discharge. He seems to consider it as a novel and important fact, and calls upon the "principal scientific bodies in Europe and America," and "the ablest electricians the world can produce," in order that it may be fully sifted and explained. He takes great credit for having placed this subject before them in a "*proper light*," and cannot account for the circumstance of my having overlooked it*.

8. But since it is clear that this supposed lateral explosion really resolves itself into one or two simple facts (*a*) (*b*), known to electricians for more than a century since, "the ablest electricians the world can produce," may perhaps be disposed to think such an occupation of their time unnecessary, and the several "Learned Societies in Europe and America" may consider it would have been quite as well for Mr. Sturgeon's credit, as a lecturer on natural philosophy, if he had not troubled them on the occasion.

9. The following is Mr. Sturgeon's version of these experiments:

This kind of lateral discharge, "consists in the displacement of the electrical fluid of bodies vicinal to a continuous conductor carrying the primitive discharge."

Exp.—If a Leyden jar, J, fig. 3, be discharged through a rod *c c*, a spark will appear at the opening *o*, between the metallic body B placed near the rod.

Exp.—If instead of discharging the jar through the rod *c c*, fig. 4, we discharge it by a common discharging rod *t*, still the spark will appear at *o* as before.

* "I mean to submit the substance of my Memoir to the consideration of the principal scientific bodies in Europe and America, in order that the subject may be fully sifted and explained by the ablest electricians the world can produce."—*Ann. of Elect.*, p. 191.

"The effect," he says, "is much increased by connecting the body B with the ground, and diminished to a certain extent by connecting the outside of the jar with the ground." I have produced the spark, he says, between *cc*, and the body B when placed at 50 feet from the *direct* discharge.

"By this kind of lateral discharge," he observes, "a dense spark may be produced when the bodies B and *cc*, fig. 3, are half an inch apart. Though the jar be only of the capacity of a quart, chemical decompositions may be effected by it."

10. Mr. Sturgeon does not state precisely how these experiments were conducted, but the nature of the manipulations would have a material effect on the result. If for example a small jar of a quart capacity were charging from a very powerful machine, and the discharge produced at the time of charging, either by a spontaneous explosion between the balls, *mc*, fig. 3, or by an insulated discharger, then, as is evident, not only would the outer coating and its appendages become charged with the residuary electricity proper to the jar, but also by electricity from the prime conductor, which would assuredly pass over at the instant of the discharge. In Mr. Sturgeon's account of his experiments this fallacious method would appear to have been resorted to. He says, "a spark is felt at every discharge through the circuit represented in the figure," that is *mcc*, fig. 3. Now the continued discharges implied in this statement, could only be produced by continuing to work the machine in connexion with the jar. This circumstance alone would be sufficient to falsify the whole.

11. The following experiments are not unimportant as bearing on the present question.

(*k*). Let a jar, J, fig. 3, be charged positively, removed from the machine, and insulated.—Under this condition discharge it. When discharged, let the electrical state of the knob *m*, discharging conductor *cc*, the outer coating J, or any distant body *cc*, fig. 4, connected with it, be examined; they will all be found in the same electrical state, which state will be precisely that, exhibited by the outer coating and knob, whilst charging, and the small residuary spark will be plus.

(*l*). Charge the jar as before; but before discharging it, withdraw the free electricity from the knob. The electrical state of the coating and appendages will be now changed, and the small residuary spark will be minus.

(*m*). Immediately *after* the discharge, apply a metallic body B, figs. 3 and 4, either to the coating J, or any body connected with it. A residuary spark will be thrown off.

(*n*). Place a metallic body B near the discharger, or outer
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coating, previously to making the discharge; the spark will then appear to ensue at the time of the discharge.

(o). Examine the jar after this residuary spark has been taken from the outer coating, and it will be found again slightly charged as at first.

(p). Charge a jar, exposing about two square feet of coating, with a given quantity of electricity, measured by the unit jar *u*, fig. 5. Let a conducting rod terminating in a ball *r*, project from the outer coating, and place near it the electroscope *E**. Discharge the jar through the rod *c c* as before, and observe the amount of divergence of the electroscope. Double the capacity of the jar, and again accumulate and discharge the same quantity. The divergence of the electroscope will be very considerably decreased. Add a second and a third jar to the former, and the effect will be at last scarcely perceptible: connect the jar with the ground, and with a given quantity the spark will vanish altogether.

(q). Accumulate a given quantity as before, and observe the effect of the residuary charge on the electroscope. Let a double, treble, &c., quantity be accumulated and discharged from a double, treble, &c., extent of surface; that is to say, for a double quantity employ two similar jars, and so on: the effect will remain the same.

(r). The quantity and surface remaining constant, let the discharge be effected by discharging circuits *c c* fig. 3, of different dimensions from a large rod down to a fine wire which the charge in passing can make red-hot. Observe the effect on the electroscope in each case: it will be found nearly the same, being rather less where the tension in the discharging wire is very considerable.

(s). Connect the jar with the ground, and place between the discharging conductor *c* fig. 3. and a metallic mass *B*, a small quantity of percussion powder, inclosed in thin paper. The powder will not be inflamed, even in the case of the discharging conductor becoming red-hot; whereas in passing the slightest spark, it inflames directly.

(t). Insulate a circular conducting disc, *M*, fig. 6, of four feet in diameter: it may be made of wood covered with tin foil; oppose to it a similar disc, *N*, connected with the ground. Place a conducting rod, *c c*, on the lower plate, and near it a metallic body, *o*; electrify the upper plate, *m*; dense sparks will fall on the rod, *c c*, but no effect is observable on the vicinal body, *o*, even though percussion powder be placed in the opening.

* The electroscope *I* employed is described in the Transactions of the Royal Society for 1834, Part 2, page 214. For more accurate measurement we should employ the electrometer, p. 215.

12. These experiments are conclusive of the nature of Mr. Sturgeon's experiments.

Exp. (*k*) (*l*)—show, that the electricity of the spark varies with that of the coatings.

Exp. (*m*)—proves that the spark is readily obtained *after* the discharge has taken place; it is not therefore any lateral explosion caused by the discharging rod.

Exp. (*o*)—proves that the spark is merely a residuary accumulation.

Exp. (*p*) (*q*)—prove that the spark is of different degrees of force, when the electricity is discharged from a greater or less extent of surface, whilst double, treble, &c., quantities, when discharged from double, treble, &c., surfaces, give the same spark. Now as no one can doubt but that the effect of a double, &c. quantity should be greater than a single, &c. quantity, it is again evident that the spark is not caused by any lateral explosion from the discharging rod; it being a well-established law, 'that the same quantity has the same heating effect on wires, whether discharged from a great surface or a small one, from thick glass or thin; some little allowance being made for the greater number of rods, &c., when the surface is increased by an additional number of jars *.' The effect therefore depending on the jar, Mr. Sturgeon had a greater chance with a small jar than with a large one.

Exp. (*r*)—proves that the degree of tension in the rod is not of any consequence.

Exp. (*s*) (*t*)—show, that no kind of lateral action arises during the passage of the charge.

13. Mr Sturgeon confounds this residuary spark, with the Earl of Stanhope's experiments on induction: he observes, p. 176, "Viscount Mahon studied this kind of lateral discharge very extensively." But any one who considers His Lordship's work, will soon detect the fallacy of such a conclusion. Lord Mahon shows, that when an electrical charge is about to pass from a body M, fig. 7, in the direction C L, the action upon a near body N will displace some of its electricity; hence a spark will take place at E between that body and another connected with the ground whenever the discharge takes place from M, in consequence of the return of the displaced electricity. This effect His Lordship termed the "returning stroke." Now to apply this to the operation of a thunder-cloud. Let M, fig. 6, represent a mass of cloud

* Philosophical Transactions for 1834. Part II. p. 225, and Faraday's Researches.

covering a portion of the earth's surface N. Let *c c* be a discharging rod, and *o* some near body. Then by Lord Stanhope's experiment the charged cloud M will displace from the surface N, and all the bodies on it as *c c*, *o*, &c., a portion of their natural electricity, which will again return when the discharge has been effected. The conditions of Lord Mahon's experiment cannot obtain between the conductor *c c* and the body *o*, since they are both in the same forced state*. It is very easy to perceive, that the electrical relations of two bodies *o* and *c* *between* the boards, is different from that between a conductor J, fig. 1, charged with electricity, and a body B in its natural state; or that of a conductor C, fig. 6, carrying off the displaced electricity of the lower plate N, and a body B neutral. Besides, in Lord Mahon's experiment, fig. 7, the electricity of the return spark is different from that of the primitive charge in M; whereas, in Mr. Sturgeon's experiment, the spark is of the same kind. So little did His Lordship anticipate any objection to the use of lightning rods in consequence of his experiments, that he declares his conviction of their passive operation, and reproves those who "ignorantly conclude" that they are of a dangerous nature.

14. We have been here discussing what the author calls a *third* kind of lateral discharge; but he mentions a *first* and *second* kind also. The first kind, he says, "takes place at every interruption of a metallic circuit;" "it displaces loose bodies," &c. This is evidently the effect of mechanical expansion, and is the very effect we avoid by means of a lightning rod. He alludes to Dr. Priestley as authority on this point; how unfortunate for his whole doctrine! Let us consider for a moment what Dr. Priestley says: "That the cause of this dispersion of bodies in the neighbourhood of electrical explosions is *not their being suddenly charged with electric matter*, is, I think, evident. I never observed the *least attraction of these bodies toward the brass rods, through which the explosion passed*, although I used several methods which could not fail to show it. I even found that the explosion of a battery made ever so near a brass rod, did not so much as disturb its electric fluid; for when I had insulated the rod, and hung a pair of pith balls on the end opposite to that near which the explosion passed, I found the balls were not in the least moved†."

* This applies to Mr. Sturgeon's Exp. (9.)—If B fig. c, 3. were on the same insulation with the jar J and rod *c*, *no spark could occur at o*, except by a division of the charge, whatever quantity passed through *c*. This fact alone is conclusive of the point in question, proving clearly that the spark is *not* a lateral explosion.

† The reader will distinguish here between this experiment and Lord

We have seen how little support Mr. Sturgeon derived from Lord Mahon; he obtains still less from Priestley, who, without any compromise, sweeps away his whole theory. Lord Stanhope and Dr. Priestley, eminent amongst the philosophers of their day, will be doubtless admitted to be as good authority as Mr. Sturgeon.

15. The *second* kind of lateral discharge is, we are informed, “a radiation of electric matter from conductors carrying the primitive discharge.” It takes place, the author says, from edges, and that hence “sharp edges of metal carrying a flash of lightning would discharge necessarily a great quantity of fluid into neighbouring bodies.” No author is pressed into the service on this occasion, and for the best possible reason, no accredited writer has ever treated of such a phenomenon as applying to a lightning rod. It is in fact applicable only to charged conductors. Thus ragged or pointed rods attached to the prime conductor of the electrical machine exhibit brushes of light, whilst other similar bodies, within their influence, have the appearance of stars. The lights on steeples, and on the sail yard and masts of ships, mentioned by Pliny, are of this kind. Franklin explained these phenomena, and showed that pointed bodies were favourable to the rapid dissipation of electrical accumulations, and, as is well known, availed himself of the important fact in his application of the pointed lightning rod. How Mr. Sturgeon has contrived to associate this effect with the effects of discharges of lightning *through* conductors it is difficult to say. It is certainly a very strange confusion of things. That the effect in question has nothing to do with a sharp or round edge, or angular discharges, may be shown by the following experiments:—

(u). Dr. Priestley discharged a battery over a wire circuit perfectly straight, and also over the same circuit passed about pins so as to make sharp angles:—the result of the charge on fusing a given length of wire was not influenced, which could hardly have been if the angular portions had thrown off or discharged into the neighbouring pins, &c. any of the charge, it being well known that the least diminution of quantity is fatal to a delicate experiment on the fusion of wire.

(v). Discharge a given quantity of electricity by a continuous rod free of edges, through a wire passed through the ball

Mahon's. The latter relates to the influence of a permanently charged conductor on a body neutral; whereas Priestley's applies to the action of wires carrying vanishing quantities of electricity, the very essence of Mr. Sturgeon's experiment. Dr. Priestley would not have told us, had he brought his rod near the *free side* of his battery, that then the pith balls were not moved.

of an air thermometer, and also by a similar rod with ragged edges, placed near other metallic masses: the effect on the wire remains unchanged*.

It is not difficult to perceive the distinction of the two cases just alluded to. If Dr. Priestley had *insulated* his wire, and then charged it in the ordinary way, brushes of light would doubtless have escaped from the angular portions; whereas the wire when acting as a discharging circuit can exhibit no such appearance. The electricity is then evanescent, and by a law of electrical action determined rapidly toward the negative surface. Many facts might be adduced conclusive of this point, but it seems scarcely worth while to dwell longer on it.

16. The great end which the author proposes to himself in this memoir, is an exposition of the danger attendant on my method of fixed lightning conductors for ships, successfully tried in the British navy for upwards of ten years;—with a view to a substitution of an untried method of his own. It may be worth while, therefore, in conclusion, to see whether the objections he so strongly insists on, do not equally apply to his own conductors as well as to mine, and, in short, to lightning conductors generally.

17. In the first place, he tells us (see 191.) “that it is possible for the most spacious conductor that can be applied to a ship to be rendered sufficiently hot by lightning to ignite gunpowder.”

18. In the next place, he says, (202.) that the “lateral discharge will *always* take place when the vicinal bodies are capacious, and near the principal conductor or any of its metallic appendages.” This was the case, he says, when only his small jar was used, and with this small jar he could produce lateral discharges at a distance of fifty “feet from the direct discharge.”

19. Thirdly, he tells us (203.) that “the magnitude and intensity of a flash of lightning being *infinitely* greater than anything which can be produced artificially, the lateral discharges must be *proportionally greater*,” that is to say *infinitely* great.

20. Taking these data as true then, it follows that any lightning conductor carrying a flash of lightning, would at an *infinite* distance, produce a lateral explosion *infinitely* great, and of course do an *infinite* deal of mischief. Hence, every powder magazine having a lightning conductor, every ship with a lightning chain in her rigging, should whenever lightning struck the conductor be destroyed; for in no case is the

* For a description of this instrument, termed an electro-thermometer, see *Transactions of the Royal Society* for 1837, p. 18.

conductor at one third the distance from the inflammable matter, of that, at which Mr. Sturgeon can produce a lateral discharge with a jar of "only a quart capacity," viz. "50 feet."

21. But Mr. Sturgeon proposes to apply cylindrical copper rods in the rigging; their "upper extremities to be attached to the tops, &c. &c.," "their lower extremities to the chains of the shrouds," and to be united by "broad straps of copper to the sheathing," that is to say, by conductors with edges, which he says throw off the charge into neighbouring bodies; this too after having told us, that the most spacious conductor may become red-hot, and that lateral discharges *always* take place when the vicinal bodies are *capacious*, and near the principal conductor or *any of its metallic appendages*. Under such circumstances what is to become of the rigging, sails, masts? will they not be set on fire? Are not the massive iron hoops and other metals about the masts, the chains of the shrouds bolted through the ship's side, and other metallic bodies in the hull, such as bolts, tanks, chain cables, &c. &c. *vicinal capacious bodies*, and reaching by interrupted metallic circuits up to the very magazines Mr. Sturgeon talks so much about? Must not a ship with such conductors be necessarily destroyed? Surely he must give the British Association and the learned bodies of Europe and America, &c., very little credit for philosophical penetration, if he thinks they will not immediately discard such philosophy as this.

22. Either his "theoretical and experimental researches" are true, and his system of conductors fatal and absurd, or otherwise, if his conductors be good for anything, then his theoretical and experimental researches are good for nothing. He may adhere either to the one or the other, but he cannot have both; such is the *reductio ad absurdum* in which he is involved.

Mr. Sturgeon's anxiety to arrive at conclusions unfavourable to my conductors, has led him to conclusions subversive of *all* conductors, *his own especially*.

23. The mere circumstance of finding his "*third* kind of lateral explosion" decrease in power, by uninsulating his jar, might alone have led him to doubt the accuracy of his deduction. On so important a point, and before he ventured to awaken the prejudices and fears of the uninformed, we had a right to expect at his hands a profound scientific inquiry. He should at least have tried whether he could not get this spark after the main charge had passed (*m*) as well as at the *apparent* time of passing. The quantity of electricity should have been accurately measured, and its effects in producing

the spark determined, both in relation to the quantity and surface over which it was distributed (*p*). The form and dimensions of the discharging conductor should have been varied (*r*). The final electrical state of his apparatus, as also the electricity of the spark, should in common prudence have been examined (*k*), together with other manipulations quite inexcusable to neglect on such an occasion. He has, however, failed in everything calculated to give value to his inquiries, as I think has been fully shown. They are hence not entitled to the smallest confidence, and it is not a little extraordinary that he should have done so, whilst taking credit to himself for *superior sagacity*, and an acquaintance with facts of which he says I did "not seem to be aware," e. g. the most common-place facts in electricity.

24. In conclusion, I have no hesitation in giving it as my confirmed opinion, after a long and severe examination of the laws of electrical action, and of cases of ships and buildings struck by lightning;—that a lightning rod is purely passive, that it operates simply in carrying off the lightning which falls on it, without any lateral explosive action *whatever*. I do not deny the general inductive effect mentioned by Lord Stanhope on bodies opposed to the influence of the thunder-cloud, and that the displaced electricity will again find its equilibrium of distribution, and return to those bodies, which effect would necessarily take place, whether we had a lightning rod or not (13); an additional reason for linking the detached conductors in a ship's hull into one great mass, so as to have as few interrupted circuits as possible in any direction.

This opinion, by the citation of a few striking cases in which ships have been struck by lightning, I hope in a future paper fully to substantiate, should you think the subject of sufficient consequence*.

APPENDIX.

THE author, probably perceiving how little he had gained by quoting Lord Mahon and Dr. Priestley, observes, in a supplementary note, page 235, "Perhaps the experiments of Professor Henry would be more to my purpose." These experiments, however, are no more to "his purpose" than the others, as any one may see who will examine the Professor's communication, in the seventh report of the British Association, page 25. The experiments there described relate to minor electrical discharges, similar to those already mentioned (*i*). These were obtained by throwing simple sparks from an electrical machine, on small wires or rods, either insulated or connected with the earth: the wires became lumi-

[* We shall be most happy to receive and insert any further communication from Mr. Harris.—EDIT.]

nous and the rods emitted sparks. In this case, as Professor Henry observes, the electricity of the machine must be considered as free electricity; and as the bodies on which they fell were all in their natural state, the spark is immediately thrown off as a lateral discharge. Whether insulated or not, the electricity of the body is evidently acted on by induction, before the spark can be distributed over it or the earth. Hence, when sparks of about an inch long are thrown on the upper end of a lightning-rod, or other metallic body passing into the earth, the induction upon the rod and earth requiring a short time for its development, a spark is thrown off upon any adjacent conductor in a state to receive it. Such experiments, therefore, apply only to small quantities of electricity suddenly thrown upon conductors in a neutral state. This, as I have shown, (13, figure 6,) is a distinct case from that, in which a charged surface throws off its redundant electricity upon an opposite surface eager to receive it through a conducting-rod sharing in the electrical state of that surface, and which is consequently prepared already by induction to discharge it. One might be led to infer, from the particular description given by the author of this experiment, page 235, that sparks had been obtained from a lightning-rod at the time of its conveying a discharge of lightning. It may not be amiss to add, that Professor Henry did not consider these experiments as applicable to lightning-rods; and that in accordance with the opinion of Biot, he thinks the spark observable at the time of discharging a jar—that is, Mr. Sturgeon's *new* fact—is entirely owing to a small quantity of redundant electricity always existing on one side of the jar, as I have already stated, (*f*), and not to the whole charge.

I am, Gentlemen, yours, &c.

Plymouth, Nov. 5, 1839,

W. SNOW HARRIS.

LXXII. *Notices respecting New Books.*

Remarks on the Classification of the Different Branches of Human Knowledge. By J. W. LUBBOCK, Esq., Treas. R.S., &c., Vice-Chancellor of the University of London. Second Edition. London and Cambridge, 1839. 8vo. pp. 42. and xxii.

THE advancement of knowledge and the continually increasing number of those who apply themselves to its improvement and extension, are daily rendering the subject of classification, whether as relating to the objects of nature or to the different branches of science and learning, more and more important. *Arrangement*, considered as forming itself an object of science, has not been long attended to in this country, even with respect to those branches of na-