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A Course of twelve elementary lectures on galvanism

Sturgeon, William

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Lecture IV.

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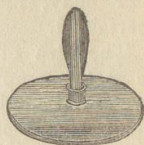
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either *directly* or *indirectly*, in producing the resultant or principal effect. In all the Galvanic experiments hitherto described, in which metals were employed, those bodies had obviously a predominant influence over the other matter which entered the circle; and what is to be particularly remarked is, that through the instrumentality of the *animal electroscope* (prepared frog), we are enabled to detect the action thus displayed, independently of the ordinary means of insulation.

LECTURE IV.

VOLTA, who had studied the electricity of the metals with great assiduity and success, brought forward, in the year 1800, his interesting experiment with the metallic discs, which still bear his name. The Voltaic discs are of copper and zinc, one of each, and usually of about six inches diameter. Each disc is furnished with a glass handle, as represented by fig. 15, for the purpose of insulation from the hands of the operator. The other face of each disc is perfectly flat and polished, to insure as extensive contact as possible, when those faces are brought together.

Fig. 15.

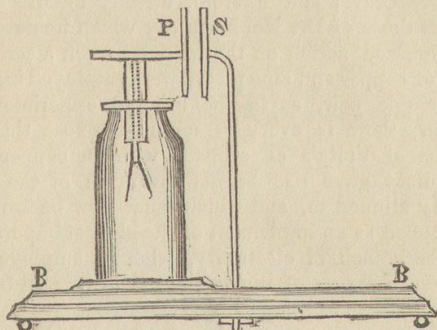


As the electric action developed by these discs is exceedingly feeble, when compared to that shown with the metallic filings in Bennet's experiments, it is usual to employ a condenser in connexion with the electroscope, in order to obtain satisfactory results. The electroscope, with its condenser, is represented by fig. 16.* Before the experiment is performed,

* To those who have read my "Lectures on Electricity," this instrument will be familiar; but as this volume is likely to fall into the hands of many who have not seen the other work, a description of its use in this place may be useful, and even convenient to all. For the theory of the condenser, I must refer the reader to the volume on "Electricity."

the uninsulated plate, s, is brought into close contact with the insulated plate, p, and afterwards withdrawn

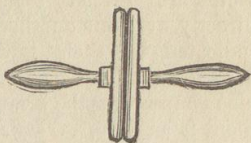
Fig. 16.



a little, so as just to discern an opening between them. The plates of the condenser are now parallel to each other, with an exceedingly thin plate of air between them. The copper and zinc discs are then taken by their glass handles, one in each hand, and brought into contact with each other, as represented by fig. 17. They are afterwards suddenly separated,

Fig. 17.

and one of them made to touch the cap of the electroscope. This operation is to be repeated six or eight times with the same disc—suppose the zinc, for instance. On withdrawing the plate, s, of the condenser from the other, the



gold leaves diverge with *electro-positive* action. When the experiment is repeated, and the copper disc is made to touch the cap of the electroscope, the gold leaves diverge as before, when the uninsulated plate of the condensor is withdrawn, but they now show an *electro-negation*. When the single gold-leaf electroscope is employed, no condenser is necessary,

as a single contact of the discs is sufficient to detect an electrical development.

Notwithstanding the previous experiments of Sultzer, Creve, and Fabroni, already described, as well as those of Dr. Robinson, by which he detected an increased action on the tongue, when a series of pairs of copper and zinc plates were employed instead of a single pair, as in the original experiment of Sultzer, there is every reason to suppose that the success of Volta's experiment with the copper and zinc discs gave rise to his invention of the pile, already alluded to, and which must now be formally introduced as an implement of the highest importance in this branch of electricity, whether employed for the mere purpose of illustration, or in its still higher capacity when applied to physical research.

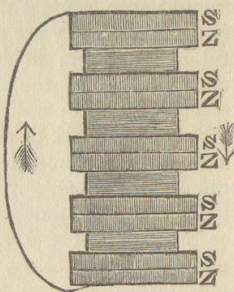
The pile, as originally constructed by Volta, consists of a number of pairs of silver and zinc discs, piled one upon another, with intervening discs of card-board, well soaked in water, in the manner represented by fig. 18. The silver discs first em-

ployed were pieces of coin, and the zinc pieces were cut to the same size; the surfaces of both metals, being made bright to insure contact, are placed together directly over one another, as indicated by their initials, z s, in the figure; which also shows that the arrangement is an uniform series of zinc, silver, moistened card-board — zinc, silver, mois-

tened card-board, &c., from the bottom to the top of the pile, which terminates in a pair of the metals. The discs of card-board are smaller than the metals, to prevent the moisture from running over the edges of the plates, which would spoil the action.

With a pile of about fifty groups of these triplets

Fig. 18.



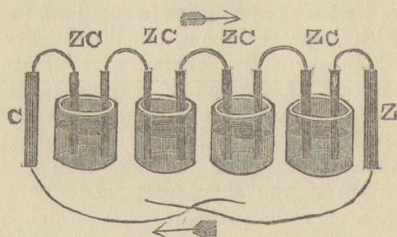
thus piled in series, a slight electric shock is produced, as high as the wrists, when the hands are made to communicate with the bottom and top of the pile. The effect is more powerful when the hands are well soaked in brine (a solution of common salt), which improves the conducting quality of the skin, and, consequently, offers less resistance to the electric force. If, instead of pure water, the cardboard discs be soaked in a solution of salt, the power of the pile in delivering shocks to the animal frame is much increased. The fifty pairs will then shake the arms up to the shoulders; and one hundred pairs give a very disagreeable blow, which is felt in the chest.

The shocks from the pile are only produced at the moment of contact being made with the hands; and no repetition of that effect is perceived so long as the hands remain attached to the extremities of the instrument. But, although no shock is distinguishable, a burning sensation is experienced in the hands and wrists during the whole time of contact, and the roots of the finger-nails smart as if immersed in an acid solution. A wound in the skin, even the finest perforation with the point of a sharp needle, is rendered excessively painful by this electric action of the pile. This is occasioned by a current of the electric fluid running through the arms and chest of the person who is placed in the circuit, and also through the pile. Its direction is that indicated by the arrows, the pile being represented as if closed by a wire.

The pile of Volta was first made known in the year 1800, and in the same year this philosopher also invented his *couronne des tasses*, which is an elegant modification of the pile. The *couronne des tasses* consists of similar elements, or component parts, to those which constitute the pile, viz., a series of pairs of dissimilar metals, and a liquid. Fig. 19 will give a good idea of the structure of this apparatus. It consists of a series of small cups or

glasses, containing the liquid, which, usually, is either a solution of common salt or a weak solution

Fig. 19.



of some acid. The metals are copper, and zinc, in narrow strips, connected in pairs by an intervening copper wire, to the extremities of which they are soldered. The metals, thus connected, are immersed in the liquid, as represented in the figure, having the copper of each pair in one vessel, and its zinc in the next in the series, so that no individual pair of metals has both of its members in the same portion of liquid. The spare unimmersed copper, *c*, at one extremity of the apparatus, and the spare zinc, *z*, at the other, are shown in the figure to give a better idea of the arrangement; and the conducting wires attached to them are supposed to be in close contact where they cross one another, by which means the circuit becomes closed, and an electric current flows through the whole arrangement in the direction indicated by the arrows.

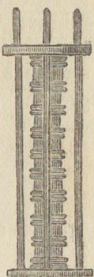
The invention of the pile and the *couronne des tasses*, may be regarded as the happiest events in the progress of Galvanism. Their announcement instilled a new zeal for experimental inquiries; their employment soon led to discoveries of the highest importance; and, in short, the invention of these apparatus commenced a new era in the history of the science.

Notwithstanding the several interesting discoveries that were made by the employment of these pieces

of apparatus in their original forms, experience soon taught philosophers that they might be modified with advantage in various processes of research. The pile, whatever may be the size of the metals employed, requires a tedious process to construct, especially when the metals are numerous, and not attached in pairs by solder; a mode of union not likely to be resorted to whilst half-crown pieces, or guineas, were employed as one of the metals, a practice very common in this country by the earliest experimenters with the pile. For as metallic contact in each individual pair is absolutely necessary, a considerable portion of time was occupied in cleaning the metals before the piling process commenced, a process no less tedious than the former.

Another inconvenience of the pile, when an extensive series of metals are employed, is its liability to tumble down. Accidents of this kind, however, are prevented by means of three glass rods, placed at equal distances from one another round the edges of the pile as supports. The glass rods should be well covered with either lac or sealing wax varnish, and their lower extremities firmly cemented into holes made for their reception on the upper side of a round wooden sole, as represented by fig. 20. The upper part of the pile, when thus supported, terminates in a metal disc, something larger than the discs forming the pile, for the double purpose of adding pressure to the upper pairs, and keeping the glass rods, which pass through it, steady in their proper places.

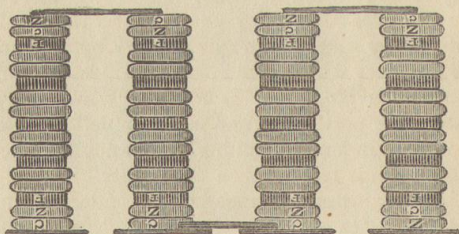
Fig. 20.



When the pile is tall, another inconvenience presents itself, over which the glass rods have no control. This is the oozing out of the liquid from the lower discs of card-board, by the pressure of the superincumbent portions of the pile. The liquid thus liberated, trickles over the edges of the metals, and destroys the insulation of

the pairs from one another. In order to avoid this annoyance, the series of pairs have been formed into several distinct groups or piles of moderate height, and so connected together as to act as one individual pile. Fig. 21 is a representation of an arrangement

Fig. 21.



of this kind, in which four small piles are united so as to operate in concert. The figure represents four groups united together by three metallic plates, by means of which the whole form one continued series from the bottom of the first to the bottom of the last group. To explain this apparatus a little more minutely, we must consider, in the first place, that the whole are piled on a well varnished glass plate, and that we commence at the bottom of the left-hand group. A metallic plate, somewhat larger than the discs of the pile, is first laid down. Upon this plate is laid a disc of copper, and upon the copper a disc of zinc, and upon the zinc a disc of moistened card-board. These three form one compound element of the pile; and a series of these, laid upon one another in the same order, form the first group or small pile. The second group from the left is formed in the reverse order to the first, having the copper of each pair *above* and the zinc *below*. The third group has its metals in the same order as in the first; and the fourth group is similar to the second, so that the arrangement in the first and third are alike, and that

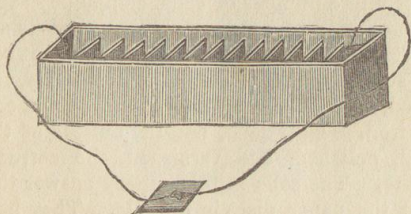
of the second and fourth are alike, but reverse with respect to the other two.

By connecting the first and second group with a metallic plate laid upon their uppermost metals, the two become one series, having its copper end at the bottom of the first group, and its zinc end at the bottom of the second one. In precisely the same manner the third and fourth groups are united, and form another distinct series; and by uniting the second and third groups at the bottom, the whole of the four groups become one uniformly continued series of *compound elements*, from the bottom of the first to the bottom of the fourth group.

By a similar distribution of the elements, a series of any required extent might be formed so as to operate in concert, without spoiling their insulation by squeezing out the water by superincumbent pressure; and when the metals are soldered together in pairs, which is now the usual practice, no cleaning for contact is required. Gold and silver coins have long been discontinued in the structure of Voltaic piles; copper and zinc are now the usual metals employed, and they are as frequently in square plates as in round ones.

The first modification which the pile received was by an ingenious contrivance of Dr. Cruickshank, of the Royal Military Hospital, at Woolwich, in the year 1800, a few months after the pile became known

Fig. 22.



in this country. Fig. 22 will afford a good idea of the Cruickshank's *trough*, or battery, as it is usually

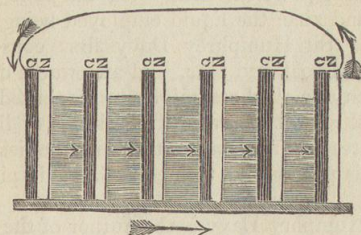
called. The metals are square flat pieces of copper and zinc, soldered together in pairs all round the edges, by soft solder, by which means a metallic contact between the copper and zinc of each pair is continually maintained without further trouble. When the soldering process is completed, the metals are filed smooth round their edges, and care is taken to have no openings in the soldered parts, and that the metals be all of one and the same size. The next business is to fix them in grooves made for their reception in the inner sides of a mahogany box, into which they should slip with ease till they reach the bottom. When thus placed, their planes stand parallel to the ends of the box, and, consequently, at right angles to its sides. When the plates are found to match their grooves, they are to be removed, and the box is to be lined with a resinous cement, composed of rosin, linseed oil, and red ochre. When the whole of the inside of the box is well lined with this cement, and the surplus cleared away from its edges, the plates are to be warmed (taking care not to melt the solder), and slipped into their respective grooves, observing that the zinc side of every pair faces one and the same end of the box. If the plates be ready warmed before the cement cools too far, they glide into their grooves very easily by employing a gentle pressure to their upper edges. A pair of pliers, or small pincers, is very convenient in this process.

When the plates are all introduced, they divide the box into a number of cells, completely separated from one another by the metallic partitions and the cement round their edges. The redundant cement, which stands above the edges of the plates, is to be removed, and the rest leveled and smoothed by a warm iron. This done, and the outside of the box cleaned, polished, and varnished, the instrument is complete. The cells in this battery answer the purpose of the paper discs in the pile. They hold the liquid, whatever kind may be chosen, when the battery is to be brought into play. A battery of

this kind, usually consists of fifty pairs of metals, which can be made ready for experiment in the course of a few minutes. It is well to have the edges of the trough a little higher than the plates, as it gives an opportunity of equalizing the height of the liquid in the whole of the cells, by leaning the battery a little on one side. Fig 22 represents an oblique view of a Cruickshank's battery when complete, having its conducting wires applied to some substance on which the battery is supposed to be acting.

Fig. 23 would represent a longitudinal section of

Fig. 23.



this battery, under the supposition of one of the sides of the box being removed. The edges of the pairs of copper and zinc plates are presented to view, and the cells are represented as when charged with the liquid to a proper height, each portion being insulated from every other. The zinc and copper ends of the battery are joined by a conducting wire, and the arrows show the direction of the electric current, as will be further explained when we come to speak of the theoretical principles upon which this and other pieces of Galvanic apparatus operate.

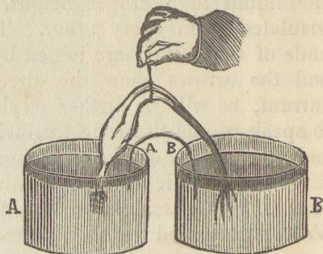
The Galvanic apparatus hitherto described, consists of two dissimilar metals and one liquid; and Volta entertained the idea, that such an association of two metals with a liquid was essential to the production of the phenomena which the pile exhibited, which

is the more remarkable since he was well acquainted with several Galvanic arrangements in which one metal only was employed. M. M. Creve and Fabroni had shown that one of the metals might be substituted by charcoal; Galvani had shown that two metals were not absolutely essential for the production of convulsive motions in frogs; and Aldini and Valli had produced these phenomena independently of any metal being concerned in the process. Hence, data were not wanting to show the incorrectness of Volta's opinion on this topic.

If, instead of employing two metals, a pile be formed of slices of charcoal and plates of zinc, it is found more powerful than when the pairs consist of copper and zinc, the liquid employed being the same in both. Sir Humphrey Davy first constructed a pile of charcoal and zinc, and afterwards discovered that even one of these might be dispensed with by the employment of two distinct kinds of liquid; so that, instead of associating two solid bodies and one fluid, this philosopher formed a Galvanic pile of two liquids and one solid.

Sir Humphrey Davy is the author of the following experiment, which shows the efficiency of a Galvanic association of two liquids and one solid in a beautiful and striking manner, and by means of an exceedingly simple apparatus. Fig. 24 represents two small glass vessels, one of which is nearly filled with a dilute solution of nitric acid, and the other with a solution of sulphuret of potassa. The liquids in the two glasses are joined by a piece of bent zinc, copper, silver, &c., as shown in the figure. The Galvanoscope for detecting the

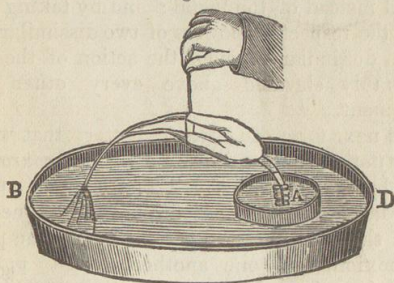
Fig. 24.



action of this arrangement, is a prepared frog, suspended from the hand by a thread of silk. When the legs of the animal are placed in one of the liquids, and the spine afterwards brought into contact with the other, the limbs are immediately thrown into the most violent convulsive agitation. The experiment may be varied by first immersing the spine and crural nerves, and afterwards bringing the toes to touch the surface of the other liquid. Charcoal may be employed instead of a metal, and the action on the animal is still as certain and complete. As the charcoal cannot be bent so as to reach into both liquids, it must be cut into a proper form, so as to accomplish that object when laid on the edges of the two glasses; or two straight pieces may be used, by immersing one in each liquid, and tying their upper ends together with thread.

This experiment may be varied by placing one of the liquids in a silver, or other metallic cup, and the cup on a dish containing the other liquid, as represented by fig. 25, in which, B D represents the

Fig. 25.



porcelain dish, and A the silver, or other metallic cup. The prepared limbs of a frog are suspended by a silken thread as before, and the crural nerves are brought into connexion with one of the liquids, and the muscles of the feet with the other, as represented by the figure.

After ascertaining that a considerable action can be obtained by a single Galvanic arrangement of one metal and two liquids, Davy was induced to form a pile of similar elements; and in order to keep the two liquids from mixing with each other, he placed between them discs of card-board steeped in distilled water. Davy's pile is thus constructed :—Provide a number of discs of sheet copper, or a number of half-crowns, also three times that number of discs of card-board, of less diameter than the metal. One-third of the card-board discs are to be soaked in a dilute solution of nitric acid, one-third in a solution of sulphuret of potassa, and the other third in pure water. Thus prepared, a disc of metal is to be placed on a glass plate, and upon the metal a disc of card-board, saturated with the solution of nitric acid; upon this a water-saturated disc, and upon the water a disc saturated with solution of the sulphuret of potassa. These form one compound element of the pile, which is completed by placing any required number of similar elements, in the same order, upon the first one. A similar pile may be formed by employing slices of charcoal instead of the metal; and by taking advantage of the respective powers of two dissimilar metals and two dissimilar liquids, the action of the pile is considerably elevated above every other known arrangement.

The next form of Galvanic battery that we shall have to notice, is a modification of the *couronne des tasses*, by Dr. Wilkinson. The copper and zinc plates, in this battery, are provided with necks, or narrow slips, at their upper edges, for the purpose of connexion with one another when coupled in pairs. Fig. 26 represents the shape of one of the flat sides of the zinc plates; but as the neck has a projecting piece on the other side, at right angles to its vertical part, it cannot be so well represented by an elevation of the flat side as by an edge view,

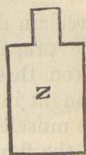


Fig. 26.

such as is shown in fig. 27, in which the unshaded part, z, represents the zinc, and the shaded part, c, the copper. The copper and zinc surfaces are of the same shape and magnitude, and fig. 27, which is an edge view of one pair, will afford a good idea of the method of keeping them in permanent contact with each other at the projecting parts of their necks, which is usually by means of a copper bolt and screw nut—one of the several errors that instrument-makers often fall into. The projecting pieces should be well *soldered* together, otherwise the contact becomes destroyed by the formation of an oxide of one, or both of the metals, where they lap over each other. I have seen very extensive batteries of this kind rendered entirely useless for want of attention to this particular.

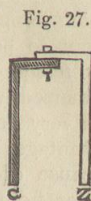
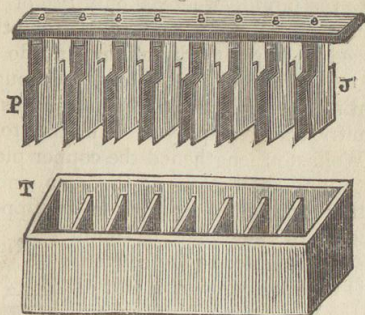


Fig. 27.

When the metals are properly secured in pairs, they are fixed, by bolts and screw nuts, to a wooden beam; generally ten or twelve pairs to one beam, as represented by P J, fig 28. The planes of the plates

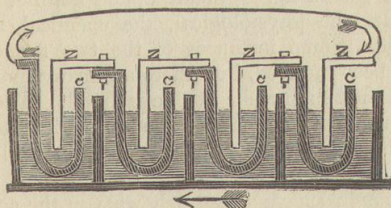
Fig. 28.



are arranged at right angles to the axis of the beam, and with their zincs all in one direction, and consequently, the copper plates all in the other. A wooden box, T, with glass partitions firmly cemented in the grooves in its sides, holds the liquid, into

and also similarly fixed to a wooden beam in groups of ten or twelve pairs. Fig. 30 represents an edge view of a *series* of Wollaston's Galvanic pairs when immersed in the liquid in a partitioned Wedgewood ware trough. The figure also represents the connexion of the extremities of the series, by means of a conducting wire, and the arrows indicate the direction of the electric current.

Fig. 30.



The Galvanic apparatus hitherto described, are those alone, by which the grandest discoveries were made in this branch of science ; and, although other modes of forming batteries have been brought forward of late years, some of which enhance the action, and others prolong it ; and in certain illustrations and enquiries have an advantage over the older forms, it will not be necessary to describe their structures and uses until a later period of our course ; nor, indeed, would it be advisable to dwell on them in this place, since some of those already described are more suitable than they are, for illustrating the theory of Galvanism, as well as for performing many of the necessary experiments.

LECTURE V.

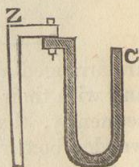
As we are now about to enter on an explanation of the fundamental principles of Galvanic Electricity, I will premise, by stating, that electrical phenomena

which the plates are introduced when the battery is about to be used. In this case, as in the *couronne des tasses*, the copper and zinc of each pair are immersed in two vicinal portions of the liquid. This is a very convenient form of battery, and has some advantages over that invented by Cruickshank, because of the facility of speedily removing the plates from the liquid when any interruption occurs in a course of experiments, and of again introducing them when the experiments are about to be renewed. Shortly after the introduction of this battery as an implement of research, the wooden box, with its glass partitions, was happily superseded by a porcelain trough, with partitions of the same material. The Wedgewood ware, which withstands the action of acids, is most suitable for this purpose, and is that now generally made use of.

Dr. Wollaston, who took an active part in Galvanic enquiries, introduced a method of improving the action of Dr. Wilkinson's form of battery, by very simple means. It will have been noticed that the battery last described has all the metallic surfaces exposed to the liquid, whereas only *two* of the *four* surfaces in each cell *face each other*, the other two being turned in opposite directions, and do not add much to the power of the battery, although they suffer continually from the acid solution, especially when the nitric acid is employed. In order to remedy this evil, Wollaston lengthened the copper plate so as to bring it round the bottom of the zinc, and return up the other side of it as high as its upper edge. By this means the zinc plate has both

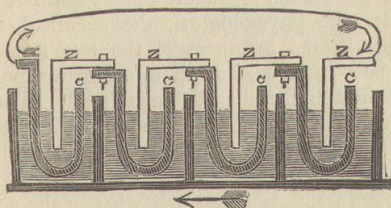
Fig. 29.

of its surfaces presented to the copper. Fig. 29 is an edge view of a pair of metals of the Wollaston's form, where the unshaded part, z, represents the zinc, and the bent shaded part, c, represents the copper. They are united at the top in the same manner as the metals in Wilkinson's battery,



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