ELECTRICITY,

&c.

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TO

MICHAEL FARADAY, D.C.L. F.R.S.

&c. &c.

AS A MARK OF ESTEEM FOR HIS SCIENTIFIC ATTAINMENTS,

THIS VOLUME

IS MOST RESPECTFULLY DEDICATED,

BY HIS OBEDIENT SERVANT,

THE AUTHOR.

PREFACE.

To the readers of the following essay its Author feels that some explanation and apology are due. That it has no pretensions to the title of a scientific treatise, is self-evident—his object, in the *first* part of the work, being simply, so to explain the several varieties of electrical action as to enable the non-scientific reader to understand the *modus operandi* of the electric fluid, in producing the different phenomena which are treated of in the *second* part.

This work is therefore submitted to the judgment of the scientific world, not under the impression that the opinions of one so humble in the ranks of science are deserving of the notice of the public, but with the firm conviction that the subjects discussed are of the utmost importance. He trusts that he has not advanced any proposition that is not founded upon, and supported by, admitted facts; and he hopes that the subject of the "AGENCY OF ELECTRICITY" will speedily be taken up by those whose talents enable them to render it that justice which its vital interest and intrinsic importance demand.

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ELECTRICITY.

ELECTRICITY,

&c.

Part I.

CHAPTER I.

Production of Electrical Phenomena, &c.

Of the importance of Electricity as an agent in the operations of Nature, there cannot be two opinions. Indeed, it may truly be said that it is incomparably the most active and momentous principle in the whole physical world. With a celerity of motion beyond that of light, it combines a chemical power superior to caloric, whilst, in its extreme subtlety, it surpasses both. The singular motions, also, to which it is capable of giving rise, (owing to the phenomena of attraction and repulsion), are exerted in opposition to, and overcome the influence of, gravitation itself. Perhaps, therefore, it is not to be wondered at that scientific men, in speaking of its general agency, should for a moment have forgotten the sober language of philosophy. "Its effects," says the writer of the article Electricity, in the Encyclopædia Britannica, "are so many and so various, that it may be said, without much exaggeration, that, whether we look to the heavens above, or to the earth beneath, we can scarcely perceive any thing that is not acted upon, and in a manner subjected to, the operations of this wonderful fluid." And Walker exclaims, "though often, Proteus-like, it eludes our grasp, tempts inquiry by fallacious appearances, and attacks our weakness under so many perplexing subtleties, yet it is impossible not to believe it the soul of the material world—the paragon of elements."

But while, on the one hand, in all discourses on any subject of physical science, these rhapsodies ought carefully to be checked—while it behoves us to hold the imagination in subjection to the judgment—on the other hand, I may, perhaps, be allowed to point out one cause of the subordinate rank that has hitherto been allotted to electrical science, in the fact, that the lecturer on electricity has generally sought rather to excite astonishment, than to satisfy or call into exercise the reasoning powers of the mind. And although, in the retirement of his study, the science affords him subjects of the deepest speculation, he often goes abroad to his lecture-room, prepared to render his discourse a matter of little else than mere entertainment. Both extremes are to be avoided, and whilst we see no reason why the paths which conduct to science should not be strewed with flowers, and rendered as inviting as possible, we must not rest satisfied with a brief glance at those objects which attract attention merely by their beauty, or excite astonishment by their singularity; but we must dwell upon, and endeavour to learn something from every object as we pass along. Were we, indeed, to lay down railways over the fields of science, along which we might transport our audience, the velocity of their progress might be pleasing, but the whole aim and object of the journey would be lost. We must be content, therefore, to progress leisurely, carefully examining every step as we advance. And we shall find ourselves repaid for any tedium or apparent loss of time, by our not being under the necessity of retracing our steps in search of some objects, which, owing to carelessness, or through our haste, we might, in the first instance, have overlooked.

I have deemed it necessary to offer these preliminary remarks, in consequence of having devoted merely a portion of the work to the chief subject, viz. an inquiry into the *modus operandi* of the electric fluid as an agent of nature, and to which the first part may be considered merely as an introduction, intended, as I have already stated, for those, and for those only, who have not bestowed much attention to the science. We have, it is true, several good elementary works, that might have answered all the purposes of this portion of the work; but they may not always be within the reach of those who may choose to peruse this little volume, and, if they were, it is much more convenient to have the explanation of any phenomenon alluded to, or of any technical term made use of, by referring at once to this part of the work.

With this apology to those who have already made themselves sufficiently acquainted with the leading facts and principles of the science, let us proceed to the consideration of the production of electrical phenomena.

When a piece of amber is rubbed upon the sleeve of the coat, or with warm flannel, it acquires the property of attracting light substances. Amber being the first body in which this power was detected, the terms *electric* and *electricity*, derived from its Greek name, *electron*, have been applied;—the former to all those bodies that are capable, under similar circumstances, of exhibiting the same phenomenon; the latter, to the science which is the subject of this volume. Sealing-wax, glass, and sulphur, for instance, if rubbed like the amber, all become capable of attracting small pieces of paper, feathers, or any other light bodies within the sphere of their attractive influence. They therefore rank under the class of *electrics*. Paper is another *electric*. If previously warmed so as to expel all moisture, and then rubbed with India rubber, it also acquires the attractive power. The effects thus produced are called *electrical phenomena*, and the means employed for their production the *excitation of electricity*.

Attraction, then, is the first phenomenon that arrests our attention, and it is one that is constantly attendant on excitation. It is therefore considered a sure indication of the presence of electricity in an active state, and forms the basis of all its tests. The various contrivances to detect the presence of active electricity are termed *electrometers* or *electroscopes*, the latter being the more correct term, as the instrument is by no means a *measurer*, but merely a test of the presence of the fluid.

The annexed figure represents what may be termed

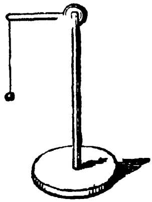

Fig. 1.

a pith-ball *electroscope*, consisting simply of a ball, turned from the pith of the elder tree, suspended by a silk thread from a rectangular arm of glass, fixed to a pillar also of glass. Another form of the electroscope is shewn by figure 2. A, B, is a brass

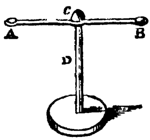

Fig. 2.

needle with rounded extremities, moving on a pivot, at the top of the glass pillar D. If now any of the bodies before mentioned as being *electrics* are excited, and the pith-ball or the needle be brought sufficiently near to them, the presence of electricity in an active state will be immediately indicated by the pith ball or the needle being at first attracted. (Fig. 3.)

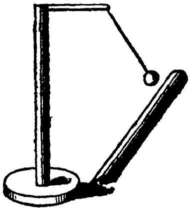

Fig. 3.

But after the electroscope has received a certain quantity of the electric fluid, (in which state it is said to be *charged*), then another phenomenon arrests our attention. The pith ball or the needle suddenly recedes from the excited body, which action is ascribed to, and is termed, *repulsion*. (Fig. 4.) Now the know-

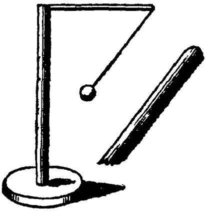

Fig. 4.

ledge of this repulsive power has led to the construction of another instrument, which is by far the most delicate of our electroscopes for detecting that species of electricity which we are now considering.

It consists of a hollow glass sphere (Fig. 5) A, B, inclosing a glass tube, C, D, to the top of which is fixed a brass cap, E, and from the bottom of which are

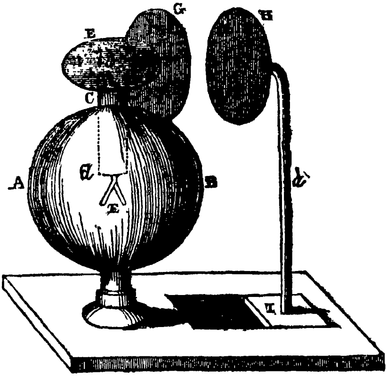

Fig. 5.

suspended two slips of gold leaf, F. At the edge of the brass cap, E, is screwed another circular brass plate, G, so as to be parallel with the circular brass plate, H, inserted, by means of its support, *à*, in a piece of wood, I, moving in the groove, J. This is called a Condensing Electroscope, from the circumstance of its being furnished with the circular metallic plates for the purpose of condensing small quantities of electricity. If now, after exciting any of the electric bodies we have named, we use this instrument in the place of the pith ball or the needle *electroscope*, we find that the slips of gold leaf recede from each other, thus indicating the presence of active electricity. The instrument, of which a sketch is here given, is copied from one which was constructed for me by Mr. Clarke, of the Lowther Arcade, and it certainly is the most delicate electroscope I ever saw; indeed it is so sensible, that the greatest circumspection is necessary in using it, in order to avoid sources of error from the action of currents of air upon the instrument, which sensibly affect it when the instrument is kept in good order; that is, free from dust and moisture, which are great enemies to all kinds of electrical apparatus.

Electrical excitement, then, is characterized by the attraction and recession of light substances, and the consequent production of motion in them; also, (as we shall subsequently point out), of sensation in living bodies, and by the evolution of light and heat. Each of these phenomena will be treated of in its proper place. In the meantime we must turn our attention to the means by which electrical excitation may be effected. The most obvious sources are—

I. MECHANICAL ACTION, which has already been illustrated. II. CHEMICAL ACTION, which, perhaps, may with propriety include the two other sources usually mentioned by authors, viz. CHANGE OF TEMPERATURE, and the CONTACT OF DISSIMILAR BODIES. We have already adduced instances under the first-named source, *Mechanical Action*; indeed, this species of excitation may almost be said to be universal, and may be illustrated by rubbing any one of a most extensive series of resinous and silicious substances, and of dry vegetable, animal, and mineral productions. The electricity thus excited is most readily shewn by presenting the rubbed substance to the cap of the *gold leaf electroscope*, (fig. 5.) As an example under the second head, *Chemical Action*, or *Change of Temperature*, if we fuse sulphur, and pour it into a conical wine-glass, it will become electrical in cooling; and, upon being withdrawn from the glass, will affect the gold leaves in a similar manner to the other excited bodies already noticed. The sulphur, if kept in a dry place, will preserve this electrical property for years, and will evince signs of electricity at any time on being withdrawn from the glass. As instances of a similar nature may be mentioned chocolate, on congealing after fusion ; glacial phosphoric acid, on congealing; calomel, when it fixes by sublimation to the upper part of a glass vessel.

During the condensation of vapour and the evaporation of liquids, although opposite processes, electricity is excited, and this is an important fact to be borne in mind, in order that we may perceive its application, when, in Part II. we come to the subject of the variations in the electrical state of the atmosphere. Some writers attribute these electrical effects to what they term *change of form or state* ; but it is obvious that they may with propriety be included under the head of *Chemical Action*. Many attribute the primary source of electrical excitation to the mere contact of dissimilar bodies ; and an instance is adduced by Singer, as decisive of the fact of the production of electricity by contact alone, viz. the electric column of De Luc. But we have every reason to infer that the effect is partly due to a slight oxidation of the more oxidable matter in the pile, and partly by inequality of temperature induced by the contact or proximity of bodies differing in the degree of their power for conducting caloric; and it is well known that no two bodies in nature possess the same conducting power for caloric.* Indeed, the quantity of electricity developed by mere contact is so minute, that the aid of the most delicate instruments is required for its detection; and the opinion seems to be gaining ground, that mere contact is incapable of causing electrical excitation. The phenomena referred by Volta, and other inquirers, to contact, may be more satisfactorily ascribed to the passage of electricity from those bodies which naturally part with the electric fluid with the greatest facility, to others that are dissimilar in their properties in thus giving out their electricity. De La Rive is of opinion that the feeble excitation from the contact of zinc and copper, is due to slight oxidation caused by moisture and oxygen acting upon the former metal. When he prevented such oxidation, by operating in an atmosphere of hydrogen or azote, no electric excitement followed; and when he increased chemical action, by exposing the zinc to acid, or by substituting for zinc a more oxidable metal, such as potassium, the effects observable on contact with copper were greatly

* The more ample consideration of electrical excitation by inequality of temperature, is reserved for the head of *Thermo-electricity*, which will be noticed in a subsequent chapter.

increased. Electrical excitation and chemical action were observed to be strictly proportional to each other. But there is, after all, nothing in these facts to warrant the inference that the *first action* is chemical, and that electrical excitement is dependent upon such action. On the contrary, they seem to strengthen the opinion that the first action is electrical; and that when any two bodies are placed under circumstances that favour the transmission of electricity between them, the one will receive and conduct electricity at the expense of that which gives out its electricity, the latter combining with oxygen, or with any other body with which it is capable of entering into combination; one of the favourable circumstances being the presence of a body with which it has what chemists term an affinity. There must also be a conducting medium between the two bodies. In De La Rive's experiment both of these conditions were absent, which sufficiently accounts for the non-appearance of any signs of electrical excitation. But we cannot now pause to inquire more minutely into the cause of electrical excitement: intimately connected, as it is, with the subject of electro-chemistry, it will naturally form a portion of the concluding remarks in the second part of the work. For the present I may observe, that I am occupied with a series of experiments, the results of which will, perhaps, warrant the inference, that it is by the agency of the electric fluid that the atoms of bodies are bound together; that the electric fluid is, in fact, the cause of cohesive attraction; and that as every body contains a certain quantity of this subtle fluid, no chemical change can possibly take place in any body until it has parted with a certain quantity of its electric fluid. For instance, take zinc. If one atom parts with its electric fluid, then that atom will combine with oxygen; if two atoms lose their natural quantity, those two atoms will combine with oxygen, and so on. If we facilitate the transmission of electricity from the oxidable body, oxidation will proceed rapidly in proportion. Hence it would appear that the combination of one body with another is not due to what has been termed affinity, but to the cessation of the cohesive attraction between the particles of one of the bodies, owing to their deficiency of the electric fluid, and the resulting attraction between the particles of the other body which has become positive, and the body which has parted with the fluid, and which, of course, has become negative.

But I fear that I have already said too much upon this point, as we shall have frequent opportunities of recurring to it, and of entering more fully into the inquiry. At the same time I found it impossible to pass over the subject in silence, whilst our attention was occupied with a consideration of the phenomena attendant on electrical excitation, and the cause of their production.

CHAPTER II.

On the two states of Electricity, commonly termed Positive and Negative Electricity.

ALTHOUGH, as we have already seen, the means employed for the excitation of electricity are various, the effects are constantly the same. In every case of excitation one body robs the other of a portion of its electricity: the former becoming over-charged, and the other being *minus* its natural quantity. To the over-charged body the term of *plus*, or *positive*, has been applied; to the other, that of *minus*, or *negative*.

Experience has also taught us that similar phenomena are exhibited by a body in either of these states, viz. attraction and repulsion, with light, if the excitation is sufficiently energetic. If, for instance, we make use of a glass tube as our electric, and a piece of flannel to excite it, upon applying the glass tube to, or bringing it near to, the brass cap of the gold leaf electroscope, a divergence of the slips of gold leaf will take place. Then we apply the finger, to draw the electricity from the instrument, and the gold leaves resume their original parallel position.

Now let the flannel be applied, and the same effect will be produced as that which took place on the approach of the glass, viz. a divergence of the gold leaves. Now it might be inferred from this that, since similar causes produce like effects, both the excited bodies are similarly circumstanced as regards their electrical condition; but we shall soon see that this is not the fact. If we repeat the excitation, and first apply the glass tube, so as to cause divergence, and then apply the flannel, the gold leaves will again resume their parallel position. This experiment, as well as the following one, teaches us that the flannel and the glass exercise a neutralizing influence over each other; and that, to all appearance, there are two electric powers, similar in their action on the electroscope when separate, the neutralizing effect taking place either when they are acting together, or in opposition the one to the other. If, for instance, we once more repeat the excitation, and without separating the two bodies bring them near to the instrument, no effect will be produced; but the instant they are separated a divergence of the leaves takes place, as before.

Philosophers at first imagined that these phenomena were peculiar to the substances that were excited; and hence the power excited by rubbing glass was termed *vitreous*, and that resulting from sealing-wax, *resinous* electricity; but it is now demonstrated that both powers are called into activity in every case of excitation; and as their mutual counteraction of effect resembles an affirmative and a negative power, the terms *positive* and *negative* have been substituted for *vitreous* and *resinous.* Indeed, what was called vitreous electricity may, under certain circumstances, be obtained from resinous bodies, and *vice versâ.* Smooth glass, for instance, acquires *vitreous* or *positive* electricity by friction with every substance with which it has hitherto been tried, except the back of a cat, which becomes positive, leaving the glass in a negative state; but roughened glass, if rubbed with the same substances, becomes negative, while the rubbing bodies are rendered positive. Again, sealing-wax, which in general becomes negative, if previously scratched, so that the surface is rendered rough, exhibits signs of positive, or vitreous, electricity. Silk, with resin, is positive, or vitreous; but with polished glass, it is resinous, or negative. The following substances acquire vitreous, or positive, electricity, when rubbed with any of those which follow, in the order in which they are set down; and resinous, or negative, with any of those which precede :—

The back of a cat.
Polished glass.
Woollen cloth.
Feathers.
Wood.
Paper.
Silk.
Gum-lac.
Roughened glass.

If a black and a white silk ribbon are rubbed together, the former will become negative, and the latter positive; but if two pieces of the same ribbon, of the same length, are rubbed, the one being drawn lengthwise and at right angles over a part of the other, the one which has been exposed to the mechanical action in its whole length becomes positive, and the other negative. So when the bow of a violin is drawn over a limited part of the string, the hairs of the bow exhibit a positive, and the string a resinous state of electricity; and so in all cases it would appear that the body whose excited portion is of the least extent generally becomes negative. At the same time it is to be remembered that the slightest difference in the conditions of these and of all similar experiments on the electrical condition of bodies excited by friction, will be often sufficient to produce opposite results.

From what has been said, we learn that one kind or state of electricity is never produced without the other; and the important fact, that during the most trifling action, whether mechanical or chemical, the equilibrium of the electric fluid is disturbed.

With respect to these two states of electricity, there are at present two theories, each of which has its supporters. The one, promulgated by Du Faye, is founded on the hypothesis of the existence of *two* fluids, each of which is repulsive of its own particles, but having an attraction for those of the other. The other theory is that of Dr. Franklin, and is based upon the supposition that there exists in all bodies a fluid of peculiar subtlety, repulsive of its own particles, but attracting all other matter. It is foreign to my purpose to enter into the question of the comparative merits of these two theories, for of course the reader is aware that this part of the work is not intended as a treatise upon electricity, but, as has been already stated, its sole object is to explain the various electrical phenomena so far as to enable him the better to understand the second part of the work, and that he may the more readily perceive the *modus operandi* of the electric fluid in all those changes that are continually going on in nature, as well in animated beings as in inanimate matter. It is, however, necessary to adopt one of the theories; and I trust it will be understood that in adopting Dr. Franklin's theory, I do not pretend to acknowledge its superiority; but it appears to me to be the more simple of the two, and explains sufficiently for our present purpose all the phenomena with which we are acquainted. It may, at the same time, be stated, that by substituting the terms vitreous fluid and resinous fluid, for those of positive state and negative state, it will be a matter of little difficulty to the non-scientific reader, if any such there be in the present day, to apply the two-fluid theory in the explanation of electrical phenomena, if he prefers it; and he will soon perceive that they can be nearly as readily accounted for by the one theory as the other.

The theory of Franklin, then, which I shall follow throughout the work, depends on, and may be reduced to, the following principles:—

I.—That the electric fluid is contained in the atmosphere, and in all terrestrial substances.

II.—That the phenomena exhibited depend on the action of an elementary fluid, of a peculiar nature, extremely subtle and elastic.

III.—Glass, and other electric bodies, though they contain a quantity of the fluid, are impermeable to it.

IV.—That the electric fluid repels its own particles, and attracts all other matter.

V.—By the excitation of an electric body, the equilibrium of the contained fluid is disturbed, one part becoming surcharged at the expense of another part.

VI.—Bodies that are capable of conducting the fluid are permeable to it through their whole substance.

VII.—*Positive* electricity is a superabundance, *negative* electricity a deficiency of the fluid.

On these principles we shall not find it difficult to find a solution of the simultaneous occurrence of the two opposite states of electricity, or of what Du Faye's followers would term the two electric fluids.

We must, in all cases, bear in mind that electrical phenomena are probably produced by the action of a subtle *fluid;* that it is only when the fluid is so excited as to have its equilibrium disturbed, and so to be put in motion, that electrical phenomena are exhibited. Now, if we call analogy to our aid in the explanation of the phenomena resulting from such disturbance, we shall find that similar laws regulate the transference of electricity between one body and another, to those which influence the motions of other fluids and liquids. In order to assist us in following out this analogy, we must consider solid bodies to represent vessels adapted to contain a definite quantity of the electric fluid, in like manner as a certain known measure will contain a definite quantity of water, or of any other liquid or fluid. Now if, say, a pint measure, is filled with water, it may be considered analogous to a body which is saturated with, or contains a portion of electricity equal to its capacity. If we take a sponge, and dip it into the water, allow it to remain for a short time, and then withdraw it, we find that it has absorbed a certain quantity of the liquid, and it may now represent a body that has become charged with electricity at the expense of another with which it has been in contact. Of course, the quantity of liquid abstracted by the sponge is precisely equal to the quantity lost from the pint measure. So, in all cases of the abstraction of electricity by one body from another, the quantity gained by the one (which is then said to be *plus*, or *positive*) is precisely equal to that which is lost by the other, which necessarily has become *minus*, or *negative*. Here, then, we have an explanation of that counteraction of effect which has already been noticed when speaking of the electroscope, and, indeed, an explanation of the whole (seeming) mystery of positive and negative electricity. It will be remembered, when explaining

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I trust it will now be sufficiently understood, that when the terms positive and negative are made use of in the course of this volume, they merely signify a superabundance and a deficiency of the fluid.

The following table is subjoined, to shew the electrical states produced in substances by their friction with different bodies:—

	Is rendered	*By Friction with*
The back of a cat	Positive	Every substance hitherto tried.
Smooth glass	Positive	Every substance hitherto used, except the back of a cat.
Rough glass	Positive	Dry oiled silk, sulphur, metals.
	Native	Woollen cloth, quills, wood, paper, sealing-wax, white wax, the human hand.
Tourmalin	Positive	Amber, blast of air from bellows.
	Negative	Diamonds, the human hand.
Hare's skin	Positive	Metals, silk, load-stone, leather, hand, paper, baked wood.
	Negative	The finer furs.
White silk	Positive	Black silk, metals, black cloth.
	Negative	Paper, hand, hair, weasel's skin.
Black silk	Positive	Sealing-wax.
	Negative	Hare's, weasel's, and ferret's skin, loadstone, brass, silver, iron, hand, white silk.
Sealing-wax	Positive	Some metals.
	Negative	Hare's, weasel's, and ferret's skin, hand, leather, woollen cloth, paper, some metals.
Baked wood	Positive	Silk.
	Negative	Flannel.

CHAPTER III.

Of Induction.

Intimately connected with, and naturally arising out of the phenomena we have just considered, is the phenomenon of *Induction*, to which some attention must be devoted, as the term will frequently occur when we come to speak of the agency of the electric fluid, since it is, in many instances, by a species of inductive influence that bodies continually act and re-act upon each other. It is, indeed, one of the most important phenomena connected with the subject, and, as such, must be most patiently inquired into, and attentively considered.

When a body is charged with electricity, or when it is *minus*, or deficient of its natural quantity, although it is perfectly cut off from any communication with the earth, by means of the interposition of any body which is impermeable to the fluid, (in which case it is said to be insulated), it has a tendency to produce in all bodies sufficiently near to it a state of electricity opposite to that which it itself manifests. If, for instance, the body is *positive*, or surcharged, it has a tendency to produce, in a neighbouring body, a negative, minus, or undercharged state.

This effect is termed *electrical induction,* and may be ranked among the general facts, or laws, of the science.

If a body, in either state, is presented to a body in its natural state of electricity, the electrical condition of the various parts of the neutral body is disturbed, a state of electricity being induced contrary to its own in that part of the neutral body which is nearest to the excited one, and a state of electricity similar to its own in the remote part. Various conditions operate in modifying these inductive effects; such as whether the body which is neutral is one that is permeable or impermeable to the electric fluid, &c. which it is foreign to our purpose to treat of more fully. Let one instance suffice to shew that the inductive influence will be more energetically developed, if the neutral body is permeable to the fluid. If, on the contrary, it is impermeable to the fluid, or one which will not conduct, as glass or silk, the effects are less sensibly developed. The truth of this is confirmed by a very simple experiment.

By fine silk threads, of equal length, suspend two balls of equal dimensions, made of gum-lac, but let one of them be covered with gold leaf. Place these balls at a little distance from each other, so as to admit of their motions being compared. Excite a piece of glass, or sealing-wax, and bring it near them. The ball with the metallic coating will be the more quickly attracted of the two, as it readily admits of a transfer of the fluid from one side to the other, the ball without the metallic covering allowing little or no motion in its electricity. The latter will, however, very gradually assume an electrical condition similar to its companion, and will be feebly, though sensibly, attracted. And as this change in the uncoated ball is slow, so its state is more permanent when produced; thus it adheres for a considerable time to the body by which it has been attracted. On the contrary, the gilded ball is speedily repelled; for it the more readily receives the electricity which the excited body is ready to impart to it. A small degree of permanent electricity is, however, also induced in this ball, owing to the gum-lac becoming gradually slightly impregnated with the electric fluid.

We must next proceed to trace the consequences of this important law. According to the more simple theory which I have adopted, viz., that of Dr. Franklin, the accumulation of electricity in any part can be effected in no other way than by withdrawing it from another part; nor can it be taken from the one without being given to the other; so that there is, in every case, an equal degree of positive and negative electricity, and *vice versâ*. We have seen, in the case of the two balls above noticed, that in proportion as a body opposes less resistance to the passage of the electric fluid, the disturbing force is the more distinctly manifested. And in order that we may perfectly understand this distinction, let us first take the case of an excited body, in a positive or overcharged state, acting, by induction, on a body capable of conducting the fluid, and insulated. The superabundant fluid in the excited body will repel all the fluid contained in the insulated conducting body: of course, therefore, a portion of the fluid will be driven from the side next to the excited body to the remote end. The adjacent side will thus be rendered *minus*, negative, or deficient; the remote side will become *plus*, positive, or surcharged. But this effect will take place only to a certain extent, as there is a limit at which the repulsion of the fluid accumulated at the remote end will just balance the repulsion of the fluid in the excited body, added to the attraction of the matter which is deficient in the adjacent end. When this limit has been attained, the flowing of the electric fluid from the near to the remote end of the body will cease, and the equilibrium will be restored.

Let us now shew, by experiment, the coincidence of theory with the actual fact. Let N, P, (fig. 6) represent a metallic cylinder of some length, with

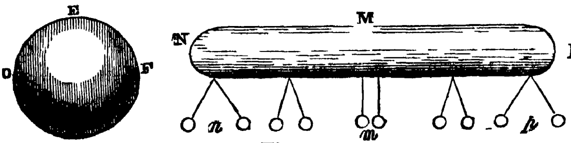

Fig. 6.

rounded ends, and having, at different parts, pairs of suspended pith balls, to serve as electroscopes. We must suppose the metallic cylinder to be insulated, by being supported on a glass pillar, or otherwise, and placed in the vicinity of an excited globe of glass, E, but not sufficiently near to attract any of the electricity from the globe.

Now, every pair of balls, with the exception of those about the middle of the cylinder at M, *m*, will immediately recede from each other, indicating the electrical states of the parts from which they are suspended. Those at the extremities, *n*, *p*, will be found to diverge the most; the divergence will diminish as we approach the middle plane M, *m*, where the body is in its natural, or neutral state. Hence that point is called the plane of neutrality; and it is necessary to remark, that its position will vary according to the distance of the excited electric, and the relation between that distance and the length of the body itself. Again, by testing the state of the balls, we shall find the electricity to be negative in the parts nearer to the electric globe E, than the neutral plane M, *m*, and positive in those most remote.

Now, these effects are simply the results of the action of electricity at a distance, for they depend upon no other circumstance. It is no matter what substance is interposed between the bodies which are thus acting on each other, provided the interposed body undergoes no change in its own electrical condition. For instance, induction will take place as effectually when a plate of glass is interposed, as if no such substance had intervened.

We must now vary the experiment, and suppose that the acting body E, instead of an electric is a conducting body, as a globe of metal, charged with positive electricity, (fig. 6.) At first, the effects will be the same as in the former experiment; but the electrical state which the globe has communicated to the cylinder will react on its own electricity. The negative end, N, has a tendency to induce positive electricity in the globe, particularly at the adjacent side, F, or, to speak more plainly, it will tend, by its attraction for the fluid, to draw it to that side, and thus increase its positive state. This is effected at the expense of the other side, O, which, parting with a portion of its fluid, is thus rendered less positive than before. And, of course, the increased positive state of the side, F, tends to increase its inductive influence on the fluid in the cylinder; that is, to repel an additional quantity of the fluid from the negative to the positive end. Then ensues a corresponding reaction in the globe, and so on, and thus a series of smaller adjustments is constituted, until a perfect equilibrum is established in every part. This attained, the electrical conditions will be the same as those consequent upon the immediate actions, though, in consequence of the series of reaction, somewhat increased in intensity*.

As a practical illustration of the preceding reasoning, we shall adduce the following experiment:—Let the metallic globe be provided with electroscopes on

* These facts ought to be remembered; for, when we proceed to speak of the actions and reactions which are said by physiologists to take place in the body in a state of disease, the application of the principles of elective induction will be obvious.

its opposite surfaces; when the globe is insulated and alone, any electricity communicated to it will diffuse itself equally over its surface, and an equal divergence will take place in both electroscopes. But bring a conducting body near to it, and the balls that are most remote from that body will begin to collapse, while the others diverge to a greater extent than before; thus shewing the nature of the reaction of the induced electricity of the conductor upon the body which was the original source of the inductive influence.

Now it must be remembered that in all these cases no transfer of the electric fluid has taken place between the bodies, which is proved by the experiment in which the glass plate is interposed. Another proof is afforded by the circumstance that the mere removal of the bodies to a distance from each other will restore each of them to its own original state. The globe remains in as positive a state as before; the cylinder resumes its state of perfect neutrality; there has been no loss—no gain on either side. The experiment may be repeated over and over again, the phenomena will not vary. But the effects would be different if the cylinder was divided in the middle, and one or both of the parts were removed separately, while they still remained under the influence of the globe. In this case each part would retain after its separation the electricity which had been induced upon it; because, by the separation, the return of the electric fluid from the positive to the negative end has been prevented. The nearer portion will continue negative ; the remoter end positive. If, in place of two, the division had been in three parts, the middle part only would have been ne .tral.

. periment.—Join two or more conductors endwise, as ii fig. 7, so that they may act on one conductor

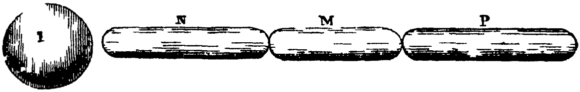

Fig 7.

when placed near to the electrified globe E, and after indu tion has thus been produced, let them be removed separately and their electrical states examined. If E is positive, N will be found negative, P positive, and M neutral.

Again, let us suppose that a long metallic cylinder, rounded at the ends, is brought into contact with the remote end of the first cylinder, P, (fig. 6,) which, by induction, has been rendered positive : the fluid accumulated at this end will now pass into, and will recede to the more distant part of, the conductor. The transit will now take place before actual contact, and will be evidenced by the appearance of a spark when the bodies are brought sufficiently near. The removal of this fluid to a greater distance will occasion a disturbance in the equilibrium that had before been established. The repulsion which that fluid had caused, and which had assisted in preventing any greater quantity of fluid from being propelled from the negative end, N, is now considerably weakened by the increased distance at which it acts : thus a fresh portion of fluid will leave the negative end, rendering it still more negative, or deficient. This, again, will occasion a further effect, by reaction on the fluid in the globe whence the action originated; and another series of changes and adjustments will follow, until a new condition of equilibrium takes place, and the fluid once again rests.

We learn from this that the effects of induction on a conductor are augmented by increasing its length; and the condition of infinite length is attainable by placing the conductor in communication with the earth, which will carry off all the fluid that the electrified body is capable of expelling from the nearest end. Accordingly, if we touch with the finger, or with a rod of metal, the remote end of an insulated conductor under the influence of induction, we obtain a spark more or less vivid according to the intensity of the induced electricity; and the conductor so touched has then only one state of electricity, viz. the opposite to that of the electrified body which is acting upon it. The part touched is brought into a state in which it appears to be neutral as long as it remains in the vicinity of the electrified body, because the actions of the redundant fluid, and the matter which is deficient of fluid in the two bodies, exactly balance each other, But the fact is, it contains less than its natural share, in consequence of the repulsive tendency of the fluid in the body which produces the induction; and this negative state will be manifest, if the conductor that has been touched is again insulated, and then removed from the influence of the inducing body. This peculiar condition, in which the parts of a body are really undercharged or overcharged with fluid, although, from the action of electrical forces, derived from bodies in its vicinity, a state of equilibrium is established, and no visible effect results, has been denominated by Biot, *Disguised Electricity.*

It is also worthy of attention, that if the communication be made between *either end* of the insulated conductor and another longer conductor, or the earth itself, the same effect will result, and the fluid accumulated at its remote end will be carried off by the longer conductor, although it has, in one case, to pass round through the end nearest to the body which repels it. The operation which here takes place may be illustrated by the motion of a fluid in a syphon. A repulsive force is acting upon the fluid, both in the shorter and the longer column; but in reference to the motion of the fluid in the bent channel, the one force is acting in opposition to the other, and the tendency of the fluid in the longer, prevailing over that in the shorter column, will draw off the latter round the bend of the supposed syphon. Thus, in the bent conductor ANP, (fig. 8,) the re-

Fig. 8.

pulsion exerted by the fluid in E, for the longer column NP, being greater than its repulsion for that in the shorter column NA, the fluid in A will be carried over the bend N, notwithstanding its tendency to move from N towards A.

In all these cases we have supposed the inducing body to be in a positive state. The same effects would take place in respect to degree, only opposite as to state, if it had been in a negative state, and, of course, the same explanations will in every respect apply, with the substitution of the term negative for positive, and attraction for repulsion, and *vice versâ*.

There is another consequence of the induction of electricity, viz. that the bodies between which it takes place necessarily attract each other; for the action of the adjacent sides, F and N, (fig. 6,) which are brought into opposite electrical states, is greater than the action of those sides which are in similar states to each other, F and P, and which are more distant; hence the attraction always exceeds the repulsive force. This circumstance sufficiently explains the fact that conducting bodies, previously neutral, are attracted by electrified bodies; and the following fact, which is more singular, and which cannot be accounted for on any other principle, is also a direct consequence of the law of induction. For instance, if a small body, weakly electrified, is placed at a distance from a larger body, more highly charged than itself with the same kind of electricity, it will, as usual, be repelled; but there is a certain distance within which attraction will take place instead of repulsion. This takes place in consequence of the inductive influence producing so great a change in the distribution of electricity, as to give a preponderance to the attracting forces of the adjacent parts of the two bodies, over the repulsive forces in the other parts, and which would have alone acted if the fluid had been immoveable.

It will now be readily understood how induction may operate through a succession of conductors, which are all of them insulated, except the last; and which are separated from each other by distances greater than that at which a transfer of electricity would take place. If, under such circumstances, the first be electrified, alternate states of opposite electricities will be produced in the two ends of each conductor in succession. In all the ends nearest to the first body the electricity will be of the opposite kind to that with which the first has been charged; in the remote ends it will be of the same kind as that of the first body. The vicinity of these opposite electricities will tend powerfully to retain them in that condition, and will diminish their electric action on surrounding bodies. A large portion of electricity so arranged and retained, is, therefore, in the condition designated by the term *Disguised Electricity*.

In proportion as the interruptions to the continuity of the line of conductors are more numerous, the more nearly will such a system approach to the condition of an imperfectly conducting body. The same principle admits of being extended, with some modification, to the constitution of electrics themselves.

At the commencement of this chapter, the importance of the class of phenomena included in the inductive influence of electricity was forced upon the reader's attention, in reference to the chief object of this work; and it will be at once confessed, that their importance has not been over estimated, if we consider for a moment what endless and ever-changing inductive actions and reactions must be perpetually taking place between a series of clouds—between those clouds and the atmosphere—and again, between them and the earth, more particularly in the neighbourhood of high mountains.

CHAPTER IV.

Of Conductors and Non-conductors of Electricity.

It has been seen by the divergence of the gold leaves of the electroscope, when a body in an excited state is brought in contact with the brass cap of the instrument, (fig. 5,) that electricity can be communicated from one body to another. But the facility with which the electric fluid is transmitted, differs greatly in different bodies. Along some bodies it is conveyed with a velocity that sets calculation at defiance; others transmit it less rapidly, and some appear almost to oppose a complete barrier to its progress. Examples of this fact are continually occurring in the most simple experiments. The divergence of an electrified electroscope may be destroyed, decreased, increased, or rendered permanent, by touching its cap with different bodies; and as the divergence depends solely on its electricity, such effects can only be produced by the relative power or property of the bodies applied to deprive it of the electricity, or to add to the quantity it already contains, for whilst the electricity remains, or is not increased, its divergence will continue unaltered.

Experiment.—Touch the cap of an electroscope (previously electrified) with a stick of dry glass, resin, sulphur, or sealing-wax, the divergence of the leaves will continue. These substances, then, do not transmit electricity. But touch the cap of the electrified electroscope with a piece of wood, a rod of any metal, a green leaf, or with the finger, its divergence is destroyed; by the wood gradually, but by the metal, the green leaf, and the finger, almost immediately. Such bodies, therefore, permit the transmission of the electric fluid, and are thence called *conductors*; but as experience has taught us that there is a difference in their facility of conducting, those bodies which are inferior in this respect are termed *imperfect conductors*; and the bodies first tried, viz. the glass, &c. are called *non-conductors*. In general, however, all bodies are naturally divided into two classes only, the remote extremes of each forming the intermediate class.

Strictly speaking, there is no substance with which we are acquainted, that is perfectly impervious to the fluid; for the intensity of electricity may be so increased as to force it, for a limited distance, through all bodies. The same observation holds good respecting conductors, there being no body in which the conducting power is perfect, the very best conductors offering a slight resistance to the passage of the fluid.

The following is a list of bodies arranged, as nearly as our knowledge will admit, in the order of their conducting power. They are arranged in one series, commencing with those which have the greatest conducting power, and ending with those which have the least. The order in which they rank as *non-conductors, electrics,* or *insulating* bodies, is, of course, the reverse.

The perfect or least oxidable metals.
The more oxidable metals.
Charcoal, prepared from the harder woods, and well burned.
Plumbago.
The concentrated mineral acids.
Powdered charcoal.
Dilute acids.
Solutions of metallic and neutral salts.
Metallic ores.
Animal fluids.
Water.
Snow.
Living vegetables.
Living animals.
Flame (?)
Smoke.
Steam.
Metallic salts.
Salts with alkaline or earthy bases.
Rarefied air.
Vapour of alcohol.

Vapour of ether.
Earths and stones in their ordinary state.
Pulverized glass.
Flowers of sulphur.

Dry metallic oxides.
Oils.
Vegetable ashes.
Animal ashes.
Dry transparent crystals.
Ice, 13° Fahrenheit.
Phosphorus (?)
Lime.
Dry chalk.
Native carbonate of barytes.
Lycopodium.
Caoutchouc, or Indian rubber.
Camphor.
Siliceous and argillaceous stones, in proportion to their hardness.
Dry marble.
Porcelain.
Baked wood.
Dry atmospheric air, and other gases (?)
White sugar, and sugar crystallized.
Leather.
Dry parchment.
Dry paper.
Cotton.

Feathers.
Hair, especially that of a living cat.
Wool.
Dyed silk.
Bleached silk.
Raw silk.
Transparent gems.
Diamond.
Talc.
Metallic vitrifications.
Glass, and other vitrifications.
Fat.
Wax.
Sulphur.
Resins, and bituminous substances.
Amber.
Gum-lac.

It is scarcely necessary to state, that the precise point in the scale forming the separation between conducting and insulating bodies is indefinite; but endeavours have been made to mark it by the division indicated by the line.

Perhaps a thread of gum-lac is the most perfect of all insulating or non-conducting substances, being, according to Coulomb's experiments, ten times more effectual than a silk thread as dry as it can be made; the gum-lac, when only an inch and a half in length, insulating as perfectly as a fine silk thread of fifteen inches. When the silk thread was dipped in fine sealing-wax, it was equal in power to a thread of pure gum-lac of four times its length. It has been found, however, by Professor Robinson, that the conducting power of silk thread in some degree depends on its colour: when of a fine white, or a black colour, its conducting power is the greatest, if of a high golden yellow, or a nut brown, its conducting power is the least: so that, of course, silk threads to be used as insulators should always be selected of one of the latter colours. This difference, occasioned apparently by the colour of the thread, may depend upon the dying materials that have been made use of; or it may be dependent on the colour, owing to some connexion, yet unknown to us, between the colours of bodies and their power of transmitting the electric fluid. Glass, even when *dry, is not a very good insulator; but when drawn into a fine thread and coated with gum-lac, it acts as well as a thread of gum-lac one third of the length. Extreme fineness is, however, requisite, for it transmits the fluid in proportion to the square of its diameter.* It ought to be stated that the insulating power of glass is less perfect by its having a bore, however small, unless that bore is coated with lac.

Many of the substances enumerated as conductors in the table we have given, do not conduct when they are perfectly dry; in others, the conducting power varies, or is quite lost, under various modifications of temperature. Thus, hot water conducts better than cold water; so also does charcoal, and some other substances: so that in many of the bodies enumerated, the conducting power does not permanently exist. Even some of the metals become very imperfect conductors when in a state of fusion. On the other hand, there is as great a variation in the degree of resistance opposed by what are termed electrics to the passage of the fluid, owing to adventitious circumstances. The accession of moisture ought carefully to be avoided. The substances least liable to attract moisture are the resins, raw silk, and Muscovy talc, which, therefore, are most useful when good non-conductors are required. Glass becomes moist on its surface only. This may be avoided by coating it with sealing-wax or good varnish, and the sealing-wax answers better when fused than when it is used as varnish. When glass is brought to a red heat it becomes a conductor; so *do melted resin, sealing-wax, and many other non-conducting bodies. The influence of heat, indeed, on this property is very remarkable*; and as its operation is not intelligible, we can only record the facts. *Wood in its* natural state conducts; if baked, the moisture is expelled, and though its organization is not altered, it becomes a non-conductor. By exposure to a greater heat its volatile elements are dissipated, and its indestructible part, charcoal, with alkali, only remains: this is a conductor, but if again exposed to heat, with access of air, it suffers combustion, and is converted into ashes and gases, which will not conduct. The conducting power of bodies does not depend upon their chemical constitution, nor upon their specific gravity, their hardness, tenacity, or crystalline arrangement. Platina, the must be evident, that without this distinction electrical phenomena would be unknown. If, for instance, all bodies in nature possessed the conducting power, the electric fluid would become dissipated at the moment of its production. By this property, electricity can be readily transmitted from one body to another; and can be retained by the latter, by means of the non-conducting power of another body made use of to support it. A body thus supported by an electric is said to be *insulated*. A support of glass, sealing-wax, silk, or other non-conducting substance, is, for the same reason, called an *insulator*, or an *insulating support*; and a piece of metal, or other conductor, so supported, is termed an *insulated conductor*.

Very simple experiments may exemplify the use of insulators and conductors in practical electricity. Previously to our entering into the consideration of more important apparatus, the following experiments may suffice to shew the application of the principle:—

Lay a sheet of writing paper, perfectly dry and warm, flat upon a table, and rub the surface briskly with a piece of Indian rubber. The paper will adhere to the table; and if lifted up by one corner, and presented quickly to any flat conducting surface, will be attracted by, and adhere to it. The cause of this adhesion is the attraction of the electricity excited on the paper, which, when dry, is an *electric,* or an *insulator,* or non-conductor.

Repeat the excitation in a dark room: when the paper is lifted up in the manner before directed, present the knuckle successively to various parts of its surface, and a series of faint divergent flashes will be seen, occasioned by the transmission of the electricity excited on the paper to the hand.

Again, excite the paper, as before, and place it on an *insulating stand (fig. 9), consisting of a round plate of*

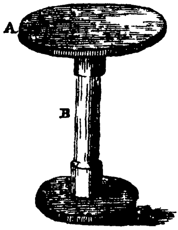

Fig. 9.

metal, about six inches in diameter, A, supported on a glass pillar, B. Present the knuckle to the edge, or the under side of the plate, a bright spark will appear; but a second approach of the knuckle will produce little, if any, effect; for the metal is a conductor, and transmits at once the *whole* of the excess of electricity received from the paper. Those who wish to try the densest of all bodies, is a conductor; but so also are charcoal and rarefied air. Carbonate of barytes has great density, and is a non-conductor; but dry air, and the different gases, which are amongst the rarest forms of matter known, are of the same character. Many electrics are brittle; but some, again, are elastic, and others fluid: and there are bodies of all descriptions that conduct.

We see, then, that different bodies are possessed of different properties as respects electricity; and it must be evident, that without this distinction electrical phenomena would be unknown. If, for instance, all bodies in nature possessed the conducting power, the electric fluid would become dissipated at the moment of its production. By this property, electricity can be readily transmitted from one body to another; and can be retained by the latter, by means of the non-conducting power of another body made use of to support it. A body thus supported by an electric is said to be *insulated.* A support of glass, sealing-wax, silk, or other non-conducting substance, is, for the same reason, called an *insulator,* or an *insulating support;* and a piece of metal, or other conductor, so supported, is termed an *insulated conductor.*

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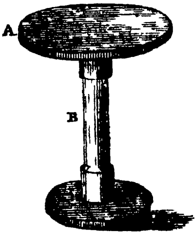

Fig. 9.

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Thus, insulated conductors are employed for the purpose of collecting or receiving electricity, and of retaining it for the purpose of experiment.

Ere we conclude this chapter, one material circumstance must be noticed, viz. that the form most favourable for the retention of electricity is that of a sphere; next to it a spheroid, and a cylinder terminated at both ends by a hemisphere. On the other hand, the electric fluid escapes most readily from bodies of a pointed figure, especially if the points project to a distance from the surface. At the same time, pointed bodies receive electricity with the greatest facility.

CHAPTER V.

Of the Electrical Apparatus; Construction of Machines; Theory of their Action; Attraction and Repulsion, &c.

Having said thus much respecting the excitation of electricity, and the difference of various bodies in their conducting and insulating powers, we shall now be prepared to understand the construction of the various apparatus which are used for the artificial excitement, the collection, and retention, of the electric fluid, for the structure of the apparatus consists in a judicious arrangement of insulating and conducting bodies, so that the former shall prevent the dissipation of the fluid which the latter are employed to collect. Thus the cap and the gold leaves of the electroscope form a conductor, and the former is insulated by being supported on the glass vessel; the gold leaves by being suspended within the vessel

Where friction is employed for electrical excitation, the amount of effect is, within certain limits, proportioned to the extent of the rubbed surface. Usually, to excite positive electricity, a glass tube, about an inch in diameter, and ten feet long, is rubbed lengthwise by a piece of dry oiled silk; in this way the equilibrum of the fluid, in both the glass and the oiled silk, is disturbed; but the conducting power of the hand prevents the development of the effects, and the electricity of the tube only appears. In a similar way, a negative state of electricity is produced in sealing-wax, by rubbing it with dry flannel or fur; the electric state of the sealing-wax being alone evident. Hence it becomes necessary to insulate both the rubber and the body rubbed, if we wish to witness the effects resulting from the two opposite states of electricity in a satisfactory manner; and this mode is adopted in the construction of the cylindrical machines now in use. There are two kinds of machines generally used, each of which has its advantages. The one, commonly called Cuthbertson's, consists of a circular glass plate, turning on an axis passing through its centre. It is excited by two pairs of cushions fixed at opposite points of its periphery by elastic frames of thin mahogany, which are made to press the glass plate between them with any degree of force, by means of regulating screws. A metal conductor (generally of brass) is fixed to the frame of the machine, with its branched extremities opposite to each other, and near the extreme diameter of the plate, in a direction at right angles to the vertrical line of the opposite cushions. The branched extremities of the conductor are furnished with pointed wires, that serve to collect the electricity from the surface of the excited plate. The machine is represented in fig. 10.

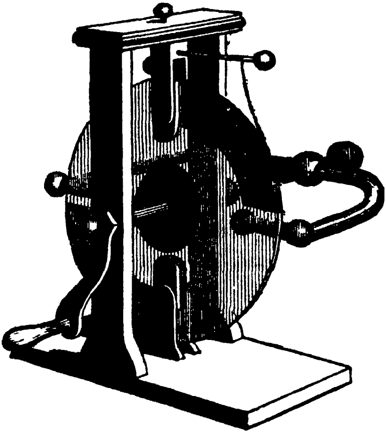

Fig. 10.

Machines of this description have considerable power, and may be constructed on a larger scale than those of other forms. They are to be recommended, therefore, when great electric power is required. One disadvantage attends them, owing to a difficulty that occurs in insulating the rubbers, so that they are seldom constructed so as to exhibit the phenomena of both states of electricity.

Fig. 11 represents the most simple and perfect machine, which consists of a glass cylinder, of from eight to sixteen inches in diameter, and from twelve to twenty-four inches long, turning between two upright pillars of glass, fixed to a stout wooden stand. Two smooth metal conductors are placed parallel to the cylinder, being supported on glass pillars, which are cemented into two separate pieces

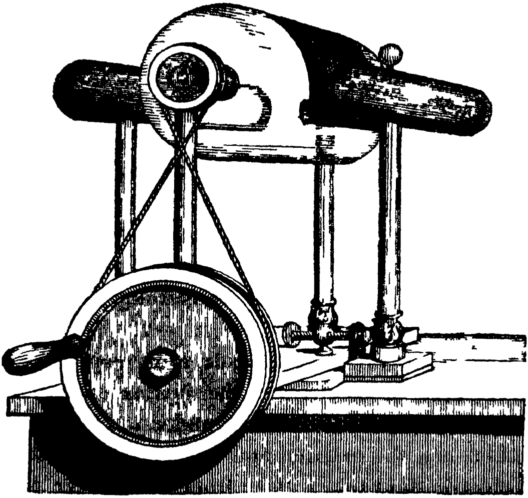

Fig. 11.

of mahogany that slide across the diameter of the base, so as to keep the conductors parallel to the cylinder, while they are brought nearer to, or placed further from it. To one of these conductors is fastened a cushion, by means of a bent metallic spring: to this cushion is attached a flap of silk, which should reach from the cushion, over the upper surface of the glass cylinder, to within about an inch of a row of points that are attached to the side of the opposite conductor. The conductor to which the cushion and silk are attached is termed the *negative conductor*, because it exhibits the electric state of the cushion, which is negative; the opposite conductor collects and exhibits the electricity of the glass cylinder, which, of course, is opposite, and is hence called the *positive conductor*. It is sometimes also termed the *prime* conductor.

The facility with which glass is rendered electrical varies with the exciting substance. Dry silk answers very well, but the most powerful effects are obtained when an amalgam is used, consisting of tin, zinc, and mercury. The amalgam generally recommended is composed of one ounce of tin and two ounces of zinc, mixed with six ounces of mercury, while they are in a state of fusion.

From what we have already said respecting the general laws of electricity, the *modus operandi* of these machines will be readily understood. By friction between the cushion and the glass a transfer of the electric fluid takes place from the former to the latter; the cushion becoming negatively, the glass positively electrified. The fluid which adheres to the glass is carried round by the revolution of the cylinder, its escape being at first prevented by the silk flaps. It is, of course, attracted by the row of points with which the prime conductor is furnished, and thus that conductor becomes surcharged with the fluid, or positively electrified, while the other is *minus*, or negative.

But, if both of these conductors are insulated, there will soon be a limit to this action; for when the cushion and negative conductor have been tô a certain degree exhausted, they cannot by the same exciting force supply a further quantity to the glass. In order to enable them to do so, we must keep up the supply to the cushion. This is usually effected by connecting the negative conductor with the earth, by means of a wire or chain. If, however, we wish to exhibit the phenomena of negative electricity with the same machine, the negative conductor must be kept insulated, and the prime conductor connected with the ground by any conducting body, which conveys the fluid to the earth as soon as it is received from the cylinder. The fluid will thus be drawn without interruption from the negative conductor. The quantity of positive electricity produced, or rather set in motion towards the prime conductor, is precisely equal to that which the cushion loses, for if both conductors are connected by a wire, all electrical appearances cease; but if, instead of being quite connected—if, for instance, the connecting body is not continuous, but interrupted at short intervals—a succession of sparks appears at each interval, indicating the passage of a stream of the electric fluid from the one to the other side of the apparatus.

We shall best learn the mode of application of the electrical apparatus, and at the same time acquire a knowledge of the phenomena produced, by a consideration of various experiments with the different apparatus commonly used by electricians. The first phenomena that claim our attention are attraction and repulsion.

The machine enables us to accumulate considerable quantities of electricity, thus to multiply and extend our observations, and to examine with the greater precision the various phenomena, and test their correspondence with theory. We have already shewn how electrical attractions and repulsions may be produced on a small scale, but the machine enables us to exhibit them in a more striking manner than with the more simple instruments we had previously employed. The experiments formerly mentioned may be repeated with either of the conductors of the machine when electrically excited; and we may now note with greater accuracy the differences in the rapidity with which the changes from one electrical state to the other take place, according as the bodies are more or less perfect conductors. A pith ball, or a fragment of Dutch metal or gold leaf, is very powerfully and instantly attracted by the electrified conductor, and the moment after it has come in contact with it, is repelled; it then becomes attracted by other neighbouring bodies to which it communicates, or from which it takes electricity (according to its state) until its natural quantity is restored: it is then in a state to be again influenced by the conductor, and to be again attracted; and this alternation of effects will continue as long as the electrical excitement is kept up.

These effects are best exhibited by placing light bodies between two circular metallic plates (fig. 12), the one over the other at a certain distance, which must be regulated by the degree of electrical excitement. The upper plate is to be suspended to, or must communicate with, the prime conductor, the lower one with the ground.

If figures of men and women are cut out of paper,

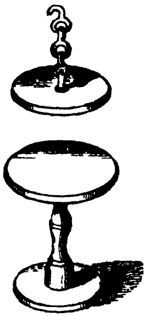

Fig. 12.

or out of the pith of the elder, and placed between the two plates, they will exhibit a rapid dance, as they are alternately attracted between the two plates.

The alternation of attractions and repulsions accompanying the transference of electricity by moveable conductors, is also illustrated by the motions of a ball (fig. 13), suspended by a silk thread,

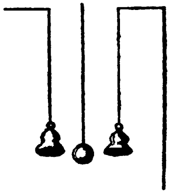

Fig. 13.

and placed between two bells, of which the one is electrified, and the other communicates with the ground. A continued ringing will be kept up by the alternate movements of the ball between the two bells. As thus described, the electrical bell-ringing apparatus is a mere toy; but with some the arrangement has been applied to the very useful purpose of apprizing the observer of changes taking place in the electrical state of the atmosphere.

The mutual repulsion of similarly electrified bodies gives rise to many amusing appearances. The filaments of a feather will start from each other when electrified. A figure in the shape of the head, and covered with hair, when placed upon the conductor and electrified, will exhibit the appearance of terror, from the bristling up and divergence of the hair. A lock of wool, highly charged with electricity, will swell out to a great size, in consequence of the mutual repulsion of the filaments of which it is composed. On bringing a needle near to it, or any other pointed conductor held in the hand, its electricity is quickly drawn off, and it suddenly shrinks to its original size.

While speaking of conductors and non-conductors, it will be remembered that allusion was made to the effects of fusion in rendering some bodies conductors that were naturally non-conductors; this may be shewn with sealing-wax: if melted and electrified, its particles will have a tendency to separate by their mutual repulsion, and to draw out into filaments. Fix a piece of sealing-wax on the end of a wire, set fire to it, and blow the flame out immediately. While the end of the wax is still in a state of fusion, present it, within the distance of a few inches, to the prime conductor; myriads of fine filaments will dart out towards the conductor, to which they will adhere, forming a sort of net-work, resembling wool. These filaments may be received on a sheet of paper, by the following variation of the experiment:—Stick the wire, to which the wax is fastened, in one of the holes of the conductor, and present the paper at a moderate distance from the wax, just after it has been ignited; on setting the machine in motion, a beautiful net-work of wax will be formed on the paper. If the paper is now gently warmed at the fire the wax will adhere to it, and thus exhibit, permanently, the result of the experiment. And it is worthy of remark that there is scarcely an angle to be detected, even although the filaments may extend over the whole surface of the paper. The most beautiful curves are produced. Camphor also exhibits similar appearances. A spoon containing a piece of lighted camphor is to be kept electrified by working the machine, while it communicates with the conductor: the camphor will be thrown out in curious ramifications, which appear to shoot like those of a vegetable*.

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* Mr. Murray some time ago advanced an opinion for which he has met with much undeserved ridicule, and, at the same time, the opinion has not been examined with any degree of fairness. I allude to his idea that the *Aranea æronautica* (the species of spider which floats in the air in such numbers in the autumn), has the power of propelling its threads by means of electricity. The publication of this opinion led him into a controversy with (among others) Mr. Blackwall. I regret that I have not within my reach the whole of the correspondence on the subject; but I copy the following reply of Mr. Murray's from *Loudon's Magazine of Natural History*, vol. iii. p. 189:—

"My devotedness to experimental electricity for the last

It is on the same principle that the motion of liquids and fluids, through a very narrow aperture, is accelerated by electricity. Suspend a metallic

fifteen years *should* certainly, at any rate, have gained for me the requisite qualification for investigations like these; and I therefore cannot cede to an assertion evidently gained through the medium of experiments diligently and carefully conducted. Atmospherical electricity has been with me a favourite study, and I trust it is one in which I find myself in some degree at home; and the employment of Coulomb's tortion balance, with Pregnet's *thermomètre métallique*, has been of essential service to me. Professor Brande has justly concluded that the divergence of the threads of the fasciculi represented in Mr. Bowman's diagram can scarcely be otherwise explained; and a very slight excess of electricity in the excited substance employed as a test for the electric condition of the thread, every electrician knows would defeat the end proposed. Is Mr. Blackwall aware of this, and have his experiments been thus secured? A spider's thread, darted through the air, must necessarily acquire electricity from the friction occasioned by its impulse through that medium; and if propelled *counter* to a current, the amount of electricity will be greater; a thread of glass is excited under such circumstances. Is Mr. Blackwall ignorant that a current of air is an excitant of electricity—a fact long ago proved by Mr. Bennet and other electricians. The air issuing from the nozzle of a pair of common bellows, and directed on the cap of the electroscope, will occasion a divergence of its pendent leaves. Now, Mr. Blackwall should have known all this; and permit me to ask, what connexion is there between heated currents emanating from the earth and an impulse of air, even on Mr. Blackwall's own showing? I am not disposed to yield to Mr. Blackwall in electrical experiment; and those who have witnessed my illustrations vessel, containing water (fig. 14), to the prime conductor. The pipe, *p*, must be of so small a diameter as scarcely to allow the water to drop from the orifice. On the machine being set in motion, the water will flow in a continued stream, and if the cylinder is in good action, will be subdivided into various extremely minute streams.

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of this branch of science will readily, if I mistake not, give me credit for successful and delicate manipulation," &c. At p. 456 of the same vol. of Loudon's Magazine will be found a reply from Mr. Blackwall, wherein he says, "To insist, as Mr. Murray does, that the spiders in question can propel the threads in a right line, *against a stream of air*, is in the highest degree unphilosophical." It certainly is far from unphilosophical on Mr. Murray's part to record *a fact* in support of his opinion, how unaccountable soever that fact may appear to those who have not themselves observed it. I can only attest the correctness of Mr. Murray's statement in this particular, as I have had opportunities of observing this species of spider propelling its threads, sometimes in the direction of the current of air, and sometimes against it. In respect to the observations of Mr. Rennie, in his work *Insect Architecture*, as evidence against Mr. Murray, perhaps it will be recollected that in the same work, besides the slight extract given by Mr. Blackwall, there is also an assertion that these threads are *neither attracted nor repelled* by a stick of excited wax. The only reply to this is—let any person try the experiment. Besides, there is abundant evidence in support of Mr. Murray's opinion: among other naturalists who entertained the same notion may be mentioned White, of Selborne, whose caution and accuracy of observation none will call in question. I have appended this note in consequence of the connexion which this subject has with electrical repulsion, as curious and worthy of investigation.

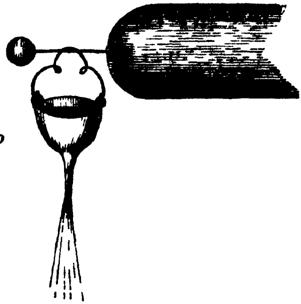

Fig. 14.

If a sponge, saturated with water, is suspended in a similar way, the water will at first only drop gradually from it; but when the conductor has become strongly charged, the drops will fall plentifully, and in the dark will present the appearance of a luminous shower.

A knowledge of this repulsive power has led to the construction of an electrometer for measuring the intensity of the electricity contained by any body with which the instrument may be placed in contact, (fig. 15.) The instrument is termed Henley's elec-

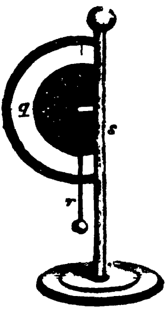

Fig 15.

trometer, from the name of the inventor. It consists of a slender rod of very light wood, *r*, serving as an index, terminated by a pith ball, and suspended from the upper part of a stem of wood, *s*. An ivory *semicircle, or quadrant, g, is fixed to the stem, having its centre coinciding with the axis of motion of the rod, for the purpose of measuring the angle of* deviation from the perpendicular, which the repulsion of the ball from the stem produces in the moveable rod. The number of degrees which is described by the index affords some evidence of the quantity of electricity with which the apparatus is charged, though the instrument cannot be considered an exact measurer of its intensity.

Ere we conclude this chapter, perhaps I may be allowed to add a few observations respecting the phenomena we have been considering. In many instances the recession of light electrified bodies may be satisfactorily accounted for otherwise than by referring such recession to any repulsive power, and may be ascribed to the counter-motion of the fluid. If, for instance, we take two bodies, as A and B, in fig. 16, it is evident that the negative end N, of

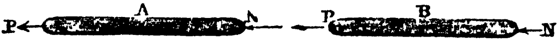

Fig. 16.

either of the bodies, will have a tendency to acquire electricity from the surrounding air, or from any body which it may be near, so that there will be a stream of electricity flowing from N to P; and it is no less evident, that if these two bodies approach, so that these streams may unite, apparent attraction will result. So, if the streams be opposed, apparent repulsion will take place, as in fig. 17.

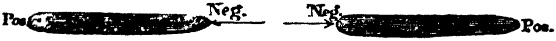

Fig. 17.

Again, this recession may frequently be partly owing to the attraction between the electrified bodies and other surrounding bodies. If it does not, in some degree, depend upon such influence, there is great difficulty in accounting for the recession of negatively electrified bodies. But theoretical discussion is far from the object of this work, and therefore I shall not further enter into the question.

CHAPTER VI.

Of the Transference of Electricity and of Electric Light.

Considerable diversity is observable in the luminous appearances produced by electricity. In order to understand the reason of this, the various forms assumed by the light must be attentively considered, and the circumstances attending their production compared with the general principles of electrical action. And first, we must turn our attention to the condition of bodies during the prevalence of the forces which tend to disturb the electric equilibrium, over those which tend to preserve it. The distribution of electricity on conductors has little or no relation to their solid contents, but depends almost entirely on surface; perhaps, indeed, the action of insulated conductors consists in the ready communication of their electric state to the contiguous particles of the surrounding stratum of air, and to the facility they offer to the discharge of that electrified stratum when an uninsulated or differently electrified body approaches them; every positively electrified conductor being surrounded by a positive atmosphere, and a negative conductor by a negative atmosphere, whose densities increase as the square of their distance. Hence it follows that any insulated electrified body will remain in its electrical state until the intensity of the electricity is such as to overcome the resistance of the air. The interval through which it is then enabled to pass, is usually termed the *striking distance.* Again, it is only a certain proportion of the whole quantity of electricity that thus suddenly escapes, but its passage is marked by many interesting phenomena, indicative of the abruptness and violence with which the transference is effected. A sharp snapping noise is heard, a vivid spark is exhibited, and an evolution of intense heat is frequently evidenced in the line of transmission.

The passage of electricity along a perfect conductor is unattended with light. It appears only when the course of the electric fluid is impeded by imperfect conductors: and such is the velocity of its passage, under such circumstances, that the light is visible at the very same instant along the whole line of its course. This may be illustrated by pasting a row of tin-foil

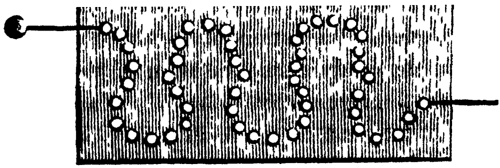

Fig. 18.

discs of a small size on a piece of glass, (fig. (18), and a spark from the prime conductor is sent through the discs by connecting one of the ends of the glass with the conductor, while the other communicates with the earth. It is impossible to detect the least interval of time in the appearance of the light between the various discs. The light may be distributed in every fanciful way by varying the arrangement of the discs.

Even when conducting bodies appear to be in contact, if the experiment is made in the dark a spark is generally seen to pass between them, unless the bodies are pressed together with considerable force. Hence, a chain appears luminous at each link, while electricity is travelling along it.

The most vivid and the largest sparks occur between conductors of a rounded form, and the more so in proportion as those conductors are both portions of spheres of large diameter.

The spark very frequently takes a zig-zag course, presenting an appearance similar to forked lightning (fig. 19.)

Fig. 19.

This irregularity has been ascribed to the influence of minute conducting particles floating in the air, a little removed from the direct line of passage, and to which the fluid darts obliquely in its course*. When the air is either moist or rare, the electric fluid passes with facility, its track being indicated by streams of light; probably occasioned by many parallel series of minute sparks passing from particle to particle.

The electric spark, viewed through a prism, exhibits all the prismatic colours, and is perfectly analogous to the solar light in its power of displaying them separately by the intervention of different media. Dr. Brewster has also proved that the electric light is capable of undergoing polarization, either by its being transmitted through a doubly refracting crystal, by reflection at the proper polarizing angle from a polished plane surface, or by oblique refraction through a series of glass plates.

The brilliancy of the sparks appears to be proportioned to the perfection of the bodies as conductors, between which they pass; hence metals are

* This curious phenomenon demands a greater share of attention than has been usually allotted to it; for it is doubtless owing to the obliquity of the course of the fluid depending on the impediments with which it meets, and the conducting particles that divert it from its course, that the various crystalline forms are produced in minerals. It is probably owing to the same phenomenon that various vegetables shoot in definite directions, and the forms of animals even are, perhaps, dependent on the same action; but more of this in the second part. It was, however, impossible to avoid adverting to the subject in this chapter.

exclusively employed for obtaining sparks, wood and other imperfect conductors producing only faint red streams; yet these substances act as points with some efficacy.

In proportion as the medium is rare, its conducting power increases, and a lower intensity of electricity is required for the production of light. In the ordinary vacuum of the air-pump, the passage of electricity is rendered sensible by streams or columns of diffused light, occasionally varying in their breadth and intensity, and exhibiting motions which give them a marked resemblance to the Aurora Borealis.

We have already stated that the distribution of electricity has little, if any, relation to their solid contents, but depends almost entirely on surface. The same effects are produced by the thinnest cylinder or sphere as by the most compact solid body of the same form and dimensions.

When the conductor presents a uniform surface, the reaction of the circumambient air is also uniform; if the surface of the conductor is irregular, the tendency of the electric fluid to escape will be greatest at the most prominent parts, and this tendency will be greatest when these are angular or pointed. The reason of this is obvious, if we bear in mind what has been stated as to every electrified conductor being surrounded by an atmosphere of its own figure, the contiguous particles of the air being similarly electrified to the conductor. Electricity is only transmitted, in such cases, through the air by the motion of the aerial particles; now, this motion is *resisted* by a uniform surface from the similar action of the air around it, which is all *equally* capable of receiving electricity, and cannot tend to distribute it in one direction more than in another; the electrical atmosphere of the conductor will thus be resisted in any attempt to recede from it by a *column* of air offering uniform resistance in every part; but, if there is any prominent point on the conductor projecting into the atmosphere, the recession of the electrified particles opposite to the projecting part will be facilitated; for they will thus be removed further from the electrified surface, and will be opposed to a greater number of *unelectrified* particles.

Hence, the action of pointed or angular bodies consists in promoting the recession of the particles of rarefied air, by protruding a portion of the electrical atmosphere of the conductor into a situation more exposed to the action of the circumambient unelectrified air, and thereby producing a current of air from the point towards the nearest unelectrified body*. Hence the most *prominent* and the most *pointed* bodies are such as transmit electricity the most readily.

A spherical surface, considered with regard to its surrounding atmosphere, is the most uniform; balls,

* A fact which it is material to bear in mind, when, in the Second Part, we proceed to speak of the electrical actions between distant clouds, or between the clouds and the earth, particularly in the neighbourhood of mountains, elevated buildings, trees, &c.

therefore, or cylinders with rounded ends, are employed for insulated conductors, their magnitude being proportioned to the intensity of the electrical state they are intended to retain; for a point is virtually a ball of indefinite diameter, and will even act as such with very small quantities of electricity; and *vice versâ*, a ball, if very strongly electrified, may be made to act as a point.

If two spheres of equal size are connected together by a long wire, and electrified, their atmospheres will be equi-distant, and they will of course have respectively the same intensity; but if the spheres are of unequal size, the atmosphere of the smaller will extend the further, and it will necessarily have the greater intensity, so that a longer spark can be drawn from a small ball annexed to the side of a conductor, than from the conductor itself, and longer in proportion as the ball projects further from the side. The ratio of electrical intensity has been investigated by Mr. Cavendish, Coulomb, Laplace, and Poisson, accounts of whose results respectively will be fonnd in the *Phil. Trans.* vol. lxi. p. 624, &c., and the *Mémoires de l'Institute*, 1812. The analysis of each involves an hypothesis. It is probable that the intensities are in the inverse ratio of the surfaces, proceeding from a flat surface, where it is least, to a point, where it may be considered as infinite. The finer the point, and the more freely it projects beyond any part of the conductor, the more rapidly it will receive or transmit electricity.

By inserting a fine point in the axis of a large brass ball, from beneath the surface of which it may be protruded more or less by the action of a screw, the effect of a ball of any size may be obtained; when beneath the surface of the ball, the point does not act; but in proportion as it is protruded, it increases the transmitting power, and, if projected far enough, at length entirely overcomes the influence of the ball.

From the probable law of electrical distribution above stated, it follows that the larger any insulated conductor, the electrical charge required to pass through any given striking distance will be the greater. Very different effects are produced with the same electrical machine, when the size of its conductor is varied; hence, also, sparks of the same length, taken from different-sized conductors, must vary in force, as they do in quantity of the electrical fluid. Very long and extended conductors give shorter sparks than those which are compact, but they are sometimes more powerful.

In reference to the action of points, one fact remains to be mentioned, viz.: that a point loses its power of concentrating and dispersing electricity when it is surrounded by other parts of the conducting body which are equally prominent; as, indeed, might have been inferred from what has been said relative to its *modus operandi*. And again, the effect of one point is much diminished even by the vicinity of another point, so that if several points placed near each other are presented to the conductor, the electricity is transferred much less rapidly, and is drawn off in the form of sparks, instead of a continued stream.

When the electric fluid is transferred between smooth surfaces of equal extent, there is no perceptible difference in the appearance of the spark, whatever be the position of the negative surface. But in the passage of electricity by points, the effect is considerably modified by the direction in which the fluid passes. When, for instance, it is escaping from a pointed conductor, the luminous appearance is that of diverging streams, forming what electricians term a *pencil of light*, and resembling the filaments of a brush, (fig. 20.)

Fig. 20.

When, on the contrary, the fluid is entering the pointed body, the light is much more concentrated at the point itself, resembling a *star*, in which, if any streams appear, they are disposed like radii. An approach to these different modifications may be obtained when sparks pass between balls of small diameter, especially if the charge is high. Thus, the direction of the lateral ramifications sent out from the principal line, in the branched spark (fig. 19), is from the positive to the negative body.

All the phenomena relating to electric light are certainly conformable to the idea that they result from material agency, but whether the light evolved is the electric light itself, or whether it is elicited from the various media that transmit it, we shall not now pause to inquire.

CHAPTER VII.

On the Leyden Jar, and the Nature of Electrical Influence.

We have hitherto confined our remarks to excited bodies and insulated conductors, and we have shewn that the form and arrangement of the latter materially influence the appearance of the electricity they convey. When an electrified conductor has its surface *extended,* its intensity is diminished; and as this extension is virtually an exposure to a greater portion of unelectrified air, it might be inferred that a similar effect would be produced by approximating the conductor to the ground, or to any other body of sufficient magnitude, in its natural electric state. Such is found to be the fact. Insulate a flat metal plate, with smooth rounded edges, and connect with it a pith-ball electroscope; electrify the plate either positively or negatively, and the balls will diverge; bring a similar plate, *uninsulated,* near that which is electrified, keeping their flat surfaces parallel and opposite to each other, the balls gradually collapse as the plates approach, and when they are within about half an inch of each other, the insulated plate appears unelectrified; but on the removal of the other plate the original divergence is restored. In this experiment the plates are not brought in contact, and consequently there is no *communication* or *loss* of electricity, but a disposition of the fluid to have its equilibrium restored, the attraction being exerted

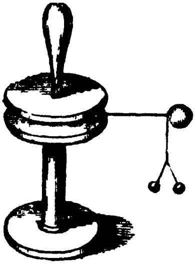

Fig. 21.

solely between the electric fluid and the other plate which communicates with the earth, supposing the insulated plate to be positively electrified. Hence, when the uninsulated plate is removed, the divergence of the balls is restored.

This fact shewing the *diminished intensity* of insulated electrical bodies when opposed to *uninsulated conductors*, supplies a method of increasing the positive and negative states (usually obtained), to a great extent; for it is evident the electrical state of any body may be altered in the greatest degree while it is opposed to a conductor communicating with the ground, since in that situation its electricity will be compensated by the proximity of an exhaustless store, and cannot so soon acquire an intensity which would oppose its further progress; in like manner as the diminished or increased elasticity of the air by rarefaction or condensation, limits the operation of the air-pump and condenser.

Again, as electrical attraction diminishes as the square of the increased distance, the action of this compensating principle will be greater in proportion as the distance of the opposed surfaces is less, provided the transmission of the fluid between them is prevented by some resisting medium. When air is the intervening body, it resists the passage of small quantities of electricity only, owing to the mobility of its particles; glass and Muscovy talc are the most compact of the solid non-conductors that can be reduced to thin laminæ, and these bodies, therefore, afford fit media for such experiments.

If a sheet of glass is placed between two pieces of metal, one of which only is connected with the ground, the insulated plate will have a greater capacity for electrical change than if fully insulated, and may be rendered either positive or negative to a greater extent. The condition of the experiment is the opposition of an insulated to an uninsulated conductor. Its success, therefore, does not depend on the form of the glass, but its thickness, which forms the medium of separation between the two plates. They may be laid on the opposite surfaces of a glass plate, a sphere of the same substance, or a jar; but in either case the glass must extend two or three inches beyond the limit of the metal coatings, that they may be separated by a sufficient interval of air. The middle only of a plate of glass should be covered with metal, leaving an interval of at least two inches all round. A plate thus prepared is termed a *coated* *plate*, and is represented by fig. 22. But the most convenient form is that of a cylindrical jar, coated

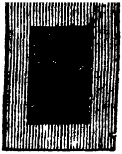

Fig. 22.

inside and outside with tinfoil to within two or three inches of the top edge. The uncoated part must be kept clean and dry. To the inside coating a wire and ball are attached, rising two or three inches above the top of the jar. This is nearly the form of the instrument as it was first used at Leyden. It is termed the *Leyden jar*, or phial, or the *electric jar*. The uncovered portion of glass is termed the *uncoated interval*; the metal inside, the *inner coating*; that on the outside, the *outer*, or *external coating*. It is represented in fig. 23.*

Fig. 23.

* An electrical battery consists of a number of these coated jars, so connected that they can be charged and discharged simultaneously.

Present the knob of the jar to the conductor of the machine within the distance of about half an inch, the jar being held in the hand, the hand grasping the outer coating; a series of sparks will pass from the conductor to the ball of the jar, but will gradually grow weaker, and at last cease. Remove the jar from the conductor, and (its outer coating being still held by one hand) touch the ball of the jar with the other, a smart snap will be heard, and a violent and curious sensation experienced, principally at the wrists, elbows, and across the breasts. This sensation is called the *electric shock;* the effect is momentary, and leaves no permanent impression save that arising from surprise or fear.

To effect a discharge without experiencing the shock, a communication must be made by means of a good conductor between the inner and the outer coatings, the effect just described arising from the different electrical states of these coatings; and as their communication destroys all signs of electricity, they must be positive and negative in an equal degree. The discharge is usually effected by what is termed a *discharging rod* (fig. 24), which consists of two knobbed wires, connected by a joint, like a pair of compasses, and mounted on a glass handle.

To ascertain the degree to which the jar is charged, advantage is taken of Henley's electrometer, or the quadrant electronometer, an instrument which has been already described. The recession of the index from the stem is greatest when it stands at right angles to it, or points horizontally; and having thus moved over the quarter of a circle, it is said to indicate an electrical intensity of 90 degrees.

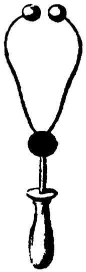

Fig. 24.

The power of the jar, as a source of electrical accumulation, depends on the opposite states of its two surfaces. One of them, therefore, must be in conducting communication with the ground. Suspend a globular jar, (fig. 25) by its knob, from the positive

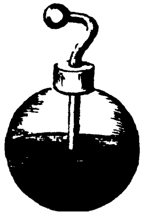

Fig. 25.

conductor; its outer coating being surrounded by the air, a non-conductor, cannot part with any of its natural electricity, and, consequently, if an attempt is made to charge the jar, it will fail, as may be seen by applying the discharging rod to it. For the coatings only serve as conductors to the opposite surfaces of the jar: the glass having an attraction for a *certain quantity* of electricity, which in its natural state is equal on both surfaces, cannot admit of any addition to one surface, without a corresponding diminution of the quantity naturally existing at the other. But if, during the suspension of the jar, the finger is presented to the outer coating, or a chain is suspended from it so as to form a communication with the earth, part of the electricity of the outer surface will then have a means of escape, and the jar will receive a charge. If we take two Leyden jars, of the same size, insulate one of them, and place the other on the table, with its ball at the distance of about half an inch from the outer coating of the insulated jar, the ball of which should be placed at the same distance from the conductor of the machine, we shall find that for every spark that enters the ball of the first jar from the conductor, a similar spark passes from its outer coating to the ball of the second. If they are then successively discharged, the sound of the explosion and the brilliancy of the light will indicate that they had both been charged to the same degree. Now as the second jar was charged by sparks from the outer coating of the first, and as they were equally charged, it follows, that for every particle of electricity *added* to *one side* of coated glass, a corresponding particle *leaves* the *opposite surface.*

On this principle a jar may be charged by the unequal distribution of its own natural electricity. Insulate the jar, and connect its ball with the positive conductor, and its outer coating with the rubber of the machine; the rubber, which is negative, will take electricity from the outer surface, which will be conveyed to the inner surface by the positive conductor. This experiment satisfactorily proves the impermeability of glass to the electric fluid; for the conductor and the rubber of the machine are separated from conducting contact with each other only by the thickness of the glass jar, and a powerful accumulation of electricity takes place, which the contact of the thinnest film of conducting matter, or the slightest fissure in the glass, would have prevented.

Electricity, thus accumulated, may be considered analogous to condensed air, while the negative surface of the jar may represent a vessel of rarefied air. Of course, if a communication is made between two equal vessels, the one containing condensed and the other rarefied air, the fluid will rush from the former to the latter until an equilibrium is attained. So with the electric fluid. No sooner is a conducting communication made between the two surfaces of the jar, than the fluid rushes with violence from the overcharged to the undercharged surface.

The experiments that may be performed with the Leyden jar are endless. But, as it is merely intended to make the reader acquainted with the leading facts of the science, I shall pass on to the description of two other sources of electrical accumulation, viz. the *Electrophorus* and the *Condenser*, whose *modus operandi* depends on the tendency of electrified bodies to produce an unequal distribution of the natural electricity of all such substances as are brought within their inductive influence.

The *Electrophorus* and the *Condenser* were invented by Professor Volta. The former consists of two circular pieces of metal, or of wood covered with tin-foil, and well rounded at the edge: these are called the conductors: between them is placed a resinous plate, formed by melting together equal parts of shell-lac, resin, and Venice turpentine, and pouring the mixture, in a state of fusion, within a tin hoop of the required size, placed on a marble table, from which the plate may be readily separated, when cold. This resinous plate should be about half an inch in thickness. It is sometimes made by pouring the fluid mixture on one of the conductors, which is then formed with a rim for that purpose. The conductor on which the resinous plate is placed is called the lower conductor, or sole; that which is placed upon the resinous plate, the upper conductor, or cover. The latter must be furnished with an insulating handle, consisting of glass, or other good non-conducting substance. And when the electric state of the lower conductor is to be examined, the whole apparatus is placed on an insulating stand. (See fig. 26.) Rub the upper surface of the resinous plate with a piece of dry fur, it will be excited; and if tested by means of the electroscope, it will be found negative. Place the upper conductor upon it, and then raise it by its insulating handle, it will exhibit very feeble, if any, electrical signs. Replace the conductor, and, whilst it lies on the surface of the excited plate, touch it with the

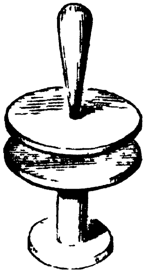

Fig. 26.

finger, or with any other conducting body; raise it again by its insulating handle, and it will now afford a spark, having been positively electrified. Replace it on the resinous plate, again touch it, and raise it, another spark will be procured; and this process may be continued for some considerable time without any apparent diminution of effect.

The real explanation of this experiment is, perhaps, by no means what would be inferred from a superficial view of the phenomena. The resinous plate being a non-conductor, and the imperfect contact with the flat conductor precluding the transmission of electricity of low intensity, they may be considered only as very near each other: now, it has been already shown, that when an *insulated conductor* is brought *near* an electrified body, the natural distribution of its electric fluid is disturbed, and the conductor becomes *oppositely* electrified at the *anterior* surface, and *similarly* electrified at the *posterior* or *remote* surface; hence, the *cover* of the electrophorus, when laid upon the resinous plate, which is *negative*, will have its natural electric fluid determined towards that plate, and it must then also appear negative, and will *receive* electric fluid from any body brought near it. This increased capacity, arising solely from its proximity to the resinous plate, ceases when the cover is raised by its insulating handle; and the additional electricity it has received is then given off in the form of a spark, to the first conducting body that approaches it.

The condenser consists of a small metallic plate, connected with the substance on which the electricity is to be determined, and so contrived that it may be alternately brought near to, and removed from, another plate communicating with the earth. The instrument is frequently connected with the gold leaf electroscope, as represented in fig. 5. The principle on which its action depends is as follows:—The small portion of electricity received by the first plate, from the substance to be tested, acts by induction on the second plate, throwing it into the opposite electrical state: this latter state reacts upon the first plate, increasing its capacity for the electricity which it had at first received, and tends to accumulate a greater quantity in it, which additional quantity it must derive from the substance with which it communicates. The mutual action and reaction continue until an equilibrium is attained.

We have thus taken a cursory view of the various phenomena that include the most important diversities of electrical action. And it must be evident that there is a distinction between the *causes* of the electrical appearance of different insulated conductors; that there are two separate methods of exciting those appearances,—by an actual alteration of the *natural quantity* of the electric fluid the conductors contain, and by its *unequal* distribution in their *proximate* and *remote* parts. Electrical states that are only occasioned by a disturbance in the electrical arrangement, during the proximity of an insulated body to an excited body, only last so long as such proximity continues. Such phenomena are classed under the general term of electrical influence. Some writers term the positive and negative states so produced, the *electricities of approximation or position*, others *electricity by induction.*

CHAPTER VIII.

Of the Motion and Effects, Mechanical and Chemical, of Accumulated Electricity.

ALTHOUGH electricity invariably prefers a direct path, it will pass through the best conductors in preference to bodies of inferior conducting power, although the latter may be so arranged as to offer a less circuitous route; again, when different paths are open for its passage along bodies equal in their conducting power, the electric fluid will always strike, and pass along the shortest. Thus, if we hold a wire between the hands, we may discharge a Leyden jar with the wire, which transmits the whole of the fluid, without our receiving the slightest shock; but, if a piece of dry wood is substituted for the wire, we then experience a shock. The wood is a worse conductor than the body. The charge, therefore, passes through the latter, as being the path that offers the least resistance, although it is the longer of the two. The shock is felt only in the parts situated in the direct line of communication; and if made to pass through a number of persons who join hands, thus forming part of the circuit between the two surfaces of the jar, each will experience the shock in the same manner, and at the same time, the sensation reaching from hand to hand, directly across the breast.

The force of the discharge is weakened, if, for making the discharge, a conductor of great length is employed. But we have no data to justify us in forming an approximation towards a limit to the number of persons through whose nerves even a small charge may be sent, so that all shall feel the shock, as to the distance along which it may be conveyed by good conductors. Inquiries on this point were entered into at a very early period. The Abbé Nollet communicated an electric shock from a small phial to 180 of the King's Guards, and afterwards to the inmates of a convent of Carthusians. The sensation was felt at the same moment by all the persons forming the circuit.

The velocity of the electric fluid has hitherto set all calculation at defiance. Dr. Watson, assisted by some other members of the Royal Society, formed a circuit with iron wires, of upwards of four miles in extent, but the charge required no appreciable time in passing through this extensive circuit. These experiments were made at an early period; at the same time there seems no good reason to doubt their accuracy. Metals, it may be said, oppose some resistance to the passage of the fluid, although they are the best conductors we have: a charge will prefer a short passage, even through air, to a circuit of twenty or thirty feet through thin wire. But, if the surface of the wire had been of sufficient extent to convey the fluid with facility, there can be little doubt it would have preferred the metallic path.

Another experiment was made on Shooter's Hill, at a time when the ground was remarkably dry. The electric fluid was sent along a circuit of four miles, being conducted for two miles along wires supported on baked sticks, and for the other two miles through the dry ground. In this experiment also not an instant elapsed during the restoration of the equilibrium of the fluid.

The first effect of an impediment to the passage of the electric fluid is a retardation of its motion; therefore a conductor of inadequate extent of charge for the transmission of the electricity accumulated, may be viewed in the light of a bad conductor. So, in the case of the small wire mentioned above, the fluid preferred a path through the air, which is a non-conductor when free from moisture. A second effect produced by its being obstructed is a tendency in the fluid to diverge from the direct line of its course, and to strike neighbouring bodies. Lightning affords many examples of this effect. When it strikes a building, its route is frequently very irregular; and the destruction it has caused in various parts of its path, indicate that it had darted towards the various conducting bodies in the vicinity of its passage, injuring or entirely destroying the bodies intervening whose conducting power was less perfect. The position of such conducting bodies has a material influence in determining the striking distance. Dr. Priestley ound that the explosion from a large battery extends to a greater distance over the surface of water than in air alone.

If the charge of a large jar, or of a battery, is rather high, and it is discharged by a wire held in the hand, without the interposition of a glass handle or other insulating matter, it often happens that a shock is felt in the hand that grasps the wires. This effect also depends upon the tendency of the fluid to diverge in consequence of obstruction, although it has been referred by some to a distinct principle, and has been termed the *lateral explosion.* This overflow as it were of the fluid, when rushing through a narrow space barely sufficient to contain it, may be illustrated by the following experiment, mentioned by Dr. Priestley:—A thick metallic rod, R (fig. 27) is insulated on a stand, and placed with

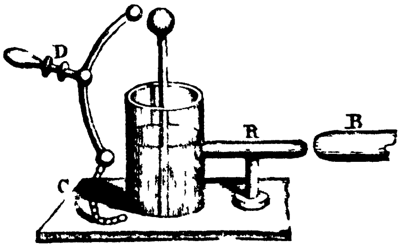

Fig. 27.

one of its ends in contact with the outer coating of a Leyden jar; at the distance of half an inch from its other extremity, place a long conducting body, B, of at least six or seven feet in length, and only a few inches broad. Place a chain, C, on the table, so that one of its ends may be about an inch and a half distant from the outer coating of the jar, and apply one end of the discharging rod, D, to the other extremity of the chain. As soon as the other knob of the discharging rod is made to touch the top of the jar, so as to effect the discharge, a brilliant spark passes between the insulated rod, R, and the adjacent conductor, B. This lateral spark has the same length and brilliancy whether it is received on flat or smooth surfaces, or on sharp points. Dr. Priestley states that this appearance takes place without any apparent change in the electrical conductor, B; and hence it was believed by Cavallo, that the lateral spark was given out by the jar, and returned to it almost at the same instant, allowing no perceptible time for an electroscope to be affected. It was, however, always observed by Dr. Robison, on repeating the experiment, that a very delicate electroscope was affected—an observation which is confirmed by Biot.

With the exception of the phenomena of attraction and repulsion, the simple accumulation of electricity in any quantity in bodies, as long as it remains quiescent, does not appear to produce the least change in their properties. A person standing upon an insulating stool may be charged with any quantity of electricity from a machine without being perceptibly affected, until the equilibrium of the fluid is disturbed by drawing sparks from his body, or from the conductor with which he communicates. It is the mere surface on which electricity is active, the substance of the body being perfectly neutral and inactive. Neither is any perceptible alteration caused in the mechanical properties of a conducting body, as a rod of metal, provided the rod is of sufficient thickness to afford the charge an uninterrupted passage.

When, however, the charge is sent through even a good conductor, whose surface is not of sufficient extent to convey the fluid without impeding its motion, or through an imperfect conductor of considerable extent of surface, violent effects are produced. Thus, an iron conductor, of sufficient size, will carry off the whole of the electricity of a thunder cloud; while a beam of wood, or a tree, would have been rent by the discharge into a thousand fragments. During the passage of electricity, fluids are acted upon with a greater degree of violence than solids; for the cohesive power of the particles of solids may be supposed to oppose greater resisting force to the tendency of electricity to separate them. Thus, the portion of a thermometer tube, filled with mercury, may be shattered by sending the discharge through it. If, again, matter is contained in a tube of much greater diameter than in the preceding experiment, even a moderate charge will be sufficient to shatter the tube. In the former experiment, we used a conductor (mercury) of inadequate surface for the free transmission of the fluid; in the latter, we employed an imperfect, or rather a bad conductor, which, although presenting greater extent of surface, resisted the passage of the electricity. Oil, alcohol, and ether, oppose still greater resistance; consequently, when they are used in similar experiments, the effects of the discharge are still more explosive. If two wires are introduced through holes in the opposite sides of a perforated ball of solid glass of two inches diameter, the ends of the wires being separated by a drop of water, which must occupy the centre of the perforation, on passing a discharge through the wires and the drop the ball will be shattered with great violence. A variety of other experiments of a similar nature might be added. But we shall only instance another, for which we are indebted to Beccaria. He constructed a small mortar with a ball, behind which a drop of water was placed, so as to be between the two wires that passed through the sides of the mortar. The charge being sent through the two wires, the drop of water was expanded with such force as to drive out the ball with great velocity. By using oil, instead of water, the ball is projected with greater force.

The following experiment is brought forward, as affording some indication of the direction which the fluid takes during the discharge of the jar. A varnished card (fig. 28), is to be suspended by silk threads, in such a manner that two blunt wires proceeding from, or in connexion with the two surfaces of a large jar or battery, may be in contact with the opposite sides of the card, but half an inch distant from each other. On the discharge being made, the card will be perforated, and the perforation will invariably occur at the point where the *negative* wire of the battery or jar had touched it; and this, even if

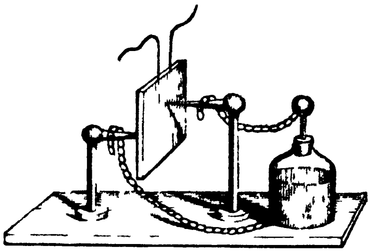

Fig. 28.

a hole had been previously made in the card at the part where it is touched by the positive wire. The course of the fluid is indicated still more plainly, if both sides of the card are coloured with vermilion. A black mark will be observed after the discharge, extending from the point of the positive wire to the perforation, while on the opposite side there will be a diffused black line round the perforation, and next to the negative wire.

These mechanical effects strongly evince the materiality of the electric fluid, whilst the result of the last experiment furnishes us with a fact as to the direction of the fluid from the positive to the negative surface.

The effects of a powerful charge upon metallic bodies are attributable, in some degree, to the evolution of heat produced by the rapidity of the passage of the fluid along them, and partly to the operation of other forces. A piece of metal may, for instance, undergo a permanent alteration in its form, by transmitting through it repeated shocks, which are not powerful enough to effect either its fusion or ignition; and this effect could scarcely be supposed to have resulted solely from heat. Dr. Priestley and Mr. Nairne found that a chain, through which a charge had passed, had undergone a diminution in its length. A piece of hard drawn iron wire, ten inches long, and one hundredth of an inch in diameter, was found, after fifteen discharges, to have lost $1\frac{1}{10}$th inch of its length; and it must have increased in thickness in proportion, for the wire had not lost in weight. A copper wire, plated with silver, of the same dimensions as the former, underwent, by the same treatment, a diminution in length two-thirds as great as that of the iron wire.

If, however, a weight is suspended to the wire, so as to give it considerable tension, the length of the wire becomes increased instead of diminished.

But the chemical effects of electricity are infinitely more remarkable than its mechanical action; and although a consideration of the phenomena of decomposition and recomposition, resulting from the agency of the subtle fluid, comes more legitimately within the scope of the second part of the work, and partly under the head of Galvanic Electricity, it would be improper to pass the subject entirely in silence. The most obvious and simple of these effects of the fluid are generally connected with the production of light and heat. The motion of electricity through air occasions an increase of temperature, as may be observed by placing the bulb of a thermometer between two balls of wood oppositely electrified. Perhaps the suffocating heat we sometimes experience on a summer's evening may be mainly attributable to some electric action of this nature. My friend, Lieutenant Morrison, R. N. of Cheltenham, a most intelligent and accurate observer, and to whose interesting correspondence I am deeply indebted for much valuable information, informs me in one of his communications, that he has sometimes observed the thermometer stand higher at *midnight* than in the middle of the day. Now, if electricity is not concerned in the production of this singular effect, how, otherwise, can it be accounted for?

The spark or explosion, and, indeed, every appearance of electric light, is accompanied by a peculiar smell, which is considered, by some electricians, an indication of a species of combustion; but the continued appearance of the spark in a confined portion of air, in which a limited change only is effected, and the production of the light under the surface of water, are facts totally at variance with such an opinion. The odour is a very peculiar one, and not precisely similar to any that is given out during combustion, under any circumstances*.

* The peculiar smell emitted during the excitation of the electrical machine precisely resembles that which is given out during the decomposition of water by galvanic agency, when the hydrogen gas is allowed, after having filled the tube, to escape into the atmosphere. This similarity of odour may appear of too trifling a nature to be named, but it is cal-

Electricity, in a concentrated state, is capable of inflaming combustible bodies, if passed through a stratum of air in contact with them; and this effect cannot be owing to the direct agency of heat, for if the transmitting conductor is formed of substances that would absorb heat, the same results are obtained. If, for instance, a series of glasses filled with a freezing mixture are employed to transmit the electricity from the conductor to a glass containing water, on the surface of which a little ether is placed, conducting communication being formed with the water by

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culated to give rise to a train of curious reflection. Is there any connexion between the electric fluid and the gases? or, may not electricity, in its various modifications of electricity, galvanism, magnetism, light, and heat, (if, indeed, the three last *are* modifications of the same fluid), may it not be one or more of the gases, in a still more etherial form than that in which they exist as gases? We cannot, it would appear, obtain electricity excepting at the expense of oxygen. We cannot have a *permanent* magnet without the presence of *carbon.* The intense heat capable of being evolved by galvanic agency, and that arising from the combustion of hydrogen and oxygen gases, bear some analogy, as do also the splendid light produced by the action of those gases, when in a state of ignition, on lime. These hints are, of course, only thrown out in order that the subject may be examined by those who have the means to investigate the subject experimentally. One other singular effect may be added, which is, that on the inner surface of a Leyden jar a quantity of moisture frequently becomes condensed, although the jar must have previously been perfectly dry, otherwise it could not have received and retained an intense charge. These are subjects of inquiry that are deserving of attention.

means of a wire, on the knuckle being brought near the ether a spark will pass from the water to the knuckle, and the ether will be inflamed. It is evident, then, that the power of the freezing mixture in absorbing heat, does not interfere with the effect produced.

Dr. Franklin was the first to observe the action of electricity on metals. His experiments were repeated and extended by Kinnersley and Beccaria, and have since been followed up by Mr. Brook, Dr. Van Marum, and Cuthbertson.

A single jar, presenting a coated surface of about 190 square inches, is sufficient for the fusion of iron wire, provided the wire is sufficiently thin. Watch-pendulum wire answers very well. The circuit should be rendered as short as possible, and the wire intended for the experiment placed in a straight line, and confined at the ends between small wire forceps.

Cuthbertson's balance electrometer is almost an indispensable instrument in these experiments to regulate the charge employed for fusing wire of a given size (fig. 29.) It consists of a metal rod, about 13 inches long, terminated by balls, and balanced on a knife-edged centre like a scale-beam. One arm of the balance rod is graduated, and has a slider upon it, which, when placed at different distances from its fulcrum, loads the arm with a proportionate weight from one grain to sixty. The graduated extremity of the balance rests upon a similar brass ball, which is supported by a bent metal tube from the same insulating stand; and at four inches below the opposite extremity another insulated ball is placed, which is to be connected with a jar or battery. If a connexion is made between the metallic support of the

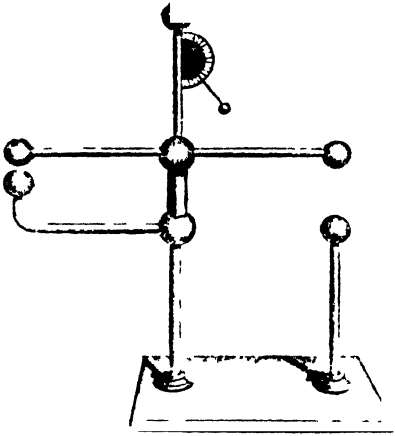

Fig 29.

balance and the conductor, or the inner coating of the jar, and the latter is electrified, attraction will take place between the extremity of the balance and the lower insulated ball, they being connected respectively with the opposite surfaces of the jar. Of course, when the force of the attraction exceeds the weight with which the opposite arm is loaded, the attracted arm will descend, and the electricity will be discharged on the lower ball. The attractive power is always proportioned to the intensity of the charge; and, as the attraction has to overcome a resistance proportioned to the weight that loads the balance, that weight becomes a proper comparative measure of the intensity of the charge. It is convenient to surmount this instrument with the quadrant electrometer, as represented in the figure. The latter instrument indicates the *progress* of the charge, which, of course, cannot be pointed out by the balance electrometer.

The power of electricity in fusing metallic wires, is *equally* increased by *doubling* the *extent* of *coated surface*, or the *height* to which the jar or battery is *charged*. *Two* jars, charged to a certain degree, will melt *four* times the length of wire that is fused by *one*, and the effect will be again *quadrupled* by *doubling* the height of the charge. Cuthbertson's batteries usually contain fifteen jars, and one of the jars will just fuse half an inch of iron wire of $\frac{1}{150}$ of an inch diameter; but the whole battery will fuse sixty inches of the same wire. There are circumstances which materially influence this law of the proportion of igniting power, one of which is, the different thickness of the glass in different jars. Thick jars will display the same intensity with a comparatively small quantity of electricity, and consequently possess less fusing power. Mr. Cavendish, indeed, has stated that the quantity of electricity required to charge different coated jars of the same extent, will be in the inverse proportion of their thickness*.

Since, then, any given quantity of electricity will fuse the same extent of wire, the fusing power may be employed as a measurer of the quantity accumulated on any charged surface. Electroscopes and elec-

* Phil. Trans. vol. lxvi. p. 196, &c.

trometers indicate only the intensity, being equally affected by one jar as by a battery of twenty. When, however, the foregoing test is employed, the length of the circuit should always be the same, and the degrees of ignition uniform. The lowest degree of perfect ignition should be obtained in comparative experiments; as soon as the discharge is made, the wire should become red hot in its whole length, and then fall into balls.

Curious effects are obtained by a gradual increase of the power of the charge, when wires of the same length and diameter are employed. If the wire is iron or steel, it first appears of a yellow colour: increase the charges, it changes to blue; by another increase it becomes red hot; and if we proceed with a still higher charge, it fuses into balls. If we still increase the charge, it becomes red hot, drops into balls, then disperses in a shower of balls, and last of all disappears with a bright flash, accompanied by an apparent smoke, which, if collected, is found to be a very fine powder. In short this powder is an oxide of the metal.

The changes produced in the metals by exposure to heat, with free access of air, have been observed from a very early period; but, until the discovery of a peculiar gas by Dr. Priestley, the nature of those changes was not understood. This gas, which is termed *oxygen*, constitutes a fifth part of our atmosphere, and is absorbed by metals when they lose their metallic appearance. Hence, the earth-like powders which result from the combustion of the metals are termed *oxides*. The red lead of commerce is an oxide of lead; the crocus an oxide of iron; putty powder an oxide of tin. Metals differ greatly in their disposition to become oxidated. Platina, gold, and silver, do not undergo this change when exposed to heat; they are therefore converted into oxides by other means; but all metals yield under the powerful influence of the electric fluid, and are made to combine with oxygen. A large battery is necessary for the oxidation of metals, a greater power being required than that which is merely capable of fusing them. Again, different metals require charges of different powers. The following table shews the results as regards the extent of the charge, in a series of experiments by Mr. Cuthbertson. The column A contains the diameter of the wires in parts of an inch; B, the number of grains with which the electronometer was loaded; and C, the colour of the oxide. In each experiment the extent of coated surface was the same, and the length of wire was ten inches, the battery being composed of fifteen jars, presenting about seventeen feet of coated surface.

	A.	B.	C.
Lead wire	$\frac{1}{90}$	20	Light grey.
Tin wire	$\frac{1}{90}$	30	Nearly white.
Zinc wire	$\frac{1}{90}$	45	Nearly white.
Iron wire	$\frac{1}{150}$	35	Reddish brown.
Copper wire	$\frac{1}{150}$	35	Purple brown.
Platina wire	$\frac{1}{150}$	35	Black.
Silver wire	$\frac{1}{150}$	40	Black.
Gold wire	$\frac{1}{150}$	40	Brownish purple.

Mr. Cuthbertson employed high charges, which occasion a risk of fracture to the jars; but if shorter and finer wires are used, a moderate charge is sufficient. The proportions are indicated according to the preceding rule in the following table, which is taken from Singer's Elements of Electricity. The length of wire exploded in each experiment was five inches.

	A.	*Colours of the Oxides on Paper.*
Gold wire	$\frac{1}{180}$	Purple and brown.
Silver wire	$\frac{1}{130}$	Grey, brown, and green.
Platina wire	$\frac{1}{160}$	Grey and light brown.
Copper wire	$\frac{1}{100}$	Green, yellow, and brown.
Iron wire	$\frac{1}{190}$	Light brown.
Tin wire	$\frac{1}{180}$	Yellow and grey.
Zinc wire	$\frac{1}{180}$	Dark brown.
Lead wire	$\frac{1}{160}$	Brown and blue grey.
Brass wire	$\frac{1}{160}$	Purple and brown.

Singer observed, that the oxides of metals produced by electricity appear to consist of several distinct portions of different degrees of fineness. When a wire is exploded in a receiver, part of the oxide immediately falls to the bottom, but another portion remains suspended in the air for some time, and is at length gradually deposited. Perhaps this circumstance may partly account for the different colours of oxides produced in close receivers and in the open air, for in the latter case a portion of the oxide is always lost. There can be little doubt that various degrees of oxidation are produced at the same time by electricity.

But this subtle fluid exerts also another influence, the very reverse of that which we have been considering. By its agency the metallic oxides may again be restored to the metallic state. Let a little oxide of tin be inclosed in a glass tube, so that when the tube is horizontal the powder may cover about half an inch of its lower internal surface. Place the tube on the table of the universal discharger (fig. 30),

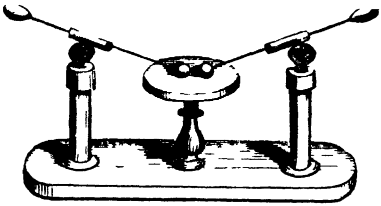

Fig. 30.

and having unscrewed the knobs, introduce the pointed wires into its opposite ends, that the portion of oxide may lie between them. Pass several strong successive charges through the tube, replacing the oxide in its situation, if it should be dispersed. If the charges are sufficiently powerful, a part of the tube will soon be stained with metallic tin, which been revived by the agency of the transmitted electricity. If vermilion is employed in the place of the oxide of tin, it will be resolved into its elements, mercury and sulphur, and with such facility, that the charge of a moderate-sized jar is sufficient: and the mercury and sulphur may again be made to combine, re-forming vermillion.

It were needless to multiply instances of this chemical power of electricity, as we shall have occasion to recur to it, under the head of Galvanism, and also in Part II. Water may be decomposed, and its elements, hydrogen and oxygen, made to combine, forming water; atmospheric air has been converted into nitric acid or aquafortis*; atmospheric air and hydrogen gas into water, and azote or nitrogen; chlorine and hydrogen into muriatic (hydro-chloric) acid, &c. &c.

The influence of the electric fluid on light is also remarkable. Place a piece of dry chalk on the table of the universal discharger, and adjust the wires on its surface, with their ends at two inches distance from each other. Pass a strong charge between the wires, and after the explosion a streak of light will be evident in the track of the discharge, exhibiting the prismatic colours: the appearance will continue for some seconds.

Singer gives the following table of substances that may thus be rendered phosphorescent, with the colour of the light:—

Native sulphate of barytes............	Bright green light.
Native carbonate of barytes	Ditto, less brilliant.
Acetate of potass (dry)	Brilliant green.
Succinic acid	Ditto, and more durable.
Loaf sugar	Ditto.

* It may be necessary to state for the information of the non-chemical reader, that the air which we breathe and nitric acid are composed of the same elements, viz. nitrogen or azote, and oxygen, but in different proportions.

Specular gypsum, or selenite.........	Ditto, transient.
Calcined oyster shells	Prismatic colours.
Oyster shells, calcined with sulphur.	Durable, and bright light.
Rock crystal	Light, first red then white.
Quartz	Dull white light.
Borax...................................	Faint green light.
Boracic acid............................	Bright green light.

(See Skrimshire's papers in Nicholson's Journal.)

The effect of an electric explosion on some opaque bodies is also remarkable. Fit two wires into a groove on the surface of a piece of smooth mahogany, so that by sliding the wires backwards or forwards their ends may be placed at any required distance from each other. When they are about half an inch apart, place a thumb over the interval, and pass a charge between the wires; the thumb will appear perfectly transparent during the passage of the spark.

Arrange five or six eggs in a straight line, and in contact with each other; pass a small charge through them, and they will appear luminous.

These experiments may be varied by using different substances that are not good conductors.

CHAPTER IX.

Of the effects of Electricity on Animals and Vegetables.

THERE are few persons in the present day who are not more or less familiar with the peculiar sensations excited in the body by the electric shock. The sensations and the effects are alike momentary. Imagination, indeed, is apt to exert its influence on many persons who may be made the subjects of experiment, and fear and wonder may frequently operate in eliciting from them the most ridiculous and exaggerated statements of their feelings. Few persons would be tempted to try the effect of the discharge of the Leyden jar, if they gave credit to the marvellous accounts that were given by the philosophers who first made the experiment. Muschenbroek tells us that he received so dreadful a concussion in the arms, shoulder, and heart, that he lost his breath, and that two days elapsed before he could recover from its effects; declaring, also, that he should not be induced to take another shock for the whole kingdom of France. Mr. Allemand reports, that the shock deprived him of breath for some minutes, and left so acute a pain in the right arm, that he was apprehensive it might be attended with serious consequences. Mr. Winkler amazes us by speaking of convulsions of his whole body, and of such a "ferment in his blood," as would have thrown him into a fever but for the timely employment of febrifuge remedies. At another time, he states that it produced copious bleeding at the nose, and that the same effect was produced upon his lady, who was almost rendered incapable of walking.

But we now know that none of these extraordinary effects are produced, and that the marvellous consequences described by these early experimentalists must have been owing considerably to the influence of the imagination.

The shock is often more sensibly felt at the joints than in any other part of a limb. The probable explanation of this is, that it is at the parts where the continuity of substance is interrupted by the joints that the electric fluid meets with the greatest resistance in passing from the surface of one bone to the other. But if the shock is directed more immediately through muscles, the effect that results is an involuntary convulsive action of those muscles. This frequently takes place in a paralysed limb, although the nerves are at the time incapable of conveying the impressions that produce sensation. According to Mr. Morgan, if the diaphragm is included in the circuit of a coated surface of two feet, fully charged, the sudden contraction of the muscles of respiration will act so violently on the air in the lungs as to occasion a loud and involuntary shout; but if the charge is slight, a fit of convulsive laughter is produced.

The nerves, however, are principally affected, but as the effects produced will be noticed more particularly hereafter, we shall not now dwell upon the subject.

There are several facts connected with the destruction of life by electricity that must not be passed over. The body rapidly undergoes putrefaction, and the action of electricity on the flesh of animals is found to accelerate this process in a remarkable degree. Another fact is, that the blood does not coagulate after death from lightning.

At one period, electricity was had recourse to as a remedy in a number of diseases. But medical practitioners have now fallen into the opposite extreme, this remedy being seldom employed, except in a very few diseases. It is used in palsy, contractions of the limbs, rheumatism, St. Vitus's dance, some kinds of deafness, and impaired vision. My own experience justifies me in stating, that the importance of electricity as a remedy in many diseases is very much underrated. In cases of paralysis, and in obstinate and painful swellings, the consequence of old sprains, its employment is frequently attended with results the most gratifying.

But there is yet much to be done ere the importance of electricity in this respect can be fully appreciated. In many cases much will depend on the *direction* in which the shock is sent through the affected part, much on the form in which it is employed, and a great deal on the proper regulating of the amount of the charge in particular cases—conditions which experience only can teach us to attain.

There are different ways of administering electricity. The most gentle is that in which a wire, or pointed piece of wood, is used in connexion with the prime conductor, and held by an insulating handle at a little distance from the affected part. The sensation produced is agreeable, and resembles that experienced from a current of cool air; indeed, there is a current of air constantly streaming from every electrified point, whether that point is in a positive or a negative state of electricity, dry air conducting only through the medium of the mobility of its particles. Another mode is that of taking sparks from a person, by placing him on an insulated stool, and connecting him with the prime conductor by means of a chain or wire, or by giving sparks to him by connecting him with the negative conductor. Another way is by discharging the Leyden jar through the diseased part,—a method which, it need scarcely be observed, requires great caution and discrimination, and I should venture to suggest, that perhaps more depends on the direction of the charge than on its intensity. Another mode is by *galvanism,* and a fifth by the *magneto-electric machine,* the effects and the mode of applying which will be touched upon under those respective heads.

In reference to the effects of electricity upon vegetables, considerable discordance of opinion prevails, and I regret that on this point I cannot do more than give my authorities in support of the opinion that electricity exercises a decided influence on vegetables; for I have not enjoyed any opportunities in London of experimenting on this subject. It affords an ample, and it may be said, a fertile field for inquiry, and is well worthy of the attention of those whose means enable them to combine the luxury of a garden with the comforts of their abodes.

Although Dr. Ingenhouz, upon the most accurate inquiry, is stated to have found that the vegetation of plants was in no sensible degree either promoted or retarded by electricity, the results of the experiments, and the opinions of other inquirers, are entitled to some degree of credit, in support of an opposite opinion. From the experiments of Van Marum, we find that the evaporation of plants is increased by electricity; but still, as he himself observes, the effect may have been owing to the increased current of air from the parts of the electrified leaves. Granting this, the cause of that increased current was electricity.

The first experiments on record as to the effects of electricity on vegetables were those of Mr. Maimbray, in 1746, in the month of October. It appeared that two myrtle trees that had been electrified, put forth their leaves earlier in the subsequent spring than others which had not been subjected to electrical influence. The Abbé Nollet supposed he had verified these results, and his experiments were repeated and varied by MM. Jallabert, Boze, the Abbé Menon, Dr. Carmoy, the Abbé D'Ormoy, and the Abbé Bertholon, who all conceived that they had found electricity to produce beneficial results upon the growth of living vegetables.

Whatever difference of opinion, however, prevails on this point, there is but one on the effect of a shock discharged through a living vegetable. Those parts through which the fluid has passed invariably die. And Cavallo mentions what a slight shock is sufficient to kill the balsam (*Impatiens*). The plants of this genus are not remarkably delicate, require little care in their culture, their stocks and branches are thick in proportion to the size of the plant, and they bear with impunity the inclemency of the weather; yet a very small shock sent through the stem of a balsam is sufficient to deprive it of life. A few minutes after it has received the shock the plant droops, the leaves and branches become flaccid, and in short its vegetation is quite destroyed. I have, indeed, known some plants of that species which have revived after a day or two, but that effect seldom takes place. A small Leyden phial, such as may contain six or eight square inches of coated surface, is sufficient for this purpose; and it may even be effected by means of strong sparks from the prime conductor of a large electrical machine.

"In this experiment, neither the internal vessels nor any other part of the plant seem to be injured; and, indeed, the size of the plant, and the inconsiderable strength of the shock which is used, are such as not to indicate the possibility of the vessels being burst, or of the vegetable organization suffering any material derangement; it would therefore be useful to investigate the immediate cause of the death of the plant.

"Having subjected several other plants to the action of electric sparks and shocks, I have not found that any can be so materially hurt by an electric power so small in proportion to its size, as that which is sufficient to destroy the vegetation of a balsam."—*Cavallo*, vol. iii. page 249.

The general conclusion arrived at by all the authors I have had an opportunity of consulting is, that feeble electricity exerts no perceptible influence on vegetable life; but its more violent effects are similar in their destructive nature to those produced by lightning.

Perhaps one cause of the discordant results that have been obtained by different experimentalists in reference to the effects of electricity on vegetables, may arise from the different means they employed in subjecting the plants to electrical influence. For it need scarcely be observed, that the mode of conducting an experiment has considerable influence over the result. For my own part, if I may presume to express an opinion, I should say that some purpose must have been intended by Nature to be fulfilled by the good *conducting power* of living vegetables; and the probability is, that electricity exercises considerable influence over the economy of vegetables. But this subject will be again considered in the Second Part of the work.

CHAPTER X.

The identity of Electricity and Lightning; Conductors for Buildings and Ships, &c.

It is commonly stated that this portion of our subject appertains more especially to the science of meteorology; but I trust the day is not far distant when it will be universally acknowledged that meteorology, as well as chemistry, are merely branches of the science of electricity. For it must be admitted that so long as meteorologists follow their favourite pursuit apart from electricity, the results of their investigations will never prove of any great practical utility, how interesting soever may be the facts they may be enabled to lay before us.

The importance of the study of atmospheric electricity cannot be too urgently enforced on the reader's attention. Convinced as I am of its importance, I can only regret that a more able pen than mine has not been wielded in its cause—that some one better qualified to command attention, has not sooner aroused the curiosity of scientific inquirers, and thus induced them to enter upon and pursue a path that will lead them to results which I feel confident will tend to the amelioration of "many of the thousand ills that flesh is heir to."

In the Second Part of the work it will be shown that there is some peculiar condition of the air which exercises a remarkable influence over animals and plants, and that the influence so exerted depends on the electrical state of the atmosphere. And, as the facts with which we have been made acquainted by various scientific men will be subsequently adduced, we need only for the present direct our attention to the experiments that have established as a fact the identity of that species of artificial electricity we have been considering, with lightning, and the phenomena that usually accompany a thunder-storm.

The analogy between the electric spark, and more especially of the explosion of an electric jar, with atmospheric lightning and thunder, was too striking to have escaped the notice even of the early electricians. Wall and Gray observed it, and the Abbé Nollet still more pointedly.

At length, Dr. Franklin, impressed as he was with the many points of resemblance, determined to ascertain, by one of the boldest experiments that mortal could conceive, the truth of his conjecture. A spire that was erecting at Philadelphia, he thought might assist him in this inquiry; but, while awaiting its completion, the sight of a boy's kite, which had been raised for amusement, immediately suggested to him a more ready method of attaining his object. "Preparing, therefore, a large silk handkerchief, and two cross sticks of a proper length on which to extend it, he took the opportunity of the first approaching thunder-storm, to take a walk into a field, in which there was a shed convenient for his purpose. But, dreading the ridicule which too commonly attends unsuccessful attempts in science, he communicated his intended experiment to no one except his son, who assisted him in raising his kite.

"The kite being raised, a considerable time elapsed before there was any appearance of its being electrified. One very promising cloud had passed over without producing any effect; when, at length, just as he was beginning to despair of his success, he observed some loose threads of the hempen string to stand erect, and to avoid one another, just as if they had been suspended on a common conductor. Struck with this appearance, he immediately presented his knuckle to the key, and (let the reader judge of the exquisite pleasure he must have felt at that moment) the discovery was complete. He perceived a very evident electric spark. Overcome with the emotion inspired by this decisive evidence of the great discovery he had achieved, he heaved a deep sigh, and, conscious of an immortal name, felt that he could have been content if that moment had been his last." He had pierced the bosom of the cloud, and called forth from the heavens to the earth the spirit of the storm. The rain now fell in torrents, and the string becoming perfectly wet, increased its conducting power, so that electric sparks could be collected from it in great abundance. With these sparks spirits were inflamed, phials charged, and the usual electrical experiments performed; and thus the discovery that electricity and lightning were identical, was established as a scientific truth.

About a month before Franklin had made these successful trials, some philosophers, in particular Dalibard and De Lors, had obtained similar results in France, by following the plan recommended by Franklin. But the glory of the discovery is universally given to Franklin, as it was from his suggestions that the methods of attaining it were originally derived.

For the purpose of making perpetual observations, Dr. Franklin afterwards placed on the top of his house an insulated rod, connected with two bells and a pendulum, so arranged as to give notice by their ringing when the apparatus was electrified.

Various philosophers in different countries repeated these experiments. Amongst others, M. de Romas, in France, constructed a kite seven feet high and three feet wide, and raised it to the height of 550 feet, by a string having a wire interwoven through its whole length. From the string of this kite streams of the electric fluid, an inch in diameter, and ten feet long, darted to the earth.

It is not to be wondered at that such experiments were not constantly conducted with security. Whilst experimenting with artificial electricity, the inquirer frequently receives an unexpected shock; and the first experimentalists on atmospherical electricity, either through incaution, or owing to the ill-contrived arrangement of the apparatus, frequently experienced narrow escapes. One fatal accident is recorded as having happened to Professor Richman, of Petersburg. His apparatus was entirely insulated, and had no contrivance for discharging the accumulated fluid. On the 6th of August, 1753, he was examining the electricity of his apparatus, in company with a friend. Whilst attending to an experiment, his head accidentally approached the insulated rod, and a flash of lightning immediately darted from it through his body, and instantaneously deprived him of life. A red spot was left on his forehead, his shoe was burst open, and part of his waistcoat singed; his companion was benumbed, and rendered senseless for some time; the door-case of the room was split, and the door torn from its hinges*.

Great caution is therefore requisite in these experiments, and security is only to be attained by placing a metal rod, connected with the earth, or with the nearest water, at a small distance from the insulated rod. By this arrangement, when the electricity accumulates to a certain degree, it passes the interval between the rods, and is conducted to the earth. But, with any arrangement of the apparatus, it is not advisable that any person who is not well versed in electrical experiments, should risk his life, by thus experimenting on the electricity of the atmosphere.

The identity of the electric fluid and lightning having been thus proved, Dr. Franklin next directed his attention towards the practical utility

* *Phil. Trans.* vol. xlviii. p. 765.—*Priestley's History of Electricity*, (quarto), p. 358.

of the discovery. He proposed to erect a perfectly continuous metallic rod by the side of any building, in order to secure it from the effects of lightning; the rod was to be pointed at each extremity, and to reach above the highest part of the building, and below its foundation, the lower extremity being connected with the nearest water, or other conducting matter. In this way a metallic circuit is provided, through which the electric fluid would pass more readily than through the detached or imperfect conductors of which the building is constructed. Experience has fully proved the utility of this proposed method, and it is now frequently adopted in situations where the chance of injury from thunder-storms is thought to be considerable. There are various contrivances to illustrate experimentally the utility of lightning conductors. A model of a powder-mill may be blown up, or a house set on fire, by making an interrupted circuit, and placing gun-powder, or other combustible matter, within them. A moveable conductor is usually attached to these models: when this conductor is fixed to the model, the charge of a jar or battery produces no effect; but if the conductor is removed, the charge passing through the interrupted circuit, the combustible matter is inflamed. To exemplify the method of defending ships, a small model is to be made, with a glass tube for the mast. In this tube two wires are to be inserted through its opposite ends, until within half an inch of each other. The tube is then to be filled with water, and the ends stopped. Connect the lower wire with a small metal thread tied to the stern. The upper wire is to be surmounted by a brass ball, which may serve as the top of the mast. A moveable conductor may be formed of a thin copper wire placed parallel with, and rising above the mast. This wire is to be connected at the bottom with the metal thread. If a powerful charge is passed along the mast when the conductor is attached, no effect is produced; but if the conductor is removed, the mast is shattered to pieces. If the conductors in these experiments are pointed, it is very difficult to make the charge pass with an explosion, the fluid generally being either transmitted silently, or with considerably diminished force. Hence the necessity of all lightning conductors having pointed extremities. Another material point to be attended to is the perfect continuity of the conductor, and its connexion with a considerable mass of conducting matter, as water, water pipes, or a moist stratum of earth.

There are on record two instances of houses having been struck by lightning, and damaged, although they were furnished with conductors. Even if those conductors had been perfect, (which is extremely doubtful), these two solitary exceptions, amongst thousands of cases in which conductors have been used, cannot for a moment be considered as an objection to their utility.

For the protection of ships, chains, made of a series of iron rods linked together, have generally been used. But no electrician would recommend the employment of these conductors, nor, indeed, of any that are not perfectly continuous throughout their whole length. The best contrivance that I have seen is that of Martyn J. Roberts, Esq. It is simple, presents a large extent of surface, is perfectly continuous, and flexible, the last of which properties is essential in a lightning conductor for a ship. The reader will perfectly understand its construction, when informed that it is a wire cable. The only objection that occurs to me is the danger ensuing from the wire becoming corroded, by which its conducting power would be interfered with. However, the same objection equally applies to all the conductors that I have seen. Singer suggests that, independent of the protection required for the mast of a ship, it would be expedient to surround the deck with a strip of metal, which should be connected with the copper bottom; or, if the ship is not coppered, the strip should be continued over the bottom or side of the keel, and be connected with others embracing the sides of the ship. The conductors for the masts are to be connected with these metallic slips.

Lightning conductors for powder magazines are sometimes placed at a short distance from the building. Although there does not appear to be any necessity to have them detached from the building, when this method is adopted, the conductors should rise at least eight or ten feet above the highest part of the magazine, and penetrate to as great an extent below its foundation.

When a building is struck by lightning, the discharge is most frequently determined towards the chimney. This is owing, in the first instance, to its elevation, and in some degree it is said to be attributable to the conducting power of hot air. Of the latter influence we may be allowed to be a little sceptical, for the chimney is struck when there is no fire in the stove with which it communicates. A more probable cause is the conducting power of the carbon deposited in the chimney; for it may be experimentally proved, that over a surface of carbon the electric fluid will pass with facility to a considerable distance.

Carriages are usually surrounded by metal; and if there is metallic communication between the "fillets," the inside of a covered carriage may be considered a place of comparative security during a thunder-storm.

Suggestions have been given by different writers, as to the precautions necessary to ensure perfect safety during a thunder-storm. And although some of the opinions on this point are discordant, there are others in which all electricians appear to coincide; such as, that, in the open air, shelter should not be taken below a building or tree: the distance of twenty or thirty feet from trees and buildings may be considered an eligible situation; for, should a discharge occur, the most elevated bodies are the most likely to receive the fluid. It is also essential to avoid proximity to a considerable mass of water, or even the streamlets that may have had their origin from a recent shower.

When lightning enters a house, it usually directs its course along the appendages of the walls and partitions. Hence, the most secure situation is in the middle of the room; and the person may be considered still more secure, if he is in a horizontal position, particularly if he reclines on a hair mattress, or sofa, or even on a thick woollen hearth-rug. It is generally stated that the place of greatest security is the cellar, or, if there is no cellar, the lowest story of the house. But it ought to be remembered that the discharge as frequently (indeed, perhaps, in the greater number of instances) takes place from the earth to the clouds, and not from the clouds to the earth; and many instances are on record in which the basement story was the only part of a building that sustained material injury, the electric fluid being divided, and, consequently, weakened, as it ascended. But whatever situation is chosen, any approach to the fire-place should be particularly avoided, since, as has been already stated, the chimney is very likely to determine the course of the fluid. The same caution is necessary with respect to gilded furniture, bell-wires, and surfaces of metal of every description, even of moderate extent. I believe these opinions, in some respects, are at variance with those of that accomplished electrician, Mr. Snow Harris, of Plymouth, who has recently delivered a course of lectures on the subject of lightning conductors, at the rooms of the United Service Club. I had not the pleasure to hear those lectures, and therefore cannot give my readers an account of the opinions of that gentleman—opinions which, proceeding, as they do, from one so deeply conversant with electrical science, are deserving of the greatest attention and deference.

After all, it must be admitted that much remains to be learned, ere we can acquire such a control over this subtle element, as to enable us to effect the one-thousandth part of the practical good which I am convinced will ultimately be attained, after an addition shall have been made to our knowledge of its nature, and of its various accompanying phenomena.

CHAPTER XI.

Of the Phenomena of Thunder-Storms—Atmospherical Electricity, &c. &c.

—— " By conflicting winds together dash'd,
The thunder holds his black tremendous throne,
From cloud to cloud the rending lightnings rage :
Till, in the furious elemental war
Dissolv'd, the whole precipitated mass
Unbroken floods and solid torrents pours."

THOMSON.

EXPERIMENT, then, as we have shown, has proved the identity of electricity with the phenomena of lightning and thunder. The spark, and its attendant report on the discharge of a jar or battery, are effects precisely analogous to those produced by a flash of lightning. There is, indeed, a variety of sound which characterizes the latter phenomenon, which has been ascribed to reverberation from different objects ; but I am inclined to believe, that, although this may be true in some instances, in others it is owing to the zig-zag course in which the electric fluid frequently darts, and during which the lightning will be at various distances from the places at which the resulting concussion of the air can be heard. This will sufficiently account for that inequality of loudness in a peal of thunder which we so frequently hear.

We derive data for calculating the distance at which the explosion has taken place, from the intervals between the flashes and the thunder; for light moves with such velocity that, so far as its motion is concerned, any ordinary distance need not be taken into account. Sound, however, travels only at the rate of 1142 feet in a second; consequently, the interval in seconds that elapses between the flash and the report, multiplied by 1142, will give the observer, in feet, the distance of the explosion. Suppose the flash of lightning to be seen, and we count six seconds before we hear the thunder, $1142 \times 6 = 6852$ feet, the distance from us at which the explosion has taken place. But, although one explosion may take place at this distance, the very next discharge may occur very near to us; for thunder clouds frequently extend over a considerable extent of country, and two, or even a greater number of flashes, are sometimes seen in distant points in the atmosphere nearly at the same time.

We have already described the zig-zag form of the electric spark when powerful, and compelled to traverse a considerable portion of air. In atmospheric electricity the flash sometimes traverses an immense interval, and becomes divided in the same manner as a powerful spark produced with the apparatus. The appearance of two streams, at apparently a little distance from each other, is sometimes produced, when part of a long zig-zag is concealed by an intervening cloud; and some electricians state that the sudden universal flash, commonly called sheet-lightning, results from the reflection of an explosion which is more completely concealed, and that of the last kind are also those bright flashes that sometimes occur on summer evenings, unaccompanied by thunder; but this admits of considerable doubt; for, where the striking distance between two clouds is of limited extent, compared with the intensity of the accumulated fluid, the discharge will take place at once, in a body or sheet of fire, as it were. It is also probable that what is termed "summer" or "silent lightning," is owing to a discharge that takes place in regions of the air at too great a distance for the sound to reach us.

Many of the flashes during a storm are discharges between the clouds, the only danger, of course, arising when explosions occur between the earth and the clouds; and, comparatively speaking, the instances in which the earth is struck are rare. Probably, in some cases, the opinion of Morgan is correct, that when the lightning strikes the earth, the latter may merely act as a discharging rod to shorten the striking interval between two oppositely-electrified clouds.

We have before adduced experiments to prove that, during both the evaporation and the condensation of liquids, the electric equilibrium is disturbed, and the fluid thrown into an active state; that change, or inequality of temperature, friction, and the contact of dissimilar bodies, also produce the same effects. Clouds experience, in succession, the operation of all these causes. That electrical changes in the atmosphere are connected with its hygrometric state, is obvious from a consideration of all the phenomena, as will be evident from the following facts adduced by Singer, *Elements of Electricity*, p. 239:—

"1st. The electrical phenomena of the atmosphere take place in all climates, to the greatest extent, during, or near to, the period of greatest heat, when the influence of the sun's rays has occasioned a considerable accumulation of vapour.

"2d. Where this cause operates to the greatest extent, as in the countries within the tropics, these natural electrical phenomena are produced on a scale of the most tremendous magnitude.

"3d. When the natural source of evaporation is assisted by collateral causes, electrical changes occur with astonishing rapidity. The eruption of a volcano is almost constantly attended by vivid lightning; and the regions that surround the extensive sands of Africa, where the action of the sun's rays is assisted by reflection from an arid soil, are remarkable for violent storms and tempests; the air, heated by its passage over these sands, producing a rapid evaporation of the first moisture it meets, and becoming thereby so loaded as to occasion copious showers on any sudden diminution of temperature.

"4th. By the action of winds, currents of air of different temperatures are mixed; and such as have been heated and charged with moisture are suddenly cooled: by this process water is precipitated, and electrical changes almost constantly occur; such are the hurricanes and the terrific lightnings produced by the *harmattan* on the coast of Guinea, when it comes in contact with the cool air on the surface of the ocean; and such are also the electrical phenomena of all ranges of high mountains, for they occasion a condensation of the moisture in heated winds that pass over their frozen summits; hence the magnificent lightnings of the Cordilleras, and the coruscations of the Alps.

"5th. Electrical changes are, in every situation, most frequent when the causes of evaporation and condensation suddenly succeed each other. Those who have made regular observations on the electricity of the atmosphere, have always observed the greatest diversity when a rapid succession of rain and sunshine occurs; and such variable weather is also the most frequently attended by thunder-storms. Even the diurnal changes of heat and cold produce a perceptible effect on the atmospherical electricity: for, according to Mr. Read's observations, it is most obvious during the morning and evening dew, and weakest in the intervals."

M. De Luc's observations tend to overthrow the principal hypotheses that have been advanced to account for the production of atmospherical electricity. For the ideas of that excellent meteorologist the reader may consult the "*Idées sur la Météorologie*," and the various papers by De Luc, in the "*Philosophical Transactions*," and "*Nicholson's Journal*."

The labours of M. De Luc prove that we still remain unacquainted with the nature of the process by which the apparent circulation of water through the atmosphere is effected*. "Evaporation will go on for months, and the air appear dry, and driest in its upper strata where the ascending vapours are supposed to pass: and in a stratum of this kind, where there is no evidence of any adequate quantity of moisture, clouds will suddenly form and produce violent rain, accompanied by thunder and lightning, frequently of long duration. Nor are these clouds produced by any sudden condensation, for the heat of the clouds themselves is sometimes greater than that of the air by which they are surrounded."—(*De Luc, sur la Météorologie*, vol. ii. p. 100). And clouds that have been formed in the day frequently disappear at night, when, from the increased condensation, their continuance or increase might have been expected.

It is most probable that some electrical change occurs prior to any alteration in the hygrometric condition of the air, and that, indeed, the latter is de-

* It has been calculated that about 5,280 millions of tons of water are probably evaporated from the surface of the Mediterranean Sea in one summer's day.—(*Cavallo's Nat. Phil.* vol. ii. p. 490). And a more recent estimate considers the mean evaporation from the whole earth as equal to a column of 35 inches from every inch of its surface in a year, which gives 94,450 cubic miles of water as the quantity that circulates through the atmosphere annually.—(*Thompson's Chemistry*, vol. iv. p. 78.—*Manchester Memoirs*, vol. v. p. 360.)

pendent upon the former. There are many individuals who experience peculiar nervous sensations at the approach of a thunder-storm long before the formation of a single cloud, or before there is any perceptible alteration in the air. Their common expression is, "I do not feel well; I am sure there is thunder in the air." And this I have frequently known to occur the day *previous* to the storm, and sometimes even two days preceding.

Besides the extensive changes in the electrical state of the air that occasion the sublime phenomena of thunder-storms, regular diurnal variations take place, evincing, as indeed all natural phenomena do evince, their subserviency to the direction of SUPREME POWER and INTELLIGENCE.

But these regular fluctuations will be noticed more fully when we proceed to the consideration of the probable cause of epidemic diseases.

CHAPTER XII.

Of the Electricity of Animals, &c.

From what has been said respecting electrical phenomena, and the various means of producing them, it might be conjectured that some degree and species of electrical excitation is a constant attendant upon animal, and, indeed, also vegetable life. Although we now possess instruments of great delicacy, they are still insufficient to detect its presence under all circumstances, so that we cannot yet demonstrate its beneficial or injurious influence upon the economy of animated beings. But, by means of a delicate gold-leaf electroscope, the electricity of the human body may at times be observed. In addition to the electricity developed in the human frame, which seems to be entirely independent of volition, and which may possibly arise partly from mechanical causes, and partly during the various chemical actions occurring in the frame, there is a series of regular phenomena discovered to exist in the animal kingdom, by which some of its inferior orders of beings are enabled to defend themselves from the attacks of their enemies, or to overpower the prey which is destined for their support. These facts, and those relating to the electricity of plants, we shall examine in the following order:—

1. Electricity of the Human Body.
2. Electricity of the Raia Torpedo.
3. Electricity of the Gymnotus Electricus.
4. Electricity of Plants.

1. *Electricity of the Human Body.*

The excitation that arises from the friction of articles of dress upon the human body, cannot in all instances be distinguished from that which is produced by less obvious causes. On this account, and for greater convenience in referring to the original memoirs, a short abstract of our information on these subjects will be given, without attempting to separate the one kind of action from the other.

A memoir on this subject was published in the *Transactions of the Electrical Society of Manheim*, by J. J. Hemmer, who has collected the following instances of the electricity of the human frame.

Virgil speaks of a harmless flame which was emitted by the hair of Ascanius:—

> Ecce levis summo de vertice visus Iuli
> Fundere lumen apex, tactuque innoxia molli
> Lambere flamma comas, et circum tempora pasci.
> Nos pavidi trepidare metu, crinemque flagrantem
> Excutere, et sanctos restinguere fontibus ignes.
>
> Æn. Lib. II. v. 582.

It is related by ancient authors that streams of fire issued from the hair of Servius Tullius, the Roman king, during sleep, when he was about seven years of age.—(Dionysius, *Antiq. Rom.* Lib. IV.) And Pliny says, "*Hominum quoque capita vespertinis horis stellæ magno præsagio circumfulgent.*"—(Hist. Nat. Lib. II. cap. 37.)

It is mentioned by Cardan, that the hair of a Carmelite monk emitted sparks whenever it was rubbed backwards.—(Lib. VIII. De Rerum Variet. cap. xliii.) Father Faber, in his *Palladium Chemicum*, speaks of a young woman from whose head sparks of fire always fell when she combed her hair. Franciscus Guidas produced bright flames from his body, when he rubbed his arm with his hand as he lay in bed. —(Bartholinus, *De Luce Animalium*, Lugd. 1647, p. 121.)

It is related by Ezekiel di Castro, a physician of Verona, of Cassandra Buri, a lady of that place, that, as often as she touched her body, even in a slight manner, with a linen cloth, it emitted sparks in great abundance, which were attended with a considerable noise, and could be perceived by every person near her.—(Castro, *De Igne Lambente.*)

Beccaria describes the following instance, related to him by Vandania: "For ten or twelve days past, since the cold set in, I wear between two shirts a piece of beaver's skin. Always when I pull off my upper shirt at night, I observe that it adheres in some degree to the piece of skin; and when I draw my shirt from it I see sparks which have a striking resemblance to those of electricity. Scarcely do I begin to pull off the piece of skin, when I find that it adheres, and with still greater force, to the undershirt. On taking it out I observe, when I hold it in the right hand, that the frill of my shirt moves up from my body towards it. If I remove the piece of skin to a greater distance, and draw it from the frill, the latter moves again towards my body. If I bring the piece of skin nearer, the shirt moves again towards it. This oscillation of my shirt between my body and the piece of skin continues till it is gradually lessened, and at length ceases."

These instances appear to be all referable to electricity produced by friction. It appears to be clearly proved that there exist certain predisposing causes in some persons, which render them more suitable subjects for experiments of this kind than others are.

M. de Saussure inferred that some degree of bodily motion was necessary to the excitement of his electricity. For this reason, and because he could not perceive any signs of electrical excitation when undressed, he concluded that the electricity resulted from the friction of the body against the clothing. He also states that it is necessary that the clothes should be of the same temperature as the body; for when he had on clothes that were cold, he could never obtain the least trace of electricity; neither could he when the body was in a state of perspiration The electricity developed was sometimes positive and sometimes negative; the cause of which variation he was unable to discover.

In my own experiments, these variations from positive to negative, and *vice versâ,* were sometimes rapid, at other times they took place more slowly, and occasionally I could not obtain the least sign of either a positive or a negative state of electricity.

From the long series of experiments by Hemmer, it appears that the electric excitation of the human body varies not only in different persons, but in the same person at different times; being, in many on whom he experimented, weak, in others strong, in some positive, in others negative. He also was unable to trace the cause of these variations. In 2422 experiments upon himself, 1252 shewed positive electricity, 771 negative, and in 399 there was no evidence of any excitation. In 94 experiments upon his maid, the signs were 19 times positive, 33 negative, and 42, 0.

It also appeared that in a quiescent state of the body the electricity was most frequently positive; that cold either caused a change from positive to negative, or at least diminished the intensity of the electricity, and that lassitude produced the same effect. This animal electricity is stronger in winter than in summer, and is impeded by perspiration. Here is an apparent contradiction of what was remarked of the effects of cold; but the diminution during summer is doubtless owing to the increased perspiratory action. It further appears from M.

Hemmer's experiments, that bodily action is not necessary to its development; that it does not depend upon the "motion of respiration," and that it cannot be attributed to the friction of the clothes; for M. Hemmer says, "my experiments leave no doubt upon this subject, as I found the electricity of my own body lively and durable for half an hour, or an hour, when I had not any clothes on. I do not say, however, that the friction does not increase it."—(Hemmer, *Trans. of the Electrical Society of Manheim*, vol. vi.; or *Phil Mag.* 1799, vol. v. p. 1 and 40.)

We now proceed to the consideration of instances of animal electricity, in which the fluid appears to be under the regulation of the will.

2. *The Electricity of the Raia Torpedo*

was known at a very early period, and accounts of its properties are to be found in the writings of Pliny, Appian, and others. In the *Experimenta circa res diversas Naturales* of Redi, published in 1678, are mentioned the imperfect observations of fishermen upon the properties of this animal. Lorenzini, about the same time, published an account of its anatomical structure, with illustrative engravings.

In 1702, Kæmpfer, in his *Amœnitas Exoticæ*, describes his experiments on the Torpedo. One singular circumstance might be doubted, if it had not been confirmed by the accurate observations of Mr. Walsh, viz. that any person, by holding his breath at the time he touched the animal, might avoid all sen sation of the shock.

The first suspicions that the cause of the shock from the torpedo is electrical, are to be found in Dr. Bancroft's *Natural History of Guiana*; but until the appearance of the valuable papers of Mr. Walsh, in the *Phil. Trans.* for 1773 and 1775, little was effected towards the proof of this fact. He placed a living torpedo upon a wet napkin, and formed a communication through five persons, all of whom were insulated. The person at one extremity touched some water in which a wire proceeding from the wet napkin terminated; the last person in the series having a similar mode of communication with a wire which at intervals could be brought in contact with the back of the animal. In this manner shocks were communicated to the five, and afterwards to eight persons. From the general result it appears that, as in the case of common electricity, glass, and other insulating, or non-conducting bodies, intercepted the shock, whilst metals and other conductors transmitted it. Walsh did not, however, succeed in affecting the electroscope, or in obtaining a spark by the electricity of the torpedo. Mr. Walsh, holding a large and powerful specimen in both hands, and grasping the electric organs above and below, plunged it a foot beneath the surface of some water, and again raised it an equal height in the air. The moment the lower surface of the torpedo touched the water in descending, he always gave a violent shock; a still more powerful one was produced at the instant that the same surface emerged from the water in ascending. Both these shocks were attended by a contortion of the body, as if the animal was anxious to make its escape. The intensity of the shock under water was scarcely one-fourth of that at the surface, and not much more than one-fourth of those given in the air. *The number of shocks appeared to be about twenty in a minute.*

The shock, in general, was not perceptible beyond the finger with which it was touched; and out of 200 shocks Mr. Walsh experienced one only which affected him above the elbow. If the torpedo was insulated, it was able to give forty or fifty shocks without any diminution of force, to persons who were also insulated. Whenever the animal gives a shock its eyes are depressed, and thus Mr. Walsh was enabled to tell, by observing the eyes, when the animal attempted to make an electrical discharge, even upon non-conducting bodies.

Other interesting experiments were made by Mr. Walsh, which it is unnecessary to detail.

Dr. Ingenhauz, in 1773, made numerous experiments at Leghorn, on the torpedo. Sometimes the shock was slight, and at other times so powerful as almost to oblige him to quit his hold of the animal.

Spallanzani also experimented upon the torpedo. He found that the shock was more powerful when the animal was laid upon a plate of glass; and states, that on irritating the torpedo, he invariably obtained the shock, whether the animal was in or out of the water. He also found that some minutes before the torpedo expired, the shocks were not given at intervals, as in the healthy state of the animal, but wer changed into a reiterated succession of small shocks. During a space of seven minutes of this action his fingers experienced 316 shocks; there was then an interruption, and the animal, immediately before it died, gave a few very slight shocks. But the most curious discovery of Spallanzani on this subject, was, that even the fœtus of the torpedo possessed the same electrical property before it was born.

The experiments of MM. Humboldt and Gay Lussac, on the electric irritability of the torpedo, are important. They were made in 1805; and the following is a succinct account of the results obtained:—

1.—"A person much in the habit of receiving electric shocks, can support, with some difficulty, the shock of a vigorous torpedo fourteen inches long. The action of the fish below water is not perceptible, and is not felt until it is raised above the surface of the water.

2.—"Before each shock, the animal moves its pectoral fins in a convulsive manner, and the violence of the shock is always proportional to the surface of contact.

3.—"The organs of the torpedo cannot be discharged by us at our pleasure, nor does it always communicate a shock when touched. It must be irritated before it gives the shock, and in all probability it does not keep its electrical organs charged. It charges them, however, with extraordinary quickness, and therefore is capable of giving a long series of shocks.

4.—"The shock is experienced when a single finger is applied to a single surface of the electric organs, or when the two hands are placed one on the upper and one on the under surface at the same time, and in both these cases the shock is equally communicated, whether the person is insulated or not.

5.—"If an insulated person touches the torpedo with the finger, it must be in immediate contact, as no shock is received if the animal is touched with a key, or any other conducting body.

6.—"The torpedo being placed upon a metallic plate, so that the inferior surface of its electrical organ touched the metal, the hand that supported the plate felt no shock, although the animal was irritated by another insulated person, and when it was obvious, from the convulsive motions of its pectoral fins, that it was in a state of powerful action.

7.—"If, on the contrary, a person supports with his left hand the torpedo placed on a metallic plate, and touches with his right hand the upper surface of the electric organ, a violent commotion will be felt in both his arms at the same instant.

8.—"A similar shock will be received if the fish is placed between two metallic plates, the edges of which do not touch, and if a person applies a hand to each plate at the same instant.

9.—"If, under the circumstances of the preceding experiments, there is a connexion between the edges of the two plates, no shock will be experienced, as a communication is now formed between the two surfaces of the organ.

10.—"The organs of the torpedo do not affect the most delicate electrometer. Every method of communicating a charge to the condenser of Volta was tried in vain.

11.—"A circle of connexion being formed by a number of persons, between the upper and under surfaces of the organs, they received no shock until their hands were moistened in water. The shock was equally felt when two persons who had their right hand applied to the torpedo, instead of taking hold of each other's left hands, plunged a piece of metal into a drop of water placed upon an insulated body.

12.—"By substituting flame in place of a drop of water, no sensation was experienced until the two pointed pieces of metal came in contact with the flame.

13.—"No shock will be experienced, either in air or below water, unless the body of the fish is immediately touched. The torpedo is unable to communicate its shock through a layer of water, however thin.

14.—"The least injury to the brain of this animal prevents its electrical action."

For a detail of the anatomical structure of this curious fish, the reader is referred to the paper of the celebrated Hunter, published in the *Phil. Trans.* for 1773.

One part of it, however, is so important, that we shall extract it.

"The nerves," Hunter states, "inserted into each electric organ, arise by three very large trunks from the lateral and posterior parts of the brain. The first of these, in its passage outwards, turns round a cartilage of the cranium, and sends a few branches to the first gill and to the anterior part of the head, and then passes into the organ towards its anterior extremity. The second trunk enters the gills between the first and second openings, and after furnishing it with small branches, passes into the organ near the middle. The third trunk, after leaving the skull, divides into two branches, which pass to the electric organ through the gills; one between the second and third openings, the other between the third and fourth, giving small branches to the gill itself. These nerves having entered the organs, ramify in every direction between the columns, and send in small branches on each partition, where they are lost.

"The magnitude and the number of the nerves bestowed on these organs, in proportion to their size, must, on reflection, appear as extraordinary as the phenomena they afford. Nerves are given to parts either for sensation or action. Now if we except the more important senses of seeing, hearing, smelling, and tasting, which do not belong to the electric organs, there is no part, even of the most perfect animal, which, in proportion to its size, is so liberally supplied with nerves; nor do the nerves seem necessary for any sensation which can be supposed to *belong to the electric organs. And, with respect to action, there is no part of any animal with which I am acquainted, however strong and constant its natural actions may be, which has so great a proportion of nerves. If it be, then, probable that these nerves are not necessary for the purposes of sensation or action, may we not conclude that they are subservient to the formation, collection, or management of the electric fluid, especially as it appears evident, from Mr. Walsh's experiments, that the will of the animal does absolutely control the electric powers of its body, which must depend upon the energy of the nerves."*

By a recent examination, M. Geoffroy St. Hilaire has been enabled to bear testimony to the accuracy of Hunter's description. He states that a similar organic structure is found in other animals of the Raia genus. which, nevertheless, do not manifest any electrical powers.

Mr. Cavendish constructed an artificial torpedo of wood, connected with glass tubes and wires, and covered with a piece of sheep-skin leather. To render the effect of this instrument more like that of the animal, with regard to the difference in the shock in and out of water, it was necessary to substitute thick leather in the place of the wood, and with this improvement the apparatus succeeded admirably. In air, the sensation of the shock was experienced at the elbows, but under water it was confined chiefly to the hands. On touching this artificial torpedo with one hand under water, a shock was obtained as powerful as if it had been touched by both hands. Being touched under water with two metallic spoons, it gave no shock, but in air the shock was very strong. Cavendish also made an estimate between the strength of his artificial torpedo and that dissected by Hunter, with reference to surface. His own battery consisted of seventy-six feet of coated surface; and he calculated that the animal retained a charge fourteen times as great as that of the battery, or was equivalent to 1064 feet of coated glass.

It appeared singular that from the fish neither sound, nor spark, nor attraction, could by any means be made manifest. Mr. Cavendish was led to examine the effect of distributing a given quantity of electricity over a great extent of surface. He con sidered that the distance to which the spark will fly is, inversely, in rather a greater proportion than the square root of the number of jars. With reference to attraction and repulsion, Cavendish found, that in a large battery so weakly electrified that its charge will not pass through a chain, a pair of pith balls suspended from the discharging rod, do not exhibit any divergence. At the same time, in reference to the spark, as the electricity of the torpedo is undoubtedly that modification of the fluid termed galvanism, the experiments of Mr. Cavendish were not sufficiently analogous to enable us to form any conclusion from their results.

In 1814 and 1815, when Sir H. Davy was on the shores of the Mediterranean, he wished to ascertain whether the electricity of the torpedo possessed the chemical and magnetic powers of that agent. He could not decompose water, nor did he influence a highly delicate magnetic electroscope. And he seemed disposed to infer that there is a stronger analogy between the common and artificial electricity than between the former and Voltaic electricity, and that it is probable animal electricity may be found to be of a peculiar and distinctive kind.

Ill health prevented this eminent philosopher from pursuing these inquiries; but in his last illness he requested his brother, Dr. John Davy, to carry on the investigation. He accordingly pursued the inquiry at Malta, and obtained several important results. He placed a needle, perfectly free from magnetism, within a fine copper spiral wire, $1\frac{1}{2}$ inch long and $1\frac{1}{10}$th of an inch in diameter, containing about 180 convolutions, and weighing about $4\frac{1}{2}$ grains. By the electricity of a torpedo about six inches long, he succeeded in communicating distinct magnetism to this needle; and he repeated the experiment with the same success with fishes of different sizes. Dr. Davy also succeeded in throwing into violent motion the needle of a magnetic multiplier. With every fish he tried he obtained decisive results, and he met with no instance of a fish, which had the power of magnetizing a needle in the spiral wire, failing to move the needle in the multiplier, though he met with examples of fish whose electricity was equal to the latter effect and not to the former. Dr. Davy, however, failed in obtaining any igniting power, or the faintest spark, by means of the torpedo. He also found that air was not impermeable to the electricity of the fish; but he never could affect the electroscope, or obtain any indications of attraction and repulsion in air.

On the chemical agency of this species of electricity, Dr. Davy's experiments were highly satisfactory. He decomposed strong solutions of common salt, nitrate of silver, and superacetate of lead; and he inferred that the *under* surface of the organ corresponds to the zinc, and the upper surface to the copper extremity, of the Voltaic battery. In the deflection of the needle also the action of the under surface corresponded with the zinc; that of the upper surface to the copper plate. The extremity of a needle that received polarity from a torpedo, had *southern* polarity when it was nearest the *under* surface of the fish, and the other extremity northern. In one experiment, Dr. Davy connected the spiral with the multiplier; and having placed within the former eight needles, a single discharge from an active fish moved the needle in the multiplier powerfully, and converted all the needles into magnets, each of them as powerful as if it only had been used.

3. *Electricity of the Gymnotus Electricus.*

M. Richer was the first who made public the electrical properties of this fish, which is sometimes called the Electrical Eel of Surinam. The experiments that have been made on this animal are numerous, and exceedingly curious; but not more so than are the hypotheses which writers and naturalists have advanced upon the subject.

Redi supposed its properties to be owing to the emanation of a subtle but substantial effluvium, which, entering within the pores of other animals, produced by its accumulation the shock. Schilling ascribed the influence to magnetism, and makes mention of certain experiments in which the loadstone and fish seemed to produce an influence on each other. This, at all events, was a shrewd conjecture; and if Schilling was not deceived in the experiments he mentions, it would be interesting to repeat them, now that we have obtained a glimpse of the connexion between electricity and magnetism. But to proceed to the phenomena of the electrical eel:—by touching it with one hand a shock is felt in the fingers, the wrist, and the elbow; but by making the contact with an iron rod twelve inches long, the shock was perceptible in the finger and thumb only by which the rod was held.

The hand of one person being held in water at the distance of three feet from the animal, upon a person irritating the eel, the former will receive a shock, but less violent than if he touched the animal itself.

Dr. Williamson placed a cat-fish in the same vessel of water with the eel, and then dipped his own hand in the water. The gymnotus swam up to the fish, but turned away without offering any violence to it. It soon returned, and after regarding the cat-fish attentively for some seconds, gave it a shock which made it turn up its belly and continue motionless. The shock was perceptible to Dr. Williamson at the same time. Whenever fish that had thus been rendered motionless were removed to another vessel they recovered.

By irritating the gymnotus with one hand, and holding the other at some distance in the water, a shock was felt in both arms like that of the Leyden jar. A similar effect was produced by touching the water with a wet stick, irritating the animal with the other hand as before Two persons, by joining hands, shared in the effects of this experiment as with an electrical jar.

When one of two persons joining hands touched the head roughly, while the other touched the tail gently, they both received a severe shock.

The connexion between two persons was formed by different substances, such as charcoal, brass, iron, dry wood, glass, silk, &c.; and it was invariably found that the shock was conveyed through those substances that conduct common electricity, while it was not transmitted through non-conductors. The shock was not conveyed by a brass chain, unless the chain was stretched, or the shock severe.

An insulated person, being electrified by the eel, exhibited no signs of electricity: the cork balls of the electroscope did not diverge when suspended by silk threads over the eel's back, or when touched by the insulated person when he received the shock.

Dr. Williamson was unsuccessful in his attempts to obtain the spark. Mr. Walsh, however, it is said, succeeded in performing this experiment by making a minute separation in a piece of foil between two plates of glass, on the principle of the luminous word; but we are not aware that the experiment has been verified.

Dr. Williamson concludes that the effect is solely dependent upon the will of the animal, and that even the magnitude of the shock also depends, within certain limits, upon some act of volition on the part of the fish: that the electric discharge is not at all due to any muscular action in the animal, but upon some process purely electrical.

M. Humboldt, in his *Travels in South America*, describes a singular method of catching the gymnoti, by driving wild horses into a lake which abounds with them. The fish become wearied and exhausted* by their efforts against the horses, and are then taken; but such is the violence of the shocks which they give,

* This exhaustion of the gymnotus, occasioned by repeated discharges of the electric fluid, adds considerable weight to the opinion advanced in the Second Part, respecting the "nervous fluid," or the "nervous principle," being dependent upon electricity. If exercise is too violent in its nature, or too long continued, a degree of exhaustion is produced that sometimes induces febrile symptoms. What can be the cause of fatigue? It must be owing to the loss of a material something which supplied the nerves connected with the various muscles that were brought into play. Another fact which strongly corroborates this opinion is, that after violent exercise, if any effect at all is produced on the electroscope, it indicates a negative state of the body.

that some of the horses are drowned before they can recover from the paralysing shocks of the eels. He also states, that in giving the most powerful shocks, the gymnotus does not make any motion of the head, eyes, or fins, like the torpedo.

Gymnoti are described of different sizes. One examined by Hunter was not three feet long. Another is described by Dr. Garden, which was three feet eight inches in length; and Dr. Bancroft, when in Guiana, was told of some having been seen in the Surinam river upwards of twenty feet in length, the shock of which was instantly fatal.

Upon dissection, Hunter found that the electrical organs of the gymnotus occupy nearly one-half of that part of the flesh in which they are placed, and constitute probably more than one-third part of the whole fish. There are two pairs of electrical organs of different sizes, and placed on different sides. One large organ occupies the whole of the lower end and the lateral part of the body, constituting the thickness of the fore part of the animal, and stretching from the abdomen to near the end of the tail, where it terminates almost in a point. The two organs are separated at the upper part by the muscles at the back, at the middle by the air-bag, and at the lower part by the middle partition. The smaller organ extends along the lower edge of the animal, almost as far as the other, terminating almost insensibly near the end of the tail. The two organs are separated from each other by the middle muscle, and by the bones in which the fins are articulated. In order to perceive the large organ, it is necessary merely to remove the skin which adheres to it by a loose cellular membrane; but in order to perceive the small organ, we must remove the long row of small muscles which move the fin. The organs consist of two parts, viz. flat partitions or septæ, and cross divisions between them. These septæ are very thin and tender membranes, placed parallel to one another; they stretch in the direction of the length of the fish, and having their breadth nearly equal to the semi-diameter of the animal's body. The length of the septæ differs, some being as long as the whole body. The distances between the septæ vary with the size of the fishes. In one, two feet four inches long, their distance was nearly half an inch; and in the broadest part of the organ, which was an inch and a quarter, there were thirty-four septæ. The small organ has the same kind of septæ, but they stretch in a direction somewhat serpentine: their distance is only about $\frac{1}{36}$th part of an inch; and in the breadth of the organ, which is half an inch, there are fourteen septæ. Hunter considers that the septæ answer the same purpose as the columns of the torpedo, forming walls or abutments for the subdivisions, and constituting so many distinct organs. These septæ are intersected transversely by very thin plates or membranes, whose breadth is the distance between any two septæ, and therefore differs in different parts; broadest at the edge which is next the skin, and narrowest at that edge next to the centre of the body or to the middle partition which divides the two organs. The lengths of these membranes are equal to the breadths of the septæ, between which they are situate; and there is a regular series of them, from one end of any two septæ to the other end. In one inch there were 240 of these transverse membranes.

Besides the torpedo and the gymnotus, there are others of the finny tribe that possess similar electrical properties; but they have not yet been sufficiently examined.

Among other electrical fish which have been described, may be named the *Silurus electricus*, the *Trichiurus indicus*, and the *Tetrodon electricus*.

The larvæ of some insects are also said to be capable of giving a perceptible shock; also a species of Scolopendra, hence called the *Scolopendra electrica*.

The Silunus electricus has been described by Broussonet, in the "Hist. de l'Académie Royale des Sciences," for 1782, and is but imperfectly known.

4. *Electricity of Vegetables.*

Previous to the researches of M. Pouillet, Mr. Read seems to be the only author who had made any distinct statement respecting the electricity of vegetables. From several experiments, he had concluded that "vegetable putrefaction" is always in a negative state of electricity, while the surrounding atmosphere is positive. It is to M. Pouillet, however, that we are indebted for a careful investigation of the subject. It is well known that plants act upon atmospheric air. They sometimes form a large quantity of carbonic acid gas, which disengages itself insensibly; at other times they exhale pure oxygen.

As carbonic acid gas obtained from the combustion of charcoal is, in its nascent state, electrified positively, M. Pouillet conceived that a considerable quantity of electricity ought to be produced during the exhalation of this gas from growing plants. This idea was confirmed by experiment, and M. Pouillet was led to the important conclusion that vegetation is an abundant source of electricity, and therefore powerfully aids in the generation of the electricity of the atmosphere.

He coated externally twelve capsules of glass, about nine inches in diameter, with a film of gum-lac varnish, but only to a distance of one or two inches towards the edge. They were arranged in two rows at the side of each other, either on a table of very dry wood, or on one which was itself varnished with gum-lac. When they were filled with vegetable mould, they were made to communicate with each other by metallic wires, which proceeded from the interior of the one to the interior of the other, passing over the edges of the capsules. In this manner all the insides of the twelve capsules, and the moulds which they held, formed only one conducting body. If electricity is communicated to such a system, it will be distributed over the twelve capsules, and will remain there, as it cannot pass into the ground, nor even into the exterior surfaces of the capsules, on account of the film of gum-lac round their edges. The upper plate of a condenser is now put in communication with one of the capsules by means of a wire, and its lower plate with the ground by the same means; and these communications are so made that they may be kept up even for several days. The grain of which we wish to study the effects is then sown in the capsules, and from this moment the laboratory must be closely shut, and neither fire nor light, nor any electrical body, admitted.

This experiment was made in March, when the usual dry north and east winds prevailed. During the first two days the surface of the mould was dried up, and the grains swelled; the germ projected about a line out of its envelope, without, however, appearing above the thin stratum of earth which covered the grain; and the condenser, after several trials, gave no signs of electricity. On the third day, the germs had emerged from the mould, and began to raise their points towards the window, which had no shutters. Upon now using the condenser, M. Pouillet observed a divergence of the gold leaves, and found the electricity to be negative in the capsules, and positive in the disengaged gases. Hence that philosopher infers that the rapid action which the rising germ exercises on the oxygen of the air disengages the electricity.

The apparatus was then put into its usual state, and after the lapse of some hours the action of the germ again "charged it with electricity." The following morning M. Pouillet found that it gave a very strong electric charge, the electricity being the same as before. During the next eight days, the vegetation continued active, and at all times of observation, both during the day and night, the condenser exhibited electricity of greater or less intensity, according to the time that had elapsed. After twelve hours, the divergence of the gold leaves extended to upwards of an inch, and the electricity of the earth in the capsules was always *negative*. Damp weather followed, and it was then impossible to collect the smallest quantity of electricity.

M. Pouillet next experimented on two vegetations of corn, two of cresses, one of gilliflower, and one of lucerne; but he was obliged to maintain in his laboratory an artificial dryness, by spreading in a very large apartment several bushels of quick lime broken into very small fragments; and he also distributed in porcelain saucers several kilogrammes of muriate of lime, placing them near the capsules. The condenser now exhibited a more intense electricity than before; and in each operation the development of the vegetable action, and that of the accompanying electrical phenomena, were observed during ten or twelve days. So rapid was the disengagement of electricity, that after the first three or four days of vegetation, if the condenser was put into the natural state after one observation, and was then replaced for experiment only during *one second*, it was found to be charged with electricity. "But," as M. Pouillet observes, "it is evident, that during one second, the weight of oxygen which combines and disengages during a languid vegetation, of only three or four square feet, is a weight so feeble, and a fraction of a millegramme so imperceptible, that the disengaged electricity is not rendered sensible by the condenser. One is apt to fear after this, that the electricity has another source, and that it can only be developed by some foreign cause; but, upon reflection, we see that the earth of the capsules is so dry that it becomes an imperfect conductor, that the electricity is retained, and that it is it which charges the condenser. To be certain of this, it is sufficient to place successively in contact with the condenser, one, two, three, or a greater number of capsules, and we shall see the charge increase as the number increases: in short, it is sufficient to place them in communication with the ground for a long time, when they will no longer give a charge to the condenser, and many hours will elapse before they communicate a sensible charge. It is without doubt this imperfect conducting power of the dried earth, which has rendered it impossible for me to observe until now any electrical charges during the periods of day or night, although I took every precaution to obtain it, presuming that if the disengagement of carbonic acid gas produces negative electricity in the ground, the evolution of oxygen ought, on the contrary, to produce positive electricity.

"It is, perhaps, the same cause which has given birth to another phenomenon, of which I cannot give an exact account, not having yet studied it sufficiently.

It happened twice that the electric signs had ceased during two or three days, and that they were then presented in opposite conditions, viz. the capsules had exhibited a positive state, and had continued so to do, with a very weak intensity, during the rest of the vegetation."

CHAPTER XIII.

Galvanic Electricity.

GALVANISM, or Voltaic Electricity, sometimes also termed Hydro-electricity, is a branch of science of modern date. It originated from some electrical experiments on animal irritability made by Galvani, Professor of Anatomy at Bologna, in the year 1790. He discovered the fact that muscular contractions are excited in the leg of a frog recently killed, when two metals (such as zinc and silver), one of which touches the crural nerve, and the other the muscles to which it is distributed, are brought into contact. Galvani ascribes the phenomena to the presence of electricity in the muscles, imagining that the metals only serve the purpose of conductors. He conceived that the animal electricity originates in the brain, is distributed to every part of the system, and resides particularly in the muscles; that the different parts of each muscular fibril are in opposite states of electric excitement, and that contractions take place when the equilibrium is restored. This he supposed to be effected during life through the medium of the nerves, and to have been produced in his experiments by the intervention of metallic conductors.

In these views Galvani was strongly opposed, particularly by the celebrated Volta, Professor of Natural Philosophy at Pavia, who succeeded in pointing out their fallacy. Volta attributed the electric excitement solely to the metals, and conceived that the muscular contractions are occasioned by the electricity thus developed passing along the nerves and muscles of the animal. To the experiments of this philosopher we are indebted for the first Voltaic apparatus, which was described by him in the Philosophical Transactions for 1800, and which has very properly received the name of the *Voltaic pile.* To Volta also is due the real merit of laying the foundation of the science of Galvanism.

Galvanism seems to be distinguished from the ordinary electricity (an account of which we have already given), not by any difference in the nature of the agent by which its phenomena are produced, but merely by the mode in which its power is developed and brought into action.

It has been shewn, that all electrical phenomena, how various and complicated soever they may appear, are reducible to a few facts; that they are principally comprised in the laws of electric attractions, repulsions, and inductions; in the different conducting powers of various bodies, and the mode of distribution of the electric fluid among the particles of substances of various forms and in different relative positions. From the law of electric induction we derive the power of accumulating electricity in vast quantities, by means of the Leyden jar, and electric battery, and of displaying some of its most energetic effects. We have stated that by the violent action of large quantities of electricity, suddenly transmitted through bodies, metals may be fused and volatilized, or reduced to dust, and dispersed in air; that organized bodies, or minerals of the hardest texture, may be rent asunder; and that vegetable and animal life may be destroyed.

Our knowledge on the subject of electricity had long been stationary, before the discovery of the simple fact by Galvani, as above recorded. Galvanism has put us in possession of an instrument of greater power than the electrical battery, and more adapted to an extensive application in analytical researches, and in various branches of physical science. The same power which, in a highly-charged electric battery, is dissipated by a single discharge, is developed in the Voltaic apparatus; and far from being rapidly expended, continues to be poured forth in profusion for an indefinite time, and may be directed at pleasure so as to effect different changes of composition, and to produce other affections of bodies subjected to its action. The apparatus may be regarded as a vast electric magazine, capable of furnishing a continued supply of the electric fluid for a long period, at the demand of the experimentalist, and placing this mighty agent entirely under his control. The Voltaic battery has opened a new field to the cultivators of science, and a rich harvest of discoveries has already rewarded their exertions.

Before we enter into an exposition of the facts relating to galvanism, and the theories which have been proposed for their explanation, it will be necessary to direct our attention to the nature of the arrangements of bodies which are the sources of galvanic power.

Galvanic arrangements may be divided into simple and compound; the former being elementary galvanic circles, and the latter a number of such simple circles acting together. We shall first describe the most simple arrangements.

Simple Voltaic Circles.—When a plate of zinc and a plate of copper are placed in a vessel of water, and the two metals are connected either by direct contact, or by the intervention of a metallic wire, galvanism is excited. The action is, however, so very feeble, that it cannot be detected by ordinary means; but if a little sulphuric acid is added to the water, globules of hydrogen gas will be evolved at the surface of the copper. The evolution of gas continues while metallic contact between the plates is preserved, in which case the *circuit* is said to be *closed.* The hydrogen gas results from the decomposition of water by the electric current, and its ceasing to appear indicates the cessation of the current. In this simple arrangement the Voltaic circle consists of zinc, copper, and interposed dilute acid; and the current is developed only when the two metals are in contact, or in communication by means of wires. It is shewn in fig. 31. Metallic

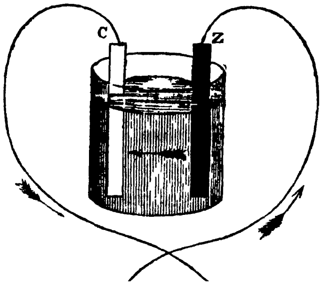

Fig. 31.

contact is readily made or broken by means of copper wires, one of which is soldered to the zinc, the other to the copper plate. By employing a galvanascope (an instrument hereafter to be described), it is found that a current of electricity continually circulates in the closed circuit from the zinc through the liquid to the copper, and from the copper along the conducting wires to the zinc, as indicated by the arrows in the figure. A current of negative electricity (agreeably to the theory of two fluids) ought to traverse the apparatus in the reverse direction; but, having hitherto followed the single-fluid theory in reference to common electricity, we have indicated in the figure, and shall continue to indicate, the course of one current only.

So far as Voltaic action is concerned, it is immaterial at what part the plates of fig. 31 touch each other—whether below, where covered with liquid, above, where uncovered, or along the whole length of the plates, provided both plates are immersed in the same vessel of dilute acid. Immersion of one of them only, in what way soever contact may be made between them, does not excite Voltaic action, nor does it suffice to have each plate in a different vessel. But if, instead of being immersed, either of the plates is made barely to touch the surface of the liquid, Voltaic action will be produced; but more energetically when the copper-plate thus slightly touches the liquid, than when the zinc is similarly placed. A plate of zinc soldered to one of copper, and plunged into dilute acid, gives a current passing from the zinc through the fluid round to the copper; but if the soldered plates are cemented into a box with a wooden bottom and metallic sides, so as to form two *separate* cells, as shewn in a vertical section by fig. 32, then the introduction of dilute acid will not

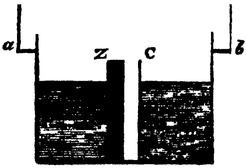

Fig. 32.

excite a current, unless the fluid of the cells is made to communicate by means of moistened twine, cotton, or some porous matter, or, as in the figure, by wires, *a*, *b*, soldered to the metallic sides of the cells which contain the dilute acid, or dipping into the acid itself. Then the current circulates in the direction indicated by the arrows.

Instead of being soldered, the plates may be connected by a wire, and plunged into separate cells, *a e*, *b e*, (fig. 33,) in which *d e* is a partition.

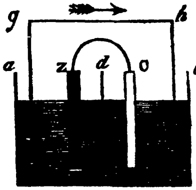

Fig. 33.

But the current must be conveyed by a wire, *f g h i*, or some other conducting medium, into the cell *b e*, in which the copper plate C is immersed.

A simple Voltaic circle may also be formed of one metal and two liquids, provided the liquids are such that a more energetic chemical action is induced on one side than on the other. On cementing a plate of zinc, Z, into a box, (fig. 34,) and putting a solution

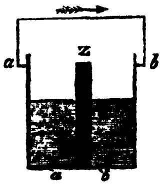

Fig. 34.

of salt into the cell, *a 'b*, a current will be excited in the direction of the arrows, provided the circuit is completed by a wire, *a b*, attached to the metallic sides of the box, or immersed in the liquid in the cells. Even the same acid solution may occupy both cells, provided the zinc is more energetically acted upon on one side than the other. This may be effected either by using a zinc plate, rough on one side and polished on the other, or by the acid being hot in one cell, and cold in the other. In this case the result is the same as when two different liquids are used.

Zinc, as sold in the shops, contains traces of tin, lead, and rather more than one per cent. of iron, which is mechanically diffused through its substance. It sometimes also contains a minute portion of arsenic. This impure zinc affords an interesting kind of simple Voltaic circle. On immersion in dilute sulphuric acid, the small particles of iron and the adjacent zinc form numerous Voltaic combinations, transmitting their currents through the acid, and disengaging a large quantity of hydrogen gas. Pure distilled zinc is very slowly acted on by dilute sulphuric acid of specific gravity ranging from 1·068 to 1·215; but if fused with about two per cent. of iron filings, it is as readily dissolved as commercial zinc. Pure iron and steel, in like manner, are less readily acted on by dilute sulphuric acid than after they have been fused with small quantities of platinum or silver.

We are indebted to Mr. Sturgeon for the fact, that commercial zinc, with its surface amalgamated, resists the action of dilute acid fully as well as the purest zinc. This fact, of which Dr. Faraday has made excellent use, appears to be "owing to the mercury bringing the surface of the zinc to a state of perfect uniformity, preventing those differences between one spot and another, which are essential to the production of minute currents: one part has the same tendency to combine with electricity as another, and cannot act as a discharger to it."—*Faraday's Researches*. The zinc may be amalgamated by dipping it into nitric acid diluted with two or three parts of water, and then rubbing it with mercury. The reader who wishes to inquire further into the advantages resulting from the employment of amalgamated zinc, may refer to the Philosophical Transactions for 1826, Part III, which contains Sir H. Davy's celebrated Bakerian Lecture for that year, in which the simple fact is stated, "that zinc, in amalgamation with mercury, is positive with respect to pure zinc;" without any allusion, however, to the probable beneficial employment of it in the general construction of batteries. Also to Mr. Kemp's paper, in Professor Jameson's New Edinburgh Philosophical Journal, for December 1828. That gentleman, we believe, was the first person who employed amalgamated zinc and copper in the regular construction of Voltaic apparatus. An extract from this paper will be found in Mr. Sturgeon's "Annals of Electricity, Chemistry, and Magnetism," for January 1837; and also a paper containing an account of Mr. Sturgeon's own experiments, which was published in 1830, in the "Experimental Researches on Electro-magnetism," &c. The same number contains an extract from

Dr. Faraday's Researches in reference to the same subject. Mr. Cooke has recently taken out a patent for a means of effecting telegraphic communications by Voltaic electricity. In his experiments (which will be described in the proper place), that gentleman has always preferred the amalgamated zinc. Mr. Cooke's batteries are of various forms, and all of considerable power. Indeed, the forms of batteries may be varied to an endless extent. The metals may be placed in any position with respect to each other, (provided they do not touch); a current of Voltaic electricity will always be produced. They may also be formed of various materials; but the combinations usually employed consist either of two perfect conductors and one imperfect conductor of electricity, or of one perfect conductor and two imperfect conductors. The substances included under the title of perfect conductors are metals and charcoal; and the imperfect conductors are water and aqueous solutions. It is essential to the operation of the first kind of circle, that chemical action take place between the imperfect conductor and one of the metals; and in case of both metals being acted upon, the action must be greater on one than the other. It is also found generally, if not universally, that the metal most energetically attacked is positive with respect to the other, or bears the same relation to it as zinc to copper, in figures 31, 32, and 33. Davy, in his Bakerian Lecture for 1826 (Phil. Trans.), gave the following list of the first kind of arrangements, the imperfect conductors being either the common acids alkaline solutions, or solution of metallic sulphurets, such as sulphuret of potassium. The metal first mentioned is positive to those following it in the series.

With common Acids.—Potassium and its amalgams, barium and its amalgams, amalgam of zinc, zinc, cadmium, tin, iron, bismuth, antimony, lead, copper, silver, palladium, tellurium, gold, charcoal, platinum iridium, rhodium.

With Alkaline Solutions.—The alkaligenous metals and their amalgams, zinc, tin, lead, copper, iron, silver, palladium, gold, and platinum.

With solutions of Metallic Sulphurets.—Zinc, tin, copper, iron, bismuth, silver, platinum, palladium, gold, charcoal.

Dr. Faraday has shewn that the presence of water is not necessary. A battery may be composed of other liquid compounds, such as a fused metallic chloride, iodide, or fluoride, provided it is decomposable by galvanism, and acts chemically on one metal of the circle more powerfully than on the other.

In Davy's Elements of Chemical Philosophy we find the following table of Voltaic circles of the second kind :--

Solution of—		
Sulphuret of Potassium.	Copper.	Nitric Acid.
Potassa.	Silver.	Sulphuric Acid.
Soda.	Lead.	Hydrochloric Acid.
	Tin.	Any Solutions containing Acid.
	Zinc.	
	Other Metals.	
	Charcoal.	

Of these combinations the most energetic is that in which the metal is chemically acted upon on one side by sulphuret of potassium, and on the other by an acid. The experiment may be made by pouring dilute nitric acid into a cup of copper or silver, which stands in another vessel containing sulphuret of potassium. The following arrangements may also be employed:—Moisten two pieces of thick flannel, one with dilute acid, the other with solution of the sulphuret of potassium, and place them on opposite sides of a plate of copper, completing the circuit by touching each piece of flannel with a conducting wire: or take two discs of copper, each with its appropriate wire; immerse one disc into a glass filled with dilute acid, and the other into a separate glass with an alkaline solution, and connect the vessels by a few threads of moistened amianthus, or cotton moistened with a solution of salt. A similar combination may be thus effected: let one disc of copper be placed on a piece of glass or dry wood; on its upper surface lay in succession three pieces of flannel, the first moistened with dilute acid, the second with solution of salt, and the third with sulphuret of potassium, and then cover the last with the other disc of copper.

Metallic bodies are not essential to the production of galvanic phenomena. Combinations have been made with layers of charcoal and plumbago, of slices of muscle and brain, and beet-root and wood; but the power of these circles, though numerous pairs are used, is very feeble, and they are very rarely employed in practice.

The only one of the simple circles above described, that has been used for ordinary purposes, is that composed of a pair of zinc and copper plates excited by an acid solution, (fig. 31.) The form and size of the apparatus are exceedingly various. Instead of actually immersing the plates in the solution, a piece of moistened cloth may be placed between them. Sometimes the copper plate is made into a cup for containing the liquid, and the zinc is fixed between its two sides, as shewn by the accompanying figure (35), which represents a transverse vertical

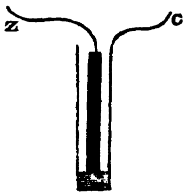

Fig. 35.

section of the apparatus. Care must be taken to avoid contact between the plates, by interposing pieces of wood, cork, or some other imperfect conductor of electricity. Another contrivance, which is the most convenient of all, and for which, I believe, we are indebted to Mr. Sturgeon, is represented by fig. 36. In this arrangement the zinc may be removed at pleasure, and its surface cleaned. C is a vessel with two cylinders of copper, of unequal size, placed one within the other, and soldered together at the bottom, so as to leave an intermediate space, *a a a*, for containing the zinc cylinder, Z, and the acid solution. The small copper

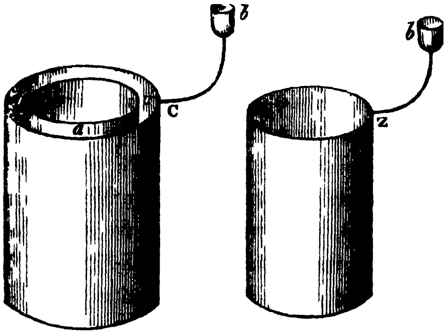

Fig. 36.

cups, *b b*, are for the purpose of holding mercury, so that by inserting the ends of two wires, the Voltaic circuit may be closed or broken with ease and expedition. This apparatus is very serviceable in electro-magnetic experiments.

Another kind of circle may be formed by coiling a sheet of zinc and copper round each other, so that each surface of the zinc may be opposed to one of copper, and separated from it by a small interval. The London Institution possesses a very large apparatus of this sort. It was made under the direction of Mr. Pepys: each plate is sixty feet long, and two wide. The contact between the plates is prevented by interposed ropes of horses' hair; and the coil, when used, is lifted by ropes and pulleys, and let down into a vessel containing dilute acid. The contrivance of opposing one large continuous surface of zinc to a similar surface of copper, originated with Dr. Hare, of Philadelphia, by whom it was termed the *Calorimotor*, from its surprising heating power.

Before we proceed to describe the improved Voltaic arrangement, which has received the name of the "Sustaining Battery," it may be interesting to the reader to be made acquainted with various methods of forming simple Voltaic circles in a few seconds, and with materials which are constantly within the reach even of the tyro. We can fully appreciate the unenviable situation of an inquirer, ardent and enthusiastic in the pursuit of science, but whose investigations are circumscribed within a very limited sphere by the absence of that necessary evil—the current coin of the realm. At the same time it must be admitted, that the inquirer, so situated, is thrown entirely on his own resources, and is induced to attempt to produce effects with such means as he can command. And it is strange, but true, that when purchasing a trifling article, if the tradesman asks you for what purpose you want it, and you unwittingly reply, that it is for some experiment, you are sure to be charged three or four times the value. We have known three-pence paid for a small piece of charcoal.

A simple circle may be formed by inserting a shilling and a piece of zinc in a potato, an apple, a lemon, or any other moist vegetable matter: but of course the current is feeble, although quite sufficient to produce a very decided effect upon the *galvana-*

*scope**. Zinc with copper will answer, but not so well as with silver. A very simple wire battery, and one by no means of trifling power, may be thus constructed :—Insert a coil of copper wire in a glass tube, within which another tube is to be placed, containing a zinc wire: with an arrangement of this kind I obtained a permanent deflection of the magnetic needle of 50°. The conducting liquid was a solution of the sulphate of the oxide of copper; the blue vitriol of the shops.

It may be as well, once for all, to state that whenever I presume to mention my own experiments, and refer to the indications of the galvanascope, that I have invariably used the same magnetic needle; that it is not an astatic needle, and is not suspended, but is mounted on the point of a common pin. The wire of the galvanascope, passing above and beneath the needle, contains thirty-one convolutions.

I prefer this common apparatus to the more delicate astatic galvanascope, for ascertaining the electromotive *force* of the galvanic current; because there is a *constant* force to be overcome in the action of the earth's magnetism. I have invariably found that a battery which deflects the needle 30° permanently, is sufficiently powerful to rotate Dr. Ritchie's electromagnet; that if the permanent deflection is much

* The reader is recommended to turn to the description of the form and use of this instrument, in a subsequent chapter, before he reads further, as the effects of various forms of batteries on the needle will frequently be referred to.

below 30°, the rotation is exceedingly slow, or is not produced at all. A battery which is capable of sustaining a deflection of 45° or 50°, produces very rapid rotation, and a brilliant spark. The maximum deflection with the small batteries we are about to describe, was 65°, which is several degrees beyond the maximum deflection produced by other batteries in my possession, presenting a very much greater extent of metallic surface: indeed, there is only one arrangement by which I have seen a permanent deflection produced beyond 65° with the instrument I have already described. It was a Voltaic apparatus which Martyn Roberts, Esq. had the kindness to shew me. It consisted of ten pairs of copper and zinc plates, each of which was a foot square. The zinc plates were covered with linen cloth: the zinc of one pair was connected with the copper of the adjoining pair throughout. The conducting liquid used was a solution of the sulphate of the oxide of copper, and I have reason to believe the solution was not near its point of saturation; but, with this disadvantage, and the still greater one arising from the plates being all immersed in one vessel, and *that* of *tin*, the electro-motive power was infinitely superior to that of any battery, or combination of batteries, whose action I have had an opportunity of witnessing. The centrifugal force of the rotating electro-magnet was such as repeatedly to raise it to a distance of at least half an inch, and several times it was nearly thrown off. The quicksilver was rapidly consumed, the large sparks (or rather flashes) keeping it in a state of apparent continued ignition, the oxide passing off in dense fumes. By the chemical action between the tin and the solution, the power of the battery was speedily weakened: its capability of decomposing water was certainly not equal to its electro-motive power; it, however, decomposed water rapidly, but not having a Volta-meter at hand, we could not ascertain its comparative power in this respect, nor had we an apparatus with which to try the sustaining power of an electro-magnet in connexion with it.

Another arrangement is what may be termed the wire battery, similar to the one above described, only with the metals reversed, viz. a coil of zinc wire outside, and a copper wire inside. The following account of a very small battery of this kind was published in "The Annals of Electricity," &c. for April, 1837:—"I formed a helical coil of zinc wire 1-16th of an inch in thickness: I inserted by means of a cork a piece of copper wire 1-8th of an inch thick. The whole length of the battery, exclusive of the terminations of the wires at the top, was only two inches and a quarter; and the diameter internally of the cylinder formed by the coils, only a quarter of an inch; yet this apparatus was sufficient to work both Dr. Faraday's and Dr. Ritchie's apparatus, and to produce a very good spark. The liquid used was a solution of the sulphate of the oxide of copper.

Another form of apparatus is the following:—Let a piece of wood be cut, so as to receive a small zinc plate; cross this plate diagonally with copper wires. The size of the zinc plate I used was only two inches by one and a half inch; the thickness of the wires only 1-18th of an inch, crossed only twice in one direction, and three times in the other. With this simple battery the following results were observed:—

Exp.	Conducting Medium.	Transient Deflect.	Permanent Deflect.
1	New River Water...	Not noted	7°
2	Moistened Carbonate of Soda ...	40°	14° 5
3	Solution of Sulphate of Zinc...........	27° 5	9° 25
4	Benzoic Acid	25°	10°
5	Tartaric Acid	35°	13° 5
6	Boracic Acid....	70°	15° 5

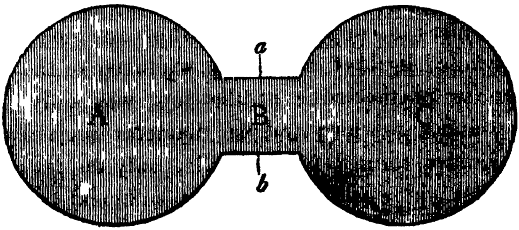

Fig. 37.

These experiments were made before the conducting wire was soldered to the zinc. After having soldered it, a solution of the sulphate of copper being added, there were four successive transient deflections of 180°, and a permanent deflection of 45° 9′. With a solution of the sulphate of the oxide of iron, the transient deflection was 80°; but the permanent deflection was only 11° 5′.

There are several circumstances in these experiments that demand attention; but it is foreign to the purpose of this elementary essay to enter into any theoretical discussion. We shall merely remark, that this simple arrangement, with the sulphate of the oxide of copper as the conducting liquid, appears to be fully as powerful as any apparatus that we have yet seen, with the solitary exception of the battery, which was shewn to me by Mr. Roberts, and from which, from its extraordinary size, much was to be expected.

A very small battery, and fully as powerful as, if not more so, than any of the zinc and copper arrangements at present in use, may be thus constructed:—Cut a piece of plate zinc into the form represented in fig. 37 (p. 173). The size of the zinc need not be greater than than that of the diagram. Cover it with with gold-beater's skin, or with a piece of bladder, so that the whole surface, A, B, C, may be protected. Bring the folds of the membrane round to the other side of the plate, and where the loose ends join, secure them with a little melted sealing-wax. It is better even to varnish the whole of that surface. Then bend the plate in the centre at *a*, *b*, so that the discs, A and C, may be brought into a parallel position. Solder the conducting wire to either of the discs, protecting it, where soldered, by dropping a little sealing-wax over it, or covering it with thick sealing-wax varnish. Solder a copper wire to a small plate of silver, which need not exceed the size of a fourpenny-piece or a sixpence. Protect the soldered part in the same manner as directed for the zinc plate. This battery is to be used with a solution of the nitrate of the oxide of silver: it was with a battery of this description, of the same size as the diagram, that I obtained a permanent deflection of 65°, and produced so rapid a motion of Dr. Ritchie's apparatus that I was obliged to insure the steadiness of the instrument by suspending weights to it, and by securing it with wires. During the action of this battery, metallic silver is deposited, partly on the membrane which protects the zinc, and partly on the silver plate. From a battery of this description on a larger scale much may be expected: its expense is objectionable; but the solution of the nitrate of silver need not be saturated, and the silver itself may be collected, and again converted into the nitrate of silver. It is probable, also, that the place of the silver plate might be substituted by copper well silvered.

It has already been stated that a Voltaic circle may be made with one metal and two different solutions. The results of the following experiment is, perhaps analogous to that produced by such an arangement:—Take a crystal of the sulphate of the oxide of copper, twist a copper wire round it. Treat a piece of the muriate of ammonia in a similar way. Place them in a vessel of water, taking care that they do not come in contact. Connect the ends of the wires with the cups of the galvanascope, and a decided deflection of the magnetic needle will be produced.

CHAPTER XIV.

Of Compound Voltaic Batteries.

THE combined influence of a number of plates is requisite for the production of many galvanic effects. Such a combination is termed *a compound Voltaic circle* or *battery*. The first battery of this nature was the pile of Volta, the discovery of which was announced in a paper in the *Philosophical Transactions* for 1800. Volta at first employed silver coins and pieces of zinc of the same form and dimensions, and circular discs of card, soaked in salt water, and of somewhat smaller dimensions than the metallic plates. Of these he formed a pile or column, shewn in fig. 38, in which the three substances, silver, zinc.

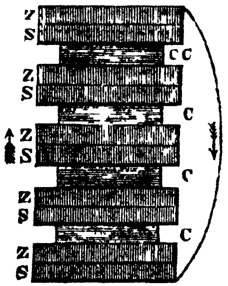

Fig. 38.

and wet card, denoted by the letters S, Z, and C, were made to succeed one another in the same regular manner throughout the series. If the uppermost disc of metal in the column is touched with one hand previously wetted, while a finger of the other hand is applied to the lowermost disc, a distinct shock is felt in the arms, resembling that from an electrical battery weakly charged. The strength of the shock is greater in proportion to the number of plates, and a repetition of shocks may be obtained for an indefinite period, whenever the circuit is completed by touching the two ends of the pile with the moistened fingers. A powerful battery may be formed by a number of these piles, by making a metallic communication between the last plate of the one and the first of the next; care being taken to preserve inviolate the order of succession of the plates in the circuit. A combination of this kind is shewn in fig. 39, in which the dark lines represent

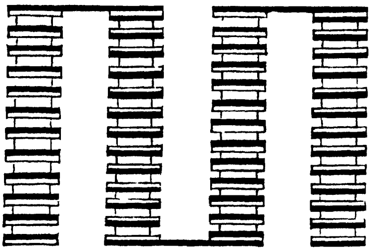

Fig. 39.

the copper, and the light lines the zinc plates. In another arrangement the plates are placed side by side in a vertical position, and combined in pairs, consisting each of one zinc and one copper (or silver) plate, connected at their upper edges by slips of metal passing from the one to the other. Glasses filled with water, or some saline or acid solution, are placed in a circle. The two plates belonging to each pair are immersed in the fluids contained in two adjoining glasses; the zinc plate in the first glass, the copper in the second. In the second and third glasses, the plates of the second pair are immersed in a similar way, and so throughout the series; care being taken to preserve the same order of alternation in the metals. A horizontal section of this battery is shewn in fig. 40. The dark lines represent the

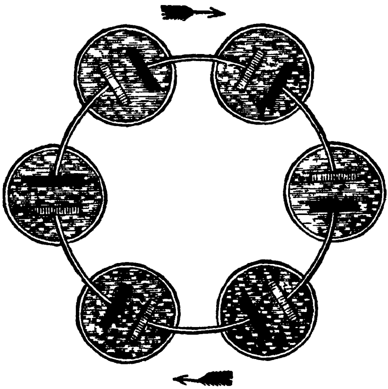

Fig. 40.

copper, the light lines the zinc plates. Volta, who was the first to employ a circular series of cups in this arrangement, gave it the name of *Couronne de* *tasses.* Another form is shewn in fig. 41, in which Z represents zinc, and C copper, the direction of the

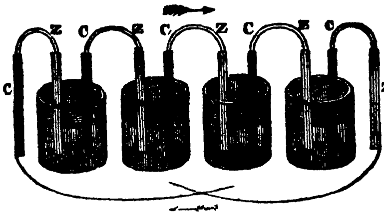

Fig. 41.

electric current being indicated by the arrows. In this apparatus, and in every other compound galvanic circle, the direction of the electric current is the same as in a simple galvanic circle composed of the same elements. If this law is kept in view, much difficulty will be avoided in reference to the distinction between the electrical state of the two terminating plates of the apparatus, and of the communicating or conducting wires, which are usually termed the poles of the battery. In the simple battery, consisting only of one pair of plates, the conducting wire communicates directly with that plate which is in contact with the fluid part of the apparatus. In the compound circle it proceeds not from the plate immersed in the fluid, but from that which is adjacent to, or associated with it. The compound circle may be simply represented by the following series:—

Copper——Zinc——Fluid——Copper——Zinc.

Here the copper end is negative, and the zinc end positive. By removing the two terminating plates we convert it into a single circle, consisting only of

Zinc——Fluid——Copper,

and the zinc end is negative, the copper positive.

Most of the arrangements of the compound Voltaic apparatus may be regarded as modifications of Volta's crown of cups. Instead of glasses it was found more convenient to employ a trough of baked wood or glazed earthenware, divided into separate cells by partitions of the same material; and in order that the plates may be immersed iu, and taken out of the liquid conveniently and at the same moment, they are all attached to a bar of dry wood, the necessary connexion between the zinc of one cell and the copper of the adjoining one being secured by a wire, or slip of copper, as shewn in fig. 42.

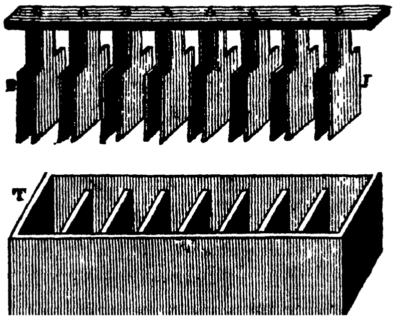

Fig. 42.

The best material for the trough, T, is Wedgwood ware. Each trough is usually fitted up with ten or twelve cells. The plates, P, adapted to them, are connected by a slip of baked wood, so as to allow of their being immersed in the liquid in the cells, or lifted out together. A number of these troughs may be combined with facility, by connecting together the terminal plates of the adjoining troughs by slips of copper; care being taken, as in the case of the pile (fig. 39), to preserve throughout the whole series the same order of the alternation of the plates, by connecting the *zinc* end of one battery with the *copper* end of the next. The large battery in the Royal Institution is constructed on this plan.

The battery contrived by Mr. Cruickshanks is composed of plates of zinc and copper, united by their flat surfaces by soldering, they themselves forming the partitions, being fixed into grooves in the sides of a trough of baked wood, which is an imperfect conductor of electricity, so as to leave sufficient intervals to hold small quantities of fluid. Care must be taken in the arrangement that all the zinc surfaces shall be on one side, and all the copper surfaces on the other. The cells are to be filled with a saline solution, or with dilute acid, and the galvanic circuit is completed by bringing the two wires proceeding from the ends of the battery in contact with each other. The section, fig. 43, will elucidate the principles of its action.

An increase of power is said to be gained when both surfaces of each plate of zinc, in contact with the liquids, are opposed to a surface of copper. In order to avail ourselves of this increase of power, it is necessary to add a second plate of copper, so that every cell may contain one zinc and two copper

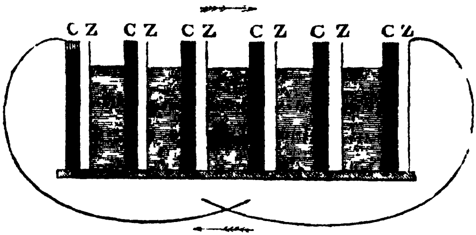

Fig. 43.

plates, the former being placed between the latter. This plan was suggested by Dr. Wollaston, and was adopted by Mr. Children in the construction of a large battery, in which each plate was six feet long, by two feet eight inches broad, so that it presented thirty-two square feet of surface.—*Phil. Trans.* for 1815, p. 363.

The size and number of the plates may be varied at pleasure. The battery of Mr. Children, above alluded to, is the largest that was ever made. The common size for the plates is four or six inches square, although we believe that plates of much smaller dimensions would answer equally as well. The great battery of the Royal Institution, with which Davy made his celebrated discovery of the compound nature of the alkalies, was composed of 2000 pairs of plates, each plate presenting thirty-two square inches of surface. It is now known, however, that such large compound batteries are not necessary. Increasing the number of plates beyond a moderate limit gives, for most purposes, no proportionate increase of power; so that a battery of fifty or one hundred pairs of plates, in vigorous action, will be just as effective as one of much greater extent.

CHAPTER XV.

Of "Sustaining," or "Constant Batteries."

WE must now proceed to the consideration of a great improvement which has recently been effected in the construction of the Voltaic apparatus, by which the action of the battery is rendered constant, and nearly uniform. As the first account of this improvement is that of Professor Daniell, we subjoin extracts of letters addressed by the Professor to Dr. Faraday, published in the *Philosophical Transactions* for 1836;—"The figure (for which see next page) represents a section of one of the cells, one of which is shewn in perspective below.

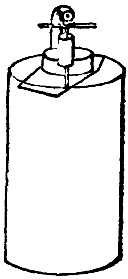

Fig. 44.

a b c d is a cylinder of copper, six inches high, and three and a half inches wide; it is open at the top

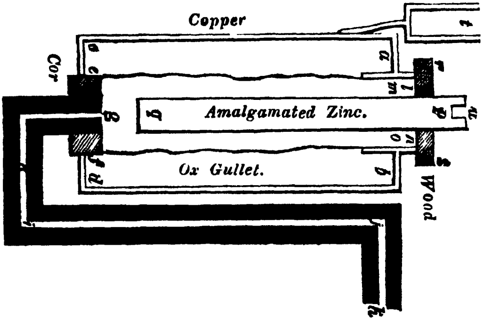

Fig. 45.

a b, but closed at the bottom, except a collar, *e f*, one and a half inch wide, intended for the reception of a cork into which a glass syphon tube, *g h i j k*, is fitted. On the top *a b*, a copper collar, corresponding with the one at the bottom, rests by two horizontal arms. Previously to fixing the cork syphon tube in its place, a membranous tube, formed of part of the gullet of an ox, is drawn through the lower collar, *e f*, and fastened with twine to the upper, *l m n o*, and when tightly fixed by the cork below, forming an internal cavity to the cell communicating with the syphon tube in such a way as that when filled with any liquid to the level, *m o*, any addition causes it to flow out at the aperture, *k*. In this state, for any number of drops allowed to fall into the top of the cavity, an equal number are discharged from the bottom, *a*, at the top of the zinc rod. Various connexions of the copper and zinc of the different cells may be made by means of wires proceeding from one to the other.

In the construction of this battery, I have availed myself of the power of reducing the surface of the generating plates to a minimum, the effective surface of one of the amalgamated zinc rods being less than ten square inches, whilst the internal surface of the copper cylinder to which it is opposed is nearly 72 inches. My principal objects have been to remove out of the circuit the oxide of zinc, which has been proved to be so injurious to the action of the common battery, as fast as the solution is formed, and to absorb the hydrogen evolved upon the copper without the precipitation of any substance which might deteriorate the latter.

The first is completely effected by the suspension of the rod in the interior membranous cell, into which the fresh acidulated water is allowed slowly to drop from a funnel suspended over it, and the aperture of which is adjusted for the purpose; whilst the heavier solution of the oxide is withdrawn from the bottom at an equal rate by the syphon tube. When both the exterior and interior cavities of the cell were charged with the same diluted acid, and connexion made between the zinc and the copper by means of a fine platinum wire 1-200th of an inch in diameter, I found that the wire became red hot, and that the wet membrane presented no obstruction to the passage of the current.

The second object is attained by charging the exterior space surrounding the membrane with a saturated solution of sulphate of copper instead of diluted acid; upon completing the circuit the current passed freely through this solution; no hydrogen made its appearance upon the conducting plate, but a beautiful pink coating of pure copper was precipitated upon it, and thus perpetually renewed its surface.

When the whole battery was properly arranged and charged in this manner, no evolution of gas took place from the generating or conducting plates, either before or after the connexions were complete; but when a voltameter* was included in the circuit, its action was found to be very energetic. It was also much more steady and permanent than that of the ordinary battery; but still there was a gradual, but very slow decline, which I traced at length to the weakening of the saline solution by the precipitation of the copper, and the consequent decline of its conducting power.

To obviate this defect, I suspended some solid sulphate of copper in small muslin bags, which just dipped below the surface of the solution in the cylinders; which gradually dissolving as the precipitation proceeded, kept it in a state of saturation. This expedient fully answered the purpose, and I found the current perfectly steady for six hours together. This arrangement I have since improved by placing the

* An instrument for collecting the gases during the decomposition of water.

salt in a perforated colander of copper fixed to the upper collar.

Fig. 46 represents a section of this additional arrangement. The colander with its central collar

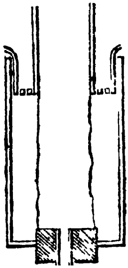

Fig. 46.

rests by a small ledge upon the rim of the cylinder. The membrane is drawn through the collar, and turning over its edge, is fastened with twine.

After this alteration, the effective length of the zinc rods exposed to the action of the acid was found to be no more than four inches and a quarter."

Professor Daniell next proceeds to give the details of a series of experiments to shew the superiority of the "Constant Battery" over the old arrangement, and adds, that he had kept "six inches of platinum wire 1-200ths of an inch in diameter permanently red hot for a considerable length of time, when the battery was merely connected in single series, and that the spark between charcoal points was remarkably beautiful."

The Professor, in another letter to Dr. Faraday, details further improvements and experiments with the battery.—*Phil. Trans.* for 1836.

Another constant, or sustaining battery, is that of F. W. Mullins, Esq. M. P. Figs. 47 and 48 present a sectional and perspective view of this battery. C, C, C (fig. 47), is a copper cylindrical vessel,

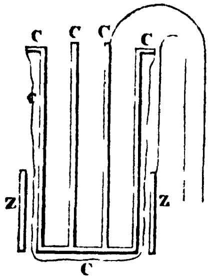

Fig. 47.

close at the bottom, but open at the top; C, C, is another cylinder of copper, soldered to the bottom of the former vessel, and concentric with its vertical sides. Round the top of the outer cylinder is a projecting shoulder, grooved like the sheave of a pulley, for the reception of the open end of a bladder and string, the former of which envelops the whole cylinder, as shewn by the waved line in the figure, and is kept in its place by several turns and a knot of the latter, over its open end in the groove. The inner copper cylinder is two, the outer about three and a quarter inches in diameter; the height of each six inches. The shoulder, C C, projects outwards about three-tenths of an inch. Outside of the bladder is a cylinder, Z Z, of stout rolled zinc, open at both ends, three and three quarter inches in diameter, and two and a half high. The whole are arranged as in fig. 47, in a porcelain jar, as seen in fig. 48. The

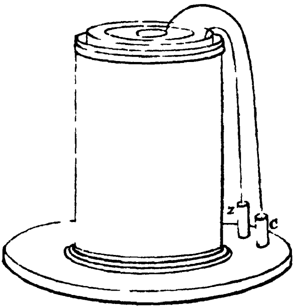

Fig. 48.

connexions are made by narrow strips of sheet copper, which bend over the edge of the jar and enter two cups Z, C, containing mercury. The cups are fixed into a circular wooden base on which the battery stands. This battery is brought into action by two liquids: a solution of muriate of ammonia outside of the bladder; and dilute sulphuric acid, charged with crystals of the sulphate of copper, which are placed in the annular space between the two copper cylinders. This description and the accompanying figures are taken from the second number of Mr. Sturgeon's "Annals of Electricity," &c. An account will be found in the third number, by Mr. Mullins, in which he thus describes his battery, the account given above being that of the battery as it was originally constructed.

"The battery I generally use for my own purposes consists of ten pots, each containing a single arrangement, and constructed in the following manner:—Close to the inner surface of an earthenware pot, four inches high and two and a half wide, is fitted a cylinder of zinc, the depth of which is about a third of the depth of the pot: a small piece of the zinc, about half an inch wide, rises above the level of the remainder, about an inch, and to this is soldered a narrow ribbon of copper, which rises to the top of the pot, and projects over it about five inches, for the purpose of communicating with a mercurial cup; within this cylinder of zinc, and as close to its surface as possible, stands a copper vessel, the height of which equals the depth of the pot. This vessel is two and a quarter inches wide, and has either a wooden or copper bottom water-tight. Round the upper edge of this cylinder, and external to it, is soldered a rim of copper about a quarter of an inch wide, on the outside of which is worked a groove all round: in the upper surface of this rim are two holes as large as it will allow, for the purpose of drawing off the charge or supplying it. The copper cylinder thus constructed, is placed upon a flat circle of cork, open in the centre, and projecting as much from the outer surface of the copper below as the rim does above; this cork is wound round with strips of membrane, and a thin calf's or pig's bladder previously steeped in tepid water, is drawn over the cylinder, the use of the cork being to preserve the membrane from contact with the copper; the bladder is drawn tight, and fastened by a string round the groove in the rim before described. A narrow band of copper is soldered to the upper edge of the cylinder, and the battery is now fit for use. In charging it, I use two solutions; that in contact with the zinc being one part of a saturated solution of muriate of ammonia to five of water; and that in contact with the copper, a saturated solution of sulphate of copper. I say saturated, not because it is requisite for the production of the maximum effect, but because it is convenient, as I will presently shew. In charging the battery, it must be borne in mind that the solution in contact with the zinc should never be more than sufficient to attain a level with the upper edge of the zinc, for it is a matter of some importance to keep that part of the zinc which is soldered to the copper band free from local action. The other solution may be allowed to rise to about two-thirds of the height of the copper cylinder, for the larger the charge of this solution, and the greater the quantity of the salt dissolved therein,—not the greater the power developed, as some persons who have written lately on the subject, would have us suppose,—but the longer will the power, which a smaller charge unsaturated can equally develop, be sustained. It is not, therefore, because the fluid contains a very large quantity of the metallic salt in solution that active effects are produced, but because there is a certain quantity present, which suffices to produce in a given moment of time that unit of metallic precipitation which is proportional to the surface of the metals employed, or rather to the various attractions called into play in the circuit. And that this quantity is exceedingly small is proved by the fact of the power continuing undiminished in the slightest degree, until the solution becomes nearly colourless; and further, by another fact, that if to this nearly colourless solution you add about six drops of the saturated solution, the original power of the battery is instantly restored, and continues for some time. It may be asked how I manage to keep the battery in action for a long period, unless I keep crystals in solution. I meet the difficulty by drawing off the original charge of sulphate, by means of a syphon or a common syringe, to which is fitted a long and narrow pipe which enters the holes before mentioned in the rim of copper, and by means of a small funnel renewing it. This may be done without interfering in the least with the action of the battery. It may be well here to observe that the other solution does not require renewal: however, as there are many who may prefer keeping crystals in solution to the trouble of drawing off and renewing the solution, for these I have designed a very simple mode of gratifying their fancies or their prejudices, and at a very trifling additional expense. It is a form I sometimes use myself, and is nothing more than the soldering a copper shelf or plate within the cylinder, and about an inch and a half from its upper edge, and making six small holes on a level with the shelf to communicate with the external surface of the cylinder. As soon, then, as it appears that the original solution has nearly lost its copper, a very few crystals may be dropped on the shelf, which will be carried in solution to the external surface of the copper. The battery exhibited at the Royal Institution on the 3d of June, 1836, was somewhat different from that described here; the copper cylinder having a number of holes at regular distances all round and near the bottom, for the purpose of admitting the fluid to internal as well as external contact. However, this *plan did not prove to be any advantage; on the contrary it led to great waste of the solution, therefore I gave it up; and I find that the simple form described, either with or without the shelf, gives* immense power and in a very small compass, which is one great advantage peculiar to this battery. Another advantage is the bringing of the zinc surface very close to that of the copper.

My intensity sustaining battery is constructed as follows:—I have first, as in the quantity battery, a shallow cylinder of zinc within, and close to the internal surface of the earthenware pot, next the copper cylinder, as before; but instead of letting the inside of this cylinder go for nothing, the internal surface of the copper is lined with very thin *caoutchouc* for insulation; then comes another small cylinder of zinc; then a copper one, lined as the last; then a zinc; and lastly a copper: each copper of course enveloped in membrane. This battery is one of extraordinary power in decompositions and other effects of intensity, which, in my opinion, depends upon a new principle which is developed in this mode of construction and arrangement, that is, the *restricting* the electric current to gradually *diminishing metallic surfaces* as it advances, so that, as the quantity accumulates, the conducting surfaces are *reduced;* and of course a much higher degree of intensity is a necessary consequence."

One of the most powerful sustaining batteries for its size, and at the same time one of the neatest and most portable, is that of the Rev. John Shillibeer, A. M. of Oundle. The following description and figures are taken from Mr. Sturgeon's "Annals" for April 1837, p. 224:—

"Finding on trial that a single piece of zinc (surface three inches) surrounded by a gut or membrane, when placed in a copper vessel containing a solution of sulphate of copper, could be soon erected, and that a rotatory motion might be kept up during pleasure, I formed the apparatus about to be described, which consists of a well-made copper trough, about three inches deep and two and a quarter wide, divided into compartments, according to the number of zinc plates employed; vide fig. 49, which represents a section of the copper trough that receives the plates. These plates are soldered firmly to a copper bar, and by the aid of a screw are fastened to a piece of hard wood answering for a cover to the trough, which, with the zinc plates and movement for directing the course of the electric fluid, may be seen by a reference to fig. 50. In a groove cut out in the cover, on each side the screw, is fitted a copper slide; and these slides are joined by an elbow to a piece of ivory forming a handle, by which, passing immediately over the screw, each wing of the slide may be brought readily into contact with the copper or zinc. The use of this movement, or pole director, I will endeavour to make apparent.

In fig. 49, let A represent a section of the wood

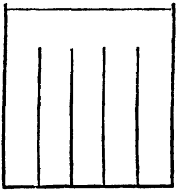

Fig 49.

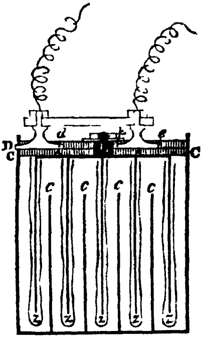

Fig. 50.

cover, with a groove for the slide to stand in. B the screw in connexion with the zinc. C, C, the opposite sides of the copper trough. D d, E e, the two wings of the slide. Now let the wing, D d, be in contact with C, and E e with B, it is evident that the stream of electricity is going out from the wire in connexion with the wing D d, and is returning by the wire appended to the wing E e, into the zinc plates, *via* B. Shift the slide so that E e be in connexion with C, and D d with B, the stream will be reversed, making its exit by E e, and returning by D d to the zinc *via* B.

The zinc plates should be covered tightly with a membrane, so as to prevent any possible precipitation of the sulphate of copper upon them. When used for suspending a weight, the membrane should be slipped off, and instead of the sulphate of copper, diluted nitrous acid should be used."

The same number (at p. 214) contains an account, by Mr. Bachhoffner, of a very simple and effective battery. To use that gentleman's own words:—"A piece of thin sheet copper is coiled up into the form of a cylinder, and retained in that position by fine copper wire. The size I usually employ is that of four inches by two and a half; it is then to be placed in a small bladder, which is secured round the copper by packthread, the top being left open, and the membrane forming the bottom of the cylinder; a piece of zinc is rolled up in a similar manner, a copper wire having been previously soldered to each zinc and copper plate, to form the connexion. The battery may be placed in a jelly-pot. To excite it, pour into the *copper* cylinder a saturated solution of the sulphate of copper. Outside of the copper, and in contact with the zinc, must be placed another solution—it matters little of what nature: one of common salt I find to be as good as any that I have tried, and it has the advantage of being cheap, and always at hand. If the battery is required to be kept in action for two or three days, a few crystals of the sulphate of copper must be added to the solution in contact with the copper."

It is evident that the plates in any of these modifications of the sustaining battery may readily be so connected as to form an effective compound battery, by connecting the zinc of one pair with the copper of the adjoining pair throughout. Mr. Clarke, of the Lowther Arcade, has devised a method of instantly forming the connexion between the pairs, so as to convert them either into a single battery, or into a compound one, at pleasure. The advantage of this contrivance is obvious.

In reference to the comparative merits of these and other various modifications of the sustaining battery, we confess that we are unable to offer an opinion; but we can confidently assert that so great are the advantages of the sustaining batteries over those of the old form, that no scientific inquirer ought to be without a series of them; and we should recommend him to provide himself at once with one to which the arrangement of Mr. Clarke is attached, for forming the connexion between the similar or dissimilar metals of adjoining pairs at pleasure.

Although many gentlemen still adhere to the old form of arrangement, and continue the use of dilute acid as the conducting liquid in their voltaic apparatus, there can be little doubt that the great and obvious advantages possessed by the "sustaining" or "constant batteries" will very soon obtain for them a decided preference.

CHAPTER XVI.

The Effects of Galvanism.

We have seen that the ordinary electricity, as obtained by the common electrical machine, manifests its presence by various positive and striking indications. Light bodies are attracted by an electrified conductor, and when they become similarly electrified to the conductor, they are repelled. The divergence of the gold leaves of the gold-leaf electroscope indicates the high state of elasticity and mobility, or tendency to diffuse itself among such surrounding bodies as are capable of receiving it. But the indications of the presence of electricity at the extremities, or in any part of the voltaic battery, even during an interruption in the circuit by the separation of the conducting wires, are comparatively feeble, although the quantity of electricity which is developed may be very great. When the circuit is completed by bringing the conducting wires into contact, the electroscope affords no indication of the presence of the quantity of electricity which is in rapid circulation. From a single combination of plates, such as that of the calorimotor, no attractive or repulsive effect can be obtained, unless electroscopes of very extraordinary sensibility are employed. With those of the usual construction, no indication of the presence of electricity is afforded either in the zinc or copper plate when separated by an acid solution. But by means of the condenser, electrical appearances may be detected either in the voltaic pile or battery; the opposite extremities of which will be found to be in opposite states. A series of fifty groups will affect a delicate electroscope with the aid of the condenser. The divergence is sufficiently distinct with one hundred pairs; and with a series of one thousand groups, even pith-balls are made to diverge. In these experiments, a wire proceeding from one extremity of the battery is to be connected with the foot of the electroscope, whilst a wire proceeding from the opposite extremity is made to touch its cap. The electricity of the zinc end is always positive, that of the copper end always negative.—(*Singer*, 329.) The ends of the conducting wires being in opposite electrical states, will be found to attract each other when they are brought together. —(*Biot*.)

By means of a condensing electroscope of great sensibility, M. Bequerel has ascertained that even in a single pair of zinc and copper plates not in contact with each other, but only immersed in an oxidating fluid, the zinc plate gives indications of negative electricity, and the copper plate of positive. From what has already been said respecting the directions of the electric current in single and compound batteries, it will be obvious that this result, although apparently contrary to that which obtains in a composite battery, is a necessary consequence of the peculiar arrangement of the plates. The electric state of the two ends of the compound battery was first ascertained by Messrs. Nicholson and Carlisle. —(*Nicholson's Journal*, 4to. iv. 174.)

One of the most remarkable of the results of ordinary electrical induction is exemplified in the capacity of accumulation possessed by the Leyden jar and electrical battery. The electricity derived from galvanism is also capable of being accumulated in those instruments. If wires proceeding from each extremity of the voltaic battery are respectively connected with the inner and outer coatings of an electrical battery of not less than twelve square feet of coated surface, the latter will be instantly charged, and all the usual electrical experiments may be performed with it in this state, when removed from the voltaic battery. If, instead of removing the electrical battery, its connexion with the voltaic apparatus be continued, sparks may be obtained from it in rapid succession, by connecting a wire with the outer coating, and repeatedly striking the knob with the other end of the wire. And so strong are these sparks, when the charge is communicated by a series of three or four hundred alternations, that the end of the wire (if of iron) is made to scintillate, or throw off abundance of its own particles in a state of combustion. With a series of one thousand, the sparks are attended by a distinct crackling noise, and have sufficient power to burn thin metallic leaves. This is the more remarkable, as the voltaic apparatus, whence the electric battery has derived its power, may itself be too weak to produce this effect. —(*Singer*, p. 331.) It always happens, indeed, that a single jar is charged by contact with a voltaic apparatus, excited merely by water, to a degree of intensity rather greater than that of the apparatus itself, and it will consequently affect an electroscope somewhat more distinctly. In all cases the full charge is communicated by the shortest possible contact with the voltaic battery. In the experiments made by Van Marum and Pfaff, a battery having 137½ square feet of coated surface was charged to the same degree of "tension" as the pile with which it was made to communicate, by a contact which did not last for the twentieth part of a second.—(*Annales de Chimie*, xl. 289.)

We have already observed that the transit of any considerable quantity of electricity through the air is always attended with the evolution of light, and generally in the form of a spark, or luminous train. Galvanic electricity, if of sufficient intensity, gives rise to a similar phenomenon. At the moment of contact between the conducting wires of a voltaic battery, composed of a considerable number of alternations, a distinct spark is obtained, which occurs every time the contact is broken and renewed. But the most striking effect is produced, by placing pieces of charcoal, shaped like a pencil, at the two ends of the wires in the interrupted circuit, and bringing their points into contact. The appearances were singularly beautiful, when this experiment was tried with the large battery at the Royal Institution. When the pieces of charcoal were brought within the thirtieth or fortieth part of an inch of each other, a bright spark was produced, and at the same time more than half the volume of the charcoal, which was about an inch long, and 1-6th of an inch in diameter, became ignited to whiteness. By withdrawing the points from each other, a constant discharge took place through the heated air, in a space equal at least to four inches, producing a most brilliant arch of light, of considerable breadth, and in the form of a double cone. Any substance introduced into this arch instantly became ignited; platina melted like wax in the flame of a candle; quartz, the sapphire, magnesia, and lime, were fused: fragments of diamond and points of charcoal and plumbago disappeared, and seemed to evaporate in it, even when the connexion was made in a receiver exhausted by the air-pump; but there was no evidence of their previous fusion. When the communication between the charcoal points was made in the receiver of an air-pump, the distance at which the discharge took place increased as the exhaustion proceeded; and when the air in the vessel supported only one quarter of an inch of mercury in the barometrical gauge of the air-pump, the sparks passed through the space of nearly half an inch, and by withdrawing the points from each other, the discharge was made through six or seven inches, producing a most brilliant coruscation of purple light, while the charcoal itself became intensely ignited, and some platina wire attached to it fused with bright scintillations, and fell down in large globules.—(*Davy's Elements of Chemical Philosophy,* p. 152–154.) The light thus produced by galvanic electricity, is more vivid and intense than any other light that can be artificially produced, not excepting even that of the oxy-hydrogen-lime light. It is so dazzling as to fatigue the eye even by a temporary glance, and effaces by its superior lustre the light produced by lamps in an apartment otherwise brilliantly illuminated, and which, on the sudden cessation of the galvanic light, appears for a short time as if left in darkness. One great difficulty in the way of rendering this extraordinary light practically useful, has already been overcome by the introduction of the sustaining batteries. Another great objection to its employment is the destruction of the charcoal, which renders it necessary to bring fresh portions of that substance into contact. If it is true (as has been stated) that this can be remedied by completing the circuit in a vessel exhausted of air, or in an atmosphere of azote, it is to be regretted that a trial has not been made with apparatus sufficiently extensive and perfect. But we should certainly prefer a very extensive series of Wollaston's batteries, brought into action by water only, to those even which are termed "sustaining batteries." In this case, the only expense attendant upon the batteries would be the first outlay for their construction; the action would be steady and uniform, and the trouble required in their care very trifling. It has been said that the light is evolved with equal splendour when the experiment is made in gases that contain no oxygen, such as azote or chlorine, and in which, therefore, combustion could not be maintained, and that "no change takes place either in the gas or charcoal in these experiments;" but we must admit that we are sceptical as respects such a result with chlorine. It remains for those who have the necessary means to repeat these experiments; and if the results be as stated, we may yet live to see the day when this light shall be applied to the purpose of illuminating our light-houses; when the same subtle fluid which guides the mariner in his trackless course, by its magnetic influence, shall also shed its radiance far and wide, over the waters of the deep, in the place of darkness, showering upon the midnight billow gems of light.

The galvanic light is also obtained, though with diminished intensity, under water, ether, oils, alcohol, and other fluids of imperfect conducting power.

Mr. Maugham has suggested the application of the galvanic light to diving bells.—(*Railway Magazine.*)

The phenomena which we have described in reference to the galvanic light may be exhibited on a small scale by a battery of Wollaston's construction of 100 pairs of plates, or with a compound sustaining battery of twelve pairs of cylinders. With the former the arched form of the stream of light is often very perceptible, when the distance between the charcoal points does not exceed half an inch. Charcoal made from some of the harder woods, such as beech, lignum vitæ, or box-wood, is the best for these experiments, and it should be carefully prepared.

The common electrical apparatus never exhibits any heating effect, except upon a sudden restoration of the equilibrium of the fluid—an event which is always accompanied with the appearance of light; and even then the rise of temperature may, perhaps, be attributable rather to the mechanical concussion which the particles sustain during this violent action, than to any direct property which is due to the electric fluid itself of producing heat. but in the voltaic apparatus, an increase of temperature is observed to take place, when the circuit remains complete, and when no light is evolved. The mere passage of voltaic electricity through bodies raises their temperature; and when the apparatus is of sufficient power, and the size and nature of the conductors are proportioned to the quantity of electricity to be transferred, the most intense ignition is produced.—(CUTHBERTSON, in *Nicholson's Journal*, viii. 97.) Fine iron wire, being made the medium of connexion between the extremities of the battery, becomes ignited, and may be fused into balls; steel-wire burns rapidly, and with great brilliancy; platina-wire may be kept at a red, or even white heat, for an indefinite length of time: indeed, so long as the battery preserves its power, there appears to be no limit to the continued evolution of heat This voltaic production of heat may be elegantly exhibited by passing a wire through a known quantity of water contained in a vessel in which a thermometer is placed. As soon as the wire is made to form part of the galvanic circuit, the thermometer rises, and rapidly advances to the boiling point; after which the ebullition continues with great steadiness. The time required for raising the water to the boiling point, or the quantity evaporated during a certain time, will afford tolerably accurate modes of estimating the quantity of electricity that has passed through the wire.

The oils, alcohol, ether, and naphtha, are easily inflamed when charcoal points in the circuit of the battery, and in ignition, are brought near each other on the surface of these fluids. But if the charcoal points are previously plunged below the surface of these fluids, no inflammation takes place. The order of the metals, as regards their facility of being brought to a state of red heat by voltaic electricity, is as follows:—platina, iron, copper, gold, zinc, and silver. Between gold and copper the difference is trifling. In reference to platina and iron, their relations to each other, in this circumstance, seem to be affected by elevation of temperature. The places which tin and lead should have occupied in the scale, cannot be ascertained, as they melt before they acquire a red heat. These results were obtained by Mr. Children, and since it appeared that the facility with which the metals were ignited varied inversely as their conducting power for electricity, he inferred that the degree of resistance to the passage of the electric current was the circumstance that occasioned the development of heat in all these instances. The fact, however, that the greatest heat is produced in air, when there is reason to suppose the least resistance, is, as Sir H. Davy observes, in opposition to this theory. In the *Philosophical Transactions*, for 1815, (pp. 368–370,) an account will be found of the most considerable effects of Mr. Children's battery.

When thin leaves of the metals are made the medium of communication between the two extremities of the battery, they take fire, and by continuing the action they may be made to burn with great brilliancy. The following is a convenient method of performing these experiments. The metallic leaves are suspended to a bent wire proceeding from one extremity of the battery. Connexion is to be made with them by means of a broad plate of metal united with the opposite extremity. If the plate is covered with gilt foil, the brilliancy of the effect is increased. Gold leaf burns with a vivid white tinged with blue, and produces a dark purple or brown oxide. Silver leaf emits a brilliant emerald-green light, and leaves an oxide of a dark grey colour. Copper produces a bluish-white light, accompanied by red sparks; its oxide is dark brown. Tin exhibits nearly the same appearances, but its oxide is of a lighter colour. Lead burns with a beautiful purple light; and zinc with a brilliant white light, inclining to blue, and fringed with red. For the distinct appearance of these colours, it is necessary to make the contacts with metal; for if charcoal is used, the vivid white light it emits effaces the colours produced by the combustion of the metal.—(*Singer*, p. 409; and *Philosophical Magazine.*)

When a slender iron wire, connected with one extremity of a powerful battery, is made to touch the surface of mercury connected with the other extremity, a vivid combustion of both metals is produced, sparks are dispersed in profusion on every side, forming thousands of rays, as if proceeding from a star or sun of considerable diameter. The effect may be continued at pleasure by gently depressing the extremity of the iron wire, in proportion as the metallic particles are dispersed by the combustion.

These effects of galvanism, as contrasted with those of ordinary electricity, are highly instructive, as demonstrative of the vast quantity of electricity evolved by the voltaic apparatus. In the case of an electric battery, the violence with which the discharge instantaneously forces itself through the substances which lie in its way, produces all the effects of a powerful mechanical concussion, and the heat which may occasionally be evolved, seems to be merely a remote consequence of the forcible compression and sudden collision of the particles of the body during the momentary transit of the electricity. On the contrary, one of the immediate and direct effects of the passage of galvanic electricity is an elevation of temperature, while the mechanical texture of the substance remains unchanged. Charcoal, which is readily ignited by galvanic electricity, sustains a powerful discharge of common electricity without its temperature being sensibly raised. As to the circumstances on which the igniting power depends, the reader is referred to *Thomson's Annals of Philosophy*, vi. 209; *Nicholson's Journal*, vii. 207, viii. 97 and 105, xxix. 32; *Singer*, 412; *Elements of Chemical Philosophy*, 156; *Annals of Philosophy*, viii. 317, &c.

CHAPTER XVII.

Electro-Magnetic Effects of Galvanism, Galvanascope, Electrical Telegraphs, &c.

FOR a long period our knowledge of the operations of electricity was confined to its more ordinary forms, and there was little probability that the circumstances attending its connexion with magnetism would ever be discovered. By supplying the means of putting into motion a vast quantity of electricity, and of continuing its circulation for a considerable period, galvanism has enabled us to detect its influence on the magnetic needle, and to ascertain the laws of its action; and the influence which the transit of electricity through conducting bodies exerts upon magnetism, with the resulting effects, now forms one of the most remarkable and interesting subjects of modern science. In fact, electro-magnetism is now a distinct science, and a volume would scarcely suffice for the description of the phenomena. Indeed, although the discovery of the relation between electricity and magnetism is of recent date, we find we cannot afford space even for an outline of the history of the science.

The power of lightning in destroying or reversing the magnetic polarity of the needle, and in communicating magnetic properties to pieces of iron, was noticed at an early period of the science of electricity, and led to the supposition that similar effects might be produced by the common electrical machine and the voltaic apparatus. Attempts were accordingly made to communicate the magnetic property by means of electricity and galvanism; but although success so far crowned their inquiries that the effects of lightning above alluded to were imitated, no results of importance were obtained until the winter of 1819, when Professor Œrsted, of Copenhagen, made the discovery which forms the basis of the science of electro-magnetism.

Professor Œrsted observed that the metallic wire of a closed voltaic circle (and the same is true of charcoal, saline fluids, and any conducting medium which forms part of a closed circle,) causes a magnetic needle placed near it to deviate from its natural position, and to assume a new one, the direction of which depends upon the relative position of the needle and the wire. On placing the wire above the magnet and parallel to it, the pole next the negative end of the battery always moves westward; and when the wire is placed under the needle, the same pole moves towards the east. If the wire is on the same horizontal plane with the needle, no declination whatever takes place; but the magnet shews a disposition to move in a vertical direction, the pole next the negative side of the battery being depressed when the wire is to the west of it, and elevated when it is placed on the east side. Ampère has suggested a useful aid for recollecting the direction of these movements. Let the observer regard himself as the conductor, and suppose an electric current to pass from his head towards his feet, in a direction parallel to a magnet, then its north pole in front of him will move towards his right side, and its south pole to his left. The plane in which the magnet moves is always parallel to the plane in which the observer supposes himself to be placed. If the plane of his chest is horizontal, the plane of the magnet's motion will be horizontal; but if he lie on either side of the horizontally-suspended magnet, his face being towards it, the plane of his chest will be vertical, and the magnet will tend to move in a vertical plane.

The extent of the declination, or, as it has also been termed, the deflection occasioned, depends upon the power of the voltaic circle, and the distance of the connecting wire from the needle. When the influence of the magnetism of the earth is neutralized by means of another magnet, the needle will place itself directly across the connecting wire; so that the real tendency of a magnet is to stand at right angles to an electric current.—(*Turner's Elements of Chemistry*, 5th edit. p. 170.)

We trust that we shall now be prepared to understand the *modus operandi* of the galvanometer, or galvanascope, an instrument which has often been referred to as indicative of the direction and force of electric currents. In this instrument some peculiar arrangements are required, in order to ensure the requisite delicacy and precision. Experiment proves that a magnet is equally affected by every point of a conductor along which an electric current is passing, so that a wire transmitting the same current will act with greater or less energy according as the number of its parts contiguous to the needle is made to vary. On this principle is constructed the *Multiplier*, or *Galvanascope*, of Schweigger. A copper wire is bent into a rectangular form, consisting of several coils, and a needle is so suspended as to hang in the centre of the rectangle, as shewn in fig. 51. Each coil of wire adds its influence to that

Fig. 51.

of the others; and as the current, in its progress along the wire, passes repeatedly above and below the needle in opposite directions, their joint action is the same. In order to prevent the electricity from passing laterally from one coil to another in contact with it, the wire should be covered with silk. The ends of the wire *a* and *b* are left for the purpose of communication with the opposite ends of the voltaic circle. This instrument has been greatly improved, and cups to contain mercury are now used, in place of the ends of the wires. When a single needle is employed, as shewn in the figure, its movements are influenced partly by the earth's magnetism, and partly by the electric current. The instrument is much more delicate when the needle is rendered *astatic*, as it is termed, that is, when its directive property is destroyed by the proximity of another needle of equal intensity fixed parallel to it, and in a reversed position, each needle having its north pole opposed to the south pole of the other: in this position, the needles, neutralizing each other, are unaffected by the earth's magnetism, while they are still subject to the influence of the galvanic current. If, as in the last figure, the lower needle is suspended within the rectangle, and the upper needle just above it, the current between will act on both in the same manner. For researches of delicacy the needle should be suspended by a long thread of glass, and the deflecting force measured, not by the length of the arc traversed by the needle, but by the torsion required to keep the needle at a constant distance from the wire.

The mutual influence of a magnetic pole and a conducting wire changes with the distance between them. Experiment shews that the action of a magnetic pole and a continuous conductor, every point of which exerts a separate energy on the pole, varies inversely as the distance. This result justifies the opinion that the force of a magnetic pole on a *single* point of a conductor varies as the square of the distance—the same law which regulates the distribution of light and heat, as well as the effects due to electricity.—(*Turner's Elements of Chemistry*, 5th edit. p. 172.)

On the principle of the action between electric currents moving along conducting wires and magnets, are founded the various contrivances for effecting telegraphic communications. The most complete and successful method is that of Mr. Cooke, through whose polite attention we were favoured with a view of the apparatus, and had the pleasure of witnessing the experiments on the London and Birmingham Railroad. In one of the experiments the electric fluid traversed a copper conducting wire fourteen miles long.

A voltaic telegraphic apparatus has recently been constructed in the Adelaide-street Gallery of Science, under the direction of Mr. Bradley, Superintendent of that Institution.

CHAPTER XVIII.

Chemical Effects of Galvanism.

A SOLITARY chapter on this branch of our subject has generally been given in treatises on galvanism; but a large volume would now scarcely suffice for the proper consideration of the various and extensive, nay, it may be said the unlimited, applications of the voltaic battery in effecting chemical changes. It is a subject of the highest degree of interest and importance; and since the remarkable experiments of M. Becquerel, and of Andrew Crosse, Esq. of Broomfield, have been made known, it has excited an intense interest in the public mind.

The power of the galvanic fluid to effect changes in the composition of bodies subjected to its action is much greater than that of electricity, commonly so called; and its application has led to a series of the most brilliant discoveries in the annals of physical science. This chemical agency is manifested when the fluid meets with impediments to its passage, being exerted chiefly on substances which are imperfect conductors. We shall first attempt to elucidate what takes place in the simplest galvanic circle composed of two metals and an interposed fluid. If a plate of zinc and one of copper are immersed in very dilute sulphuric acid, without touching each other, chemical action takes place between the zinc and the acid; part of the water is decomposed, its oxygen combining with the zinc, forming oxide of zinc, the hydrogen being liberated in the form of gas from the surface of the zinc plate. The oxide of zinc, as it is formed, is dissolved by, and enters into union with the acid, forming sulphate of zinc. The plate of copper undergoes no change, the acid in its diluted state being incapable of acting chemically upon it. But, while the above chemical process is going on, if the metals be brought into contact, or a communication be made between them by means of some conductor, the following changes will ensue: the oxidation of the zinc will proceed more rapidly and energetically, and it will not be accompanied by the evolution of the same quantity of hydrogen gas from the oxidating surface. And although the hydrogen will be disengaged from the whole fluid in quantity exactly corresponding to the amount of oxygen derived from the water, the greater part of the hydrogen gas will now make its appearance on the surface of the copper plate, from whence it will be seen arising in a copious stream of bubbles, the copper still remaining apparently unaffected. In process of time, when a considerable proportion of sulphate of zinc is held in solution by the fluid, the quantity of disengaged hydrogen gas is found gradually to diminish, and a thin film, composed partly of metallic zinc, and partly of filaments of oxide of zinc, is deposited on the surface of the copper, and then the galvanic action ceases.

If nitric acid be used, which is capable of acting upon the copper as well as upon the zinc, similar phenomena will take place, with the additional circumstance that the action between the copper and the acid will cease the instant the galvanic circle is completed. Then also the disengagement of nitrous gas, which before the completion of the circuit was evolved from the surface of the copper, will cease, and hydrogen only will be liberated. The copper is protected from all further action, the zinc being, as in the former case, oxidated and dissolved with additional energy. On this principle Sir H. Davy has effected the protection of the copper sheeting of ships from corrosion, by placing in contact with it pieces of zinc or iron, which is more readily oxidated than the copper.—(*Phil. Trans.* for 1824, p. 151, and 242; and for 1825, p. 328.)

At one of the recent meetings of the Electrical Society of London, my friend Martyn Roberts, Esq. observed that the same principle might be applied to the protection of gilded signs for shops. In taking a forenoon's walk, he remarked that in a sign of this description one half of the letters were completely tarnished, while the others remained bright. He was induced to examine the sign a little more closely, to trace, if possible, this curious effect to its cause.

He found that some of the nails by which the letters were fastened, were covered with putty or paint: it was in those parts that the metallic letters had become tarnished. Where they retained their lustre, the nails had either not been so covered, or the coating had been rubbed off, and they had undergone oxidation. Mr. Roberts concluded that the protection of the gilded letters depended upon the same principle as that which Sir H. Davy applied to the preservation of the copper sheeting of vessels. There is no doubt that the principle admits of application to many other useful purposes.

We beg leave to suggest the following application:—In all copper vessels used by cooks, confectioners, &c. if the greatest possible care be not taken to keep them perfectly clean, the metal becomes oxidated, and it is well known that all the salts of copper are highly poisonous. Indeed, in cases where any acid is present in the ingredients contained in the vessel, oxidation must take place to a greater or less degree, and the poisonous compound will be held in solution by the contents. We presume, however, that if a strip of zinc were to be soldered to the copper vessel, so that it may pass vertically down its sides, and also along the bottom, that the oxidation of the copper would be prevented.

The same chemical changes take place in compound batteries in each of the portions of fluid intervening in the compartments between the plates. And it sometimes happens that the zinc plates become so thickly incrusted with the nitrate of the oxide of zinc, (when nitric acid is used,) as to prevent further action between the fluid in the cells and the zinc. The copper then becomes the positive metal in the battery, and the zinc negative, chemical action taking place between the copper and the acid. When the battery is in this state, if we were not aware of the cause of this action, we might deceive ourselves by imagining that electro-positive elements were given off at the positive pole, and electro-negative bodies at the negative pole.

In those batteries in which a membrane and the sulphate of copper are used, metallic copper is precipitated, and attaches itself to the copper plate, while the sulphate of the oxide of zinc is held in solution, and is often obtained in well-formed large crystals in old batteries which have been allowed to stand for some time with the liquid in the jar.

When fluid conductors are placed in any part of the circuit by which the two poles of the battery are brought into communication, still more remarkable chemical actions take place. The first discovery of the chemical agency of galvanism was its power of decomposing water. This was one of the earliest fruits of Volta's invention of the pile, and is due to Messrs. Carlisle and Nicholson.

Let two metallic wires be inserted in a glass tube in the manner represented in fig. 52, by passing one at each end through the cork which closes the orifice, allowing the extremities of the wires that are in the water to be separated by an interval of only one-fourth of an inch. On a communication being made between these wires and the two poles of a voltaic battery, the following phenomena ensue:—

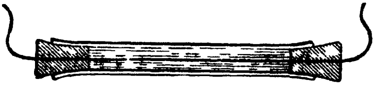

Fig. 52.

If the wire in connexion with the positive pole of the battery is an oxidable metal, it becomes rapidly oxidated, while a stream of bubbles of oxygen gas arises from the surface of the other wire connected with the negative pole. But if the wires consist of a metal which is not susceptible of oxidation in water, such as gold or platina, gases will be extricated from both the wires, and by means of a simple apparatus may be collected separately. This may be effected by inverting two glass tubes filled with water in a glass containing water. Each tube is to be furnished with a platina wire passed through the closed extremity, and descending within it through its whole length. The open ends are then to be placed as near to each other as their position in the water will allow, and the wires are to be connected respectively with the opposite poles of a voltaic battery. Gas will immediately be seen to rise from each of the wires, but in different quantities. The tube containing the wires connected with the negative pole will be soon filled with hydrogen gas, while the other, which contains the positive wire, will, in an equal time, be only half filled with oxygen gas. The reason of this is, that these two gases which compose water unite in that proportion *by volume* to form that fluid, the volume of the hydrogen being to that of the oxygen as two to one. That the water is thus perfectly resolved into its elements is satisfactorily proved by mixing together the gases thus obtained, and exploding the mixture by the electric spark; when the whole instantly loses its gaseous form, and is reconverted into water.

We have given a description of the apparatus in its most simple form: but it has been greatly improved, and is now used as a measure of the intensity of a battery, that being the best which decomposes the greatest quantity of water in a given time. It was first happily used for this purpose by Dr. Faraday, who gave it the name of the Volta-meter.

If the water employed is not perfectly pure, other substances will make their appearance at the two wires, a circumstance which occasioned great perplexity to the earlier experimentalists. But Sir H. Davy proved that when every precaution is taken to ensure the purity of the water subjected to the galvanic action, the only products obtained are the two elements of water, (oxygen and hydrogen,) in their gaseous form.

Under the influence of galvanic electricity neutral salts existing in any solution are decomposed, the acid portion being accumulated round the positive wire, on the same points where the oxygen was liberated in the first-named experiment; while the bases, whether earthy, alkaline, or metallic, are at the same moment transferred along with the hydrogen to the negative wire. To exhibit these decompositions two cups are to be used, made of glass, or, if precision is requisite, of agate or gold; the liquids contained in these cups are to be connected together by a few fibres of moistened asbestos, and subjected to the action of the voltaic battery. Nor is it requisite that the body placed in the circuit should be possessed of considerable solubility. Two cups made of compact sulphate of lime, containing pure water, were connected together by fibrous sulphate of lime, moistened by pure water, and the galvanic current transmitted through them. An hour having elapsed, the fluids were accurately examined, when it was found that the negative cup contained a pure and saturated solution of lime, partially covered with a calcareous crust: the positive cup contained a moderately strong solution of sulphuric acid. Sulphate of strontites and fluate of lime yielded similar results; sulphate of barytes was also decomposed, though with more difficulty, on account of its greater insolubility. The analysis of many minerals, whose composition was much more complicated, was greatly elucidated by the action of galvanic electricity, which liberated all the acid and alkaline matters they contained.

The decomposable body may be placed in any part of the fluid line of circuit. Place three cups, side by side, in a line, (fig. 50,) and connect them together by moistened asbestos. Put a solution of the sulphate of potass, or any other neutral salt, into the middle cup, and blue infusion of cabbage into the two outer cups. In the two latter cups immerse the two wires of the battery, and the sul-

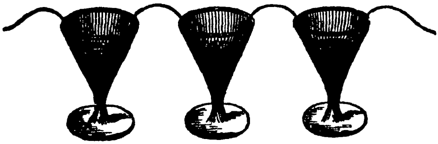

Fig. 50.

phuric or other acid will appear in the positive cup, and render the blue infusion red; the alkali will pass into the opposite (the negative) cup, and tinge the infusion green.

When electro-decomposition of metallic solutions takes place, the metal is deposited on the negative wire, generally in the form of minute crystals, and oxide is also deposited around it; the acid at the same time passing over, as before, into the positive cup. This effect occurs with solutions of iron, zinc, and tin, as well as with the more oxidable metals.

A solution of the nitrate of silver being placed on the positive side, and distilled water on the negative, a thin film of metallic silver covers the whole of the asbestos which forms the connexion.

But Sir H. Davy observed phenomena still more extraordinary in the further prosecution of his inquiries. The elements of compound bodies were actually conveyed by the galvanic influence through solutions of substances, on which, under ordinary circumstances, they would have exerted an immediate and powerful chemical action, without any chemical effect whatever being produced. *Ex. gr.* acids may be transferred from one cup, in connexion with the negative pole, to another cup connected with the opposite pole, through a portion of fluid in an interposed cup tinged with any of the vegetable-coloured infusions, (which are reddened by the presence of an acid,) without occasioning any change of colour. The same occurs also with al kalies. If cups are placed as before (see fig. 50), and connected with each other in a series by moistened cotton, the middle cup, and that next to the positive side of the battery, containing blue infusion of litmus, or of cabbage, and the cup next to the negative side containing a solution of sulphate of soda, on the circuit being completed through the fluids in the cups, the solution in the positive cup will be tinged red, and will become strongly acidulated. The sulphuric acid thus transferred must have passed through the fluid in the middle vessel, without affecting the coloured solution in its passage. On reversing the connexion between the poles of the battery, a similar transfer of the alkali occurs; it will be collected in the tinged water of the positive cup, which it will render green. The intervening portion of the fluid, either in this case or the former, will not exhibit any trace of the substance which is transmitted through it by the galvanic influence.

When an acid is thus transmitted through an alkali, or *vice versâ*, no union takes place, provided the compound which they would form remains soluble; but if the compound is insoluble, the union takes place, and the product, on falling to the bottom of the fluid, by virtue of its gravity, is removed from the line of the electrical influence. Thus, if we attempt to pass sulphuric acid through a solution of barytes, or *vice versâ*, the result is sulphate of barytes, which, being insoluble in the fluid, falls down, and being removed from the electric current, proceeds no further in its course. But if this removal from the galvanic influence be prevented by some basis of mechanical support, the transfer may sometimes be effected, although the body may have become solid; thus, magnesia or lime will pass along moist asbestos from the positive side to the negative; but the interposition of a vessel of pure water is sufficient to prevent this transfer. They do not then reach the negative vessel, but sink to the bottom. So, when nitrate of silver was on the positive side, in the former experiment, and distilled water on the negative, the silver passed along the fibres of the asbestos, and covered it with a thin metallic fibre.

When the connexion between the fluids in the same voltaic circuit is made by pieces of metal, the changes above described take place in each separate portion of fluid, each connecting wire or strip of metal between the cups being positive or negative according to its place in the circuit. Those wires into which the electricity is entering, act as negative wires; those which are giving exit to the fluid act as positive wires. Around the former the several bases of neutral and metallic salts, and the hydrogen of the decomposed water, will collect, while the latter will collect around it oxygen, the acids, and compounds in which oxygen predominates.

This brilliant career of discovery was crowned by the decomposition of the alkalies and the earths, which is theoretically only a particular instance of the general fact that combustible bodies are carried to the negative wire, and oxygen to the positive wire.

Sulphuric acid is resolved by galvanic action into oxygen gas, which is evolved at the positive wire, which is oxidated, if it consists of an oxidable metal, and sulphur is deposited at the negative wire. Phosphoric acid yields oxygen gas and phosphorus; ammonia is separated into hydrogen and azote, and a small proportion of oxygen; oils, alcohol, and ether, subjected to the action of a powerful battery, deposit charcoal, and evolve hydrogen or carburetted hydrogen.

Mr. Brande has shewn that when animal fluids, containing albumen, are placed in the voltaic circuit, the albumen is separated in combination with alkali at the negative wire, and in combination with acid at the positive wire. If the battery is powerful, the albumen separates, and appears in the solid form at the positive wire, but in the fluid form, if the battery is weaker; a fact which gives weight to the hypothesis, that electricity is concerned in the animal process of secretion.—*Phil. Trans.* for 1809, p. 385.

CHAPTER XIX.

Of Electro-crystallization.—Mr. Crosse's Experiments; formation of various Crystals by Galvanic action.—Of the probable agency of Electricity in determining the forms of Vegetables and Animals.—Electricity of the Tourmalin, and other minerals.—Questions respecting the relation between Electricity, Light, and Heat.

Closely connected with the phenomena described in the last chapter, and depending upon the same action, is the agency of the electric fluid in effecting crystallization. Andrew Crosse, Esq. of Bromfield, and M. Becquerel, have distinguished themselves by their experiments on electro-crystallization. The former gentleman has most obligingly favoured us with two communications on the subject of his experiments, which we hasten to lay before our readers; convinced as we are that Mr. Crosse's experiments have excited a deep and general interest. Mr. Crosse, in his first communication, dated 21st June, 1837, thus writes: "I have lately been making some interesting experiments on the injurious effects of light in electrical crystallization. Of this, which I have long expected, I am now convinced. Amongst other experiments, I filled a large glass jar with lime water, and suspended in it a coil of stout copper wire, and put it away in a dark place. In a few months the wire was covered with brilliant crystals (hexædral) of carbonate of lime, apparently 1-16th of an inch in length, or perhaps longer. I then removed the jar, &c. into the light, and in the course of about six weeks the crystals *entirely disappeared.* I have lately formed by electrical action, in addition to my former experiments, fluate of lime in cubes; very fine transparent crystals of sulphur; a variety of red oxides of copper; sulphate of barytes in tabular and needle crystals; sulphate of strontia; a new formation, containing lead, copper, and zinc, combined with a very large proportion of sulphur, forming a super-sulphuret, in most brilliant crimson prismatic crystals; and I have formed also some very fine specimens of sulphuret of zinc in rather large and exceedingly well-formed and brilliant crystals. Had my experiments been made in the dark I should have saved much time and labour."

The following is an extract from the other letter, dated August 4th, 1837:—"I have within the last two months obtained some very interesting results, and I think I may say have made another step in the mode of procuring or producing crystals, viz. by *transferring the electric energy from the zinc and copper plates* to other substances, *not metallic,* in contact with them. Thus, by causing the combined metallic arcs to rest upon quartz or limestone, I have altered the direction of the crystallizing action, and transferred it to those substances. In this way I have covered a piece of limestone with very perfect rhomboidal crystals of selenite, or sulphate of lime, which exactly resemble nature, and bear the scrubbing-brush quite as well as those taken out of a mine or quarry. I have likewise in the same manner covered a piece of quartz with crystallized sulphate of lead, and have other experiments in action which I cannot yet disturb, in which to all appearance I have crystals of quartz growing upon pieces of natural massive quartz. I am more than ever of opinion that it is possible to form artificially every kind of mineral found in the earth."

Among other questions which I took the liberty of asking Mr. Crosse, in my letter to him, I inquired whether he had observed any difference in the action of his batteries which seemed to depend upon their position as regards the magnetic meridian. The following extract from Mr. Crosse's letter will shew that in the course of his experiments he had noticed an effect which may or may not result from the position of the battery:—

"In one of my experiments, I have a thin incrustation of metallic copper covering to a great extent the surface of a solution of acetate of copper, and growing from the upper edge of a negative copper plate, in layers, one growing out of the other. In this experiment, the arc of zinc and copper is placed in the magnetic meridian; and it is curious to observe that on the *eastern* side the layers of copper only extend to the distance of 3-4ths of an inch from the eastern edge of the copper plate, whereas on the *western* side the layers of copper extend to the distance of *two inches and 3-4ths of an inch* from the western side of the same copper plate. Whether this depends on magnetic or other causes I cannot say.

"In another experiment, I have formed a specimen of *magnetic* oxide of iron, but not possessing polarity. In another I have formed a *mineral fungus*, in the shape of a common trumpet-mouthed fungus, which is found on trees, &c. It grew out of an electrified jar filled with hydro-sulphuret of potash, and is 3-4ths of an inch in length, and 1-4th of an inch in diameter. Whether it would have grown in an unelectrified jar I am ignorant."

From Mr. Crosse's experiments and those of M. Becquerel, it is obvious that crystallization is an effect of galvanic agency. In treatises on crystallography we read of the motions of moleculæ, and of a disposition in them to move in such directions as to cause them to assume certain forms. But there must be some material agent to cause such a motion; and as the presence of electricity can be detected during the process of crystallization, as well as during all other chemical actions, we may infer that it is the immediate cause of the motions of the moleculæ, and that the forms of the crystals are dependent upon the resistance with which the electric fluid meets in its passage, and upon the electro-chemical nature of the moleculæ to which it imparts motion. For the form of the route of free electricity is modified by the medium through which it passes, and also by the electrical state of such medium, or of that of the relative electrical conditions of two bodies between which it is transmitted. If the medium through which it passes possesses a very inferior conducting power, it is obvious that a certain momentum must be requisite to enable the fluid to force its passage to a given distance, and there will be a point at which the momentum of the fluid and the resistance of the body will exactly counterbalance each other; but so soon as the electricity has again accumulated to a sufficient degree to overcome the resistance, it will again force its way in another direction, until it arrives at another point of equilibrium. In this way we may readily see the *modus operandi* of the electric fluid in imparting regular forms to bodies; and it is highly probable that its action in this respect extends to the vegetable kingdom, and, perhaps, operates also even on animals, from the time in which they exist in the embryo state. If our readers now refer to figure 51, they will at once perceive in what way the distinctive forms of bodies may be influenced by the passage of the electric fluid. Diagram *a* represents the appearance of the electric light when a discharge takes place between a negative body and one in its natural state; at *b*, the fluid is passing from a positive body to one in its natural state; at *c*, from a positive ball to a negative one; at *d*, from a positive conductor to another in its natural state; at *f*, to a negative conductor; and

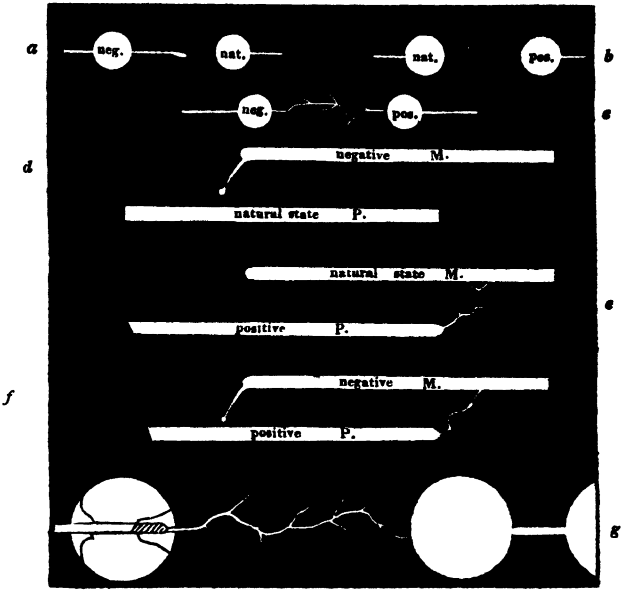

Fig. 51.

at *g*, the electricity is passing from a point inclosed in a large ball to another ball. We have no reason to doubt that the galvanic fluid is influenced in a similar way during its passage through different media, and it will be the more easily retarded in proportion as its intensity is low, and then its action on bodies susceptible of crystallization will be manifested by producing the most regular crystals. This, we should conceive, is fully demonstrated by the successful experiments of Mr. Crosse and of M. Becquerel. The former gentleman uses batteries of very low intensity, the cells being filled only with water; the action is long continued, in some cases for weeks, and in others even for months. Another fact in support of the opinion that the distinctive forms of bodies are produced by electrical action, is that crystals, and the twigs and leaves of vegetables, all terminate in points or sharp edges, so that the electrical action can proceed no further in increasing the growth, or in other words, in propelling fresh portions of matter for the extension of the plant, or the crystal, beyond the pointed or edged terminations. Then, again, let us inquire what takes place in plants, when they have attained their mature growth. We shall find the first indications of natural decay in the terminal parts of the leaves and the extreme twigs. For what reason? Vital action is not yet extinct in the root, the trunk, and main branches; but the electric fluid has now another duty to perform. As it has been the agent in the extension of the plant, and in the gradual development of its various parts, until it becomes in our sight an object of interest and of beauty, it is now converted by an All-wise Creator into the cause of its gradual decay. Those material particles which had hitherto assisted in the increase of growth, and the development of the various parts of the plant, now tend only to add to the firmness and solidity of the trunk and main branches; so that from being at first soft, and even pulpy, they are converted into a firm and woody substance, offering greater impediment to the passage of the electricity, as the change gradually progresses, until at length the fluid can no longer reach the extremities: here, then, death begins; and as the conducting power becomes more and more impaired, and the chemical actions in the plant become more and more feeble, a smaller quantity of electricity is called into action, and the process of decay progresses, until the once stately tree reminds us, by its desolate and branchless trunk, that death triumphs in the city as well as in the forest.

It is worthy of remark that the electric state of the atmosphere appears to influence the crystallization of bodies. "This is particularly observable in the laboratories of chemists, when large quantities of saline solutions are made to crystallize. It frequently happens that solutions which yield no crystals, after having been sufficiently concentrated, and left to stand undisturbed for some days, suddenly deposit the most abundant crop of crystals during or immediately after a thunder-storm."—*Accum's Elements of Crystallography*, p. 45.

"The plunging of foreign bodies into saline solutions determines the formation of the crystals, which would have been much slower without their presence." It is probable that the substance does not assist in the effect solely by its becoming a base on which the crystals may be readily deposited, but that it plays the more important part of aiding either in conducting the galvanic currents, or in developing them, according to its nature as regards electricity.

It is highly probable that the particles of bodies assume polarity, or in other words that they become oppositely electrified at opposite sides, while in a state of solution, owing to the electrical development which is invariably manifested during even the most gradual evaporation. If, then, while in a state of solution, we suppose that their particles, like those of atmospheric air, conduct only by a series of movements, we shall readily understand in what way they arrange themselves in right lines, and form different angles. It is obvious, that so soon as electrical action commences, the particles in solution must be so influenced by the electrical conditions they assume, as to attract or repel neighbouring particles, accordingly as they are opposed to each other by their similarly or dissimilarly electrified parts. And when the formation of the crystal has once commenced, it proceeds with greater or less rapidity, the attractive and repulsive forces being more energetic towards the extremities than in the centre, so that particle continues to be added to particle until the formation of the crystal is complete. The quantity of electricity developed in a given time will be proportionate to the rapidity of the evaporation of the fluid. If that process is rapidly conducted, the crystals are small and irregular; if it goes on gradually, large and perfect crystals are formed. For, the more intense the electric action, the greater will be the number of particles set in motion, and the more energetic the attraction from between two opposite sides of two particles; hence they will rush together from all directions: the crystallization is rapidly effected, but the result is the formation of crystals of inferior size and irregular form.

On the other hand, we find that certain crystallized bodies, which are in a neutral electrical state at ordinary temperatures, exhibit electrical phenomena simply by being heated or cooled. This property is peculiar to regularly crystallized minerals. The tourmalin is one of the most remarkable of these bodies, and its attractive properties are supposed to have been first noticed by Theophrastus; the name *Lyncurium*, which that philosopher used, being considered as synonymous with the *tourmalin*. Linnæus termed it the *Lapis Electricus*. Its form is generally that of a nine-sided prism, terminated by a three-sided pyramid at one end, and by a six-sided pyramid at the other. Its electric properties were noticed in the year 1717, by Lanery; but the first scientific examination of them was made by Æpinus, in 1756, and published in the Memoirs of the Berlin Academy. He found that when the temperature of a tourmalin was raised to between 100° and 212° of Fahrenheit, the six-sided pyramidal extremity becomes positive, while the other extremity is negative, and that it is capable of affecting a delicate electroscope. When the stone is of considerable size, flashes of light may be seen along its surfaee. Mr. Wilson, who made many experiments on this subject, stated that a flat tourmalin retained its electricity without diminution, after exposure to intense heat for half an hour; but Canton did not obtain the same result; and it is stated by Haüy, that very high degrees of heat destroy its electricity. It recovers its electricity, however, as it gradually cools; but in that case the electric states are generally reversed: that extremity which was before positive, becomes negative, and *vice versâ*. The electricity is manifested only at the summits of the pyramids which terminate the crystal, unless the stone is broken, and then each fragment possesses a positive and negative pole. At the ordinary temperature of the air, the tourmalin may be rendered electrical by friction; but in this case, the electricity is manifested only on the part subjected to the mechanical action, which exhibits signs of positive electricity.

Several other gems possess similar properties. Sir H. Davy ascribed to electrical excitation the luminous appearance of some diamonds, when heated. Boracite, which is composed of borate of magnesia, and crystallizes in cubes, with defective edges and angles, becomes electrical by heat, and in one variety presents the singular phenomenon of alternate positive and negative states in no fewer than eight sides; viz. four positive and four negative; the opposite poles being in the direction of the axis of the crystal.

The topaz, which consists of siliceous fluate of alumina, is another electric mineral, its poles being situated upon the two opposite summits of the secondary crystal, and in some varieties (as observed by Hauy,) there are a series of consecutive poles alternatively positive and negative. Axinite, mesotype, and prehnite, calamine (an oxide of zinc), and sphene or calcareo-siliceous oxide of titanium, also become electrical by the application of heat. M. Dessaignes has shewn that all metallic bodies are capable of a feeble electric excitation by changes of temperature; and from the results of Haüy's experiments, it is inferred that the electrical properties of mineral bodies are intimately related to the laws of their crystallization, and to the direction in which the light is most readily transmitted through them.

We believe it will be found that all bodies that are capable of being electrically excited by friction, are transparent. Does this properly depend upon the same arrangement of their particles, which causes their transparency? What becomes of all the light that is continually absorbed during the day? Does it reside in bodies in the form of caloric and electricity? This affords an interesting subject for experimental inquiry, which, if diligently pursued, might be a great step towards the discovery of the relation between (if not the identity of) electricity, light, and heat.

CHAPTER XX.

Physiological Effects of Galvinism—the Shock; Perceptions of Light and Taste; Effects on the Senses of Smell and Hearing.—Muscular Contractions.—Effects on the Functions of Secretion, &c.

THE most effectual method of receiving the whole force of a voltaic battery is to wet both hands with a solution of common salt, and to grasp a copper cylinder, soldered to the communicating wires, in each hand. Another mode is, by plunging a finger of each hand into two separate vessels filled with water, into which the extremities of the wires from the battery have been immersed. Twenty pairs of plates are sufficient to give a shock in this way, sufficiently strong, sometimes, to be felt in the arms: with a hundred pairs it extends to the shoulders.

The continued flow of the electric current through the body, as long as it forms part of the circuit, is accompanied by an acute aching pain. If it pass through any part deprived of the skin, the smarting or burning sensation is severe, continuing to increase until it is scarcely supportable. It was remarked by Volta that the shock is of a sharper kind on those sensible parts of the body included in the circuit, which are on the negative side of the pile, where the electricity flows out from the body, than on the positive side where it enters.

A luminous flash will be perceived, if a piece of silver is pressed as high as possible between the lip and the gums, whilst at the same time a piece of zinc is laid upon the tongue, and then contact between the metals made by bringing their edges together. Another mode is to introduce some tin-foil within the eyelid, so as to cover part of the globe of the eye, and to place a silver spoon in the mouth. Communication must then be made between the silver and tin-foil by means of a wire. The flash which results from the action of a pile, applied in a similar way, is very powerful; and if the plates were numerous, the experiment might be attended with serious consequences to the sight. The flash from galvanism is thus perceived, whether the eyes are open or closed, and whether the experiment is made in the day-light or in the dark. If the eye is kept open, and is watched by another person when the effect is produced, the pupil will be seen to contract at the moment when the metals are brought into contact. A flash is also perceived at the instant when the metals are separated from each other.

We have already noticed the peculiar taste which is perceived when different metals are applied to different parts of the tongue, and made to touch each other. The surface of the tongue must be moist; for if it is previously wiped, the effect is considerably diminished, and it is not at all perceptible if the surface is very dry. The oxidable nature of the metal laid upon the tongue influences the kind of taste which is perceived; the more oxidable metal giving rise to an acid, and the less oxidable metal to an alkaline taste. Berzelius observed similar differences with common electricity, directed in a stream upon the tongue, the taste of positive electricity being acid; but when the tongue was subjected to the action of a negative point, the taste was caustic or alkaline. This is probably not a mere effect of the direct impression of the electric current on the nerves of the tongue, but may be owing to the decomposition of the salts contained in the saliva by the galvanic action. From the analysis of Tiedemann and Gmelin, the chief saline constituent is chloride of potassium; but several other salts, such as the sulphate, phosphate, acetate, and carbonate of potassa, are likewise present in small quantity. The sensation is so sharp when an amalgam of mercury and sodium is applied to the tongue, as to resemble the pain occasioned by the application of a heated body; at the same time the taste is very peculiar, and seems to alternate between that of an acid and a caustic alkali.

The muscles of a frog are peculiarly sensible of the galvanic influence, and are therefore the fittest for the exhibition of the phenomenon of muscular contraction. The susceptibility of some of the *vermes* is also very great. If a crown-piece is laid upon a piece of zinc of larger size, and a living leech is placed upon the silver coin, it suffers no inconvenience as long as it remains in contact with the silver only; but the moment it has stretched itself out and touched the zinc, it suddenly recoils, as if from a violent shock. An earthworm exhibits the same kind of sensitiveness, and the *nais*, an aquatic worm. These facts, exemplifying the susceptibility of the animals we have named to electrical action, will abate our wonder why their peculiar motions should be indicative of approaching changes of weather, before our most delicate meteorological instruments have been at all affected. Small animals are easily killed by discharges which would produce only a stunning effect on larger animals.

Convulsive movements may be excited in the muscles of an animal after its death, as long as they retain their contractility. If two wires connexed with the poles of a battery of one hundred plates, are inserted into the ears of an ox, or sheep, when the head is removed from the body recently killed, the muscles of the face will be thrown into violent action whenever the circuit is completed. The convulsions are so general as to impress the spectator with the belief that the animal has been restored to the power of sensation, and that it is enduring the greatest agony. The eyes open and close, and roll in their sockets, the pupils at the same time being widely dilated. The nostrils vibrate as in the act of smelling; and the movements of mastication are imitated by the jaws. The struggles of the limbs of a horse, galvanised soon after it has been killed, are so powerful as to require the strength of several persons to restrain them.

Experiments of a similar nature are on record, as having been performed in hospitals on limbs removed by amputation; and on the bodies of criminals soon after execution. A great number of these are stated to have been made at Turin, on the victims of the guillotine; and in this country Aldini, by operating with a large battery on the body of a criminal executed at Newgate, produced effects very similar to those already described as having been performed on the ox and sheep; but they were more impressive and horrific, from their conveying the impressions of human passions and agony. The experiments of Dr. Ure will be described in the Second Part.

Muscles whose actions are involuntary are less easily affected by galvanism than those of voluntary motion; but Fowler, Vassali, Humboldt, Nysten, and others, have proved that even these muscles may be made to contract.

The most extraordinary physiological effects of galvanism, which have hitherto been unexplained, are those on the functions of secretion, more particularly that of the gastric juice, which will be treated of in the Second Part.

It has recently been found that a large battery is by no means necessary for the production of the galvanic shock; but as an account of the necessary arrangements for producing the physiological effects by gle voltaic pair, and increasing those effects as produced by compound batteries, would find its proper place in a treatise on electro-magnetism, which now constitutes a distinct science, and as we have already exceeded the limits to which we ought to have confined ourselves in this little Essay, we must refer our readers for information on this point to the second, third, and fourth number of the "Annals of Electricity," &c., and to the October number of the "Philosophical Magazine," for 1834. We may, however, simply state, that, according to the account by Dr. Henry, in the fourth number of the former periodical, the effect depends "on the influence of a spiral conductor in increasing the intensity of electricity," and the "phenomena," he conceives, "may all be referred to that species of dynamic *induction* discovered by Dr. Faraday, which produces the following phenomenon; viz., when two wires, *A* and *B*, are placed side by side, but not in contact, and a voltaic current is passed through *A*, a current in an opposite direction is produced in *B*. The current *B* exists only for an instant, although the current in *A* may be indefinitely continued; but if the current in *A* be stopped, there is produced in *B* a second current; in an opposite direction, however, to the first current.

The shock with the spiral conductor is obtained only at the instant of breaking the contact with the battery, various instruments for effecting which have been contrived: Dr. Henry's spiral conductor was formed of copper ribbon covered with silk.

CHAPTER XXI.

Phenomena of the Electric Column.

Mr. Singer, who had extensive experience in the construction of the electric column, invented by De Luc, gives the following directions for making that instrument :—Of the materials to be used, he gives the preference to thin pieces of flattened zinc, alternated with writing paper, or smooth cartridge paper, and silvered paper. They are to be cut into small round plates by means of a punch. These discs are then to be arranged in the order of zinc, paper, silvered paper, with the silver side upwards; then zinc, paper, and so on, the silver being in contact with the zinc throughout; and each adjacent pair of the metals separated by two discs of paper from each other. The plates may be introduced into a glass tube, previously well dried, and having its ends covered with sealing-wax, and capped with brass; one of the brass caps may be cemented on, before the plates are introduced into the tube, and the other afterwards. Each cap should have a screw passing through its centre, and terminating in a hook outside. This screw will serve to press the plates closer together, and to secure a perfect metallic contact with the extremities of the column.—(*Singer*, 452.) By placing two of these columns upright, side by side, but with their poles in opposite directions, and con necting their upper ends, the whole apparatus becomes equivalent to a column of double the length, of which the two lower extremities become the efficient poles. If each of these extremities is insulated, and made to terminate in a small bell, and a brass ball is suspended as a pendulum by a silk thread, so as to hang midway between the bells, and at a very small distance from each of them, the alternate alterations between the ball and each of the bells will cause the former to oscillate, and to strike the bells so as to produce a perpetual ringing. This contrivance was invented by Mr. Forster, who constructed a series of 1500 groups, and by its continued action kept up the vibrations of the pendulum for a very long time. Mr. Singer had an apparatus of this kind, containing only 1200 groups, which, during fourteen months had never ceased to ring, excepting when removed from one room to another. There was an interval of six months, during which it was never disturbed, when its motion never ceased. M. de Luc stated that he had a pendulum which had constantly vibrated between two bells for more than two years, and which still continued in motion at the time of his report.—(*Singer*.)

There appears to be some connexion between the action of this instrument and the state of the atmosphere; for although the motion may always continue, it is much more rapid at one time than another, and subject to much occasional irregularity. This fact was observed by De Luc soon after he had constructed his apparatus, and he made a number of accurate observations, from which he inferred that the cause which affected the movements of the instrument was the variable electrical condition of the atmosphere.

When the sun shines upon the column, its action increases. Mr. Hausman confirmed this observation of De Luc. He conceived the effect not to be due to the heat of the sun's rays, because he found that a column which had been put together after all the pieces had been thoroughly dried by a fire, had entirely lost its power, but again became efficacious after it had been taken to pieces, and its materials had remained exposed all night to the air, from which the paper imbibed moisture. Mr. Singer, however, observes, that a moderate heat increases the power of the column, as his apparatus, which was kept in a room where there was usually no fire, pulsated most slowly in winter; but as soon as a fire was lighted in the room, its movements were much more rapid, and the indications afforded by the electroscope much more powerful.

It appears from De Luc's experiments that the presence of a certain quantity of moisture is essential to the action of the instrument. In its driest natural state, Mr. Singer always found paper sufficiently a conductor, even when, by exposing the discs to the heat of the sun, they have been so dried as to warp considerably. When the paper is sufficiently dry, the action of the column continues without diminution; and on taking the apparatus to pieces, after two years and a half, no trace of oxidation could be perceived on the zinc plates. Mr. Singer was of opinion that the action of a column constructed with care will be permanent; and states that he had several which had been made nearly three years, and which continued as active as at first. He observes, however, that care should be taken not to allow the ends of the column to be connected by a conducting substance for any length of time; for after such continued communication, if it be applied to an electroscope, it will not possess power to affect it for some time. It is therefore necessary, when a column is laid by, to place it upon two sticks of sealing-wax, so as to keep its brass caps at a distance of about half an inch from the table, or other conducting surface, on which it is laid. If a column which appears to have lost its action be insulated in this way for a few days, it will usually recover its full power.—(*Singer's Elements, Nicholson's Journal,* &c.)

The most extensive series made by Mr. Singer consisted of twenty thousand groups of silver, zinc, and double discs of writing-paper, and possessed very considerable power. "Pith-ball electroscopes, with balls of one-fifth of an inch in diameter, and threads of four inches long, diverged to the distance of above two inches, when connected with its opposite extremities. An electroscope connected with the centre was not affected. When either extremity of the column was connected with the ground, the electroscope attached to that extremity closed, and the central electroscope opened with the same electricity; while that connected with the opposite extremity had its original divergence considerably increased; but the motion of the electricity was so slow that some minutes were required to produce the full effect. By connecting one extremity of the series with a fine iron wire, and bringing the end of this near the other extremity, a slight layer of varnish being interposed, a succession of bright sparks was produced, especially when the point of the wire was drawn lightly over the varnished surface. A very thin jar, containing fifty square inches of coated surface, charged by ten minutes' contact with the column, had power to fuse one inch of platina wire one 5000th of an inch in diameter. It gave a disagreeable shock, felt distinctly in the elbows and shoulders, and by some individuals across the breast. The charge from this jar would perforate thick drawing-paper, but not a card. It did not possess the slightest chemical action. Saline compounds, tinged with the most delicate vegetable colours, were exposed under the most favourable circumstances to its action, and, in some instances, for many days, but no chemical change could be observed."—*Singer.*

An apparatus somewhat analogous to that of De Luc, was constructed by Hachette and Desormes, with pairs of metallic plates, separated by a simple layer of farinaceous paste, mixed with muriate of soda. To this instrument they gave the inappropriate name of "*dry pile*," since its action is still more evidently owing to the moisture contained in the intervening body than even that of De Luc's electric column. In proportion as the moisture of the paste has evaporated, the action of the instrument diminishes; while on the other hand, the action is resumed when the layer of paste becomes again supplied with moisture by attracting it from the atmosphere. Like the electric column, it charges the condenser by a simple contact, and it preserves this property for whole months and years; but it does not excite shock, nor taste, nor chemical action.

Professor Zamboni, of Verona, also constructed a kind of pile, of which the electrical effects are said to be very durable It was composed of discs of paper, gilt or silvered on one of their surfaces, and covered on the other with a layer of pulverized black oxide of manganese, mixed with honey. A similar pile has also been constructed without the honey.—*Biot, Traité de Physique*, ii. 540; *Journal of Science*, ii. 451. This instrument exhibits signs of the electrical influence in the same manner as the pile in which paste is used; but possesses no chemical action, and neither affects the taste, nor produces a shock. The electrical attractions which it produces are very considerable in their degree; for if two of these piles are placed at the distance of four or five inches from each other, and a metallic needle is properly suspended between them, it will be attracted by the two piles alternately, moving between them like a pendulum. When Zamboni's pile is confined within a limited portion of air, the oxygen of the air is absorbed by it, and after this has taken place the action of the pile ceases*. When the oscillations of the pendulum have ceased, on admitting a supply of atmospheric air, without moving the apparatus, the pendulum is instantly attracted to the positive pole, the oscillations are renewed, and continue in the same manner as at first. These oscillations, however, were not found to be affected in the same manner as those of the electric column.—*Journal of Science*, ii. 161.

In a memoir relative to the dry voltaic pile, Zamboni states that its energy ceases to diminish after a lapse of two years; such at least he states to be the case after twelve years' experience. The diminution in the first two years varies according to the manner in which the pile is constructed. It is more energetic in summer than in winter, both with regard to intensity and the promptitude with which the electrical action is manifested. The tinned paper, called silvered paper, with black oxide of manganese, develops an electric force much superior to that obtained from paper covered with a thin leaf of copper, or what is called Dutch-gold paper. By using a "dry pile" of one thousand pairs, the plates being about two inches in diameter, Zamboni obtained, by the condenser, sparks of an inch in length; so that

* The same occurs with the voltaic pile. See Biot's account, in his *Traité de Physique*, of the interesting experiments instituted by him and M. Cuvier on this point.

with such a pile the electrical battery might be retained in a certain state of tension, which might be heightened at pleasure, by increasing the number of plates. He is of opinion that a pile of 50,000 pairs of plates, of the usual diameter, of leaves of tinned paper, would be a constant source of electricity, of which the tension would equal that of a strong common electrical machine.—*Annales de Chimie*, xxix, 198.

While attempts were making to construct voltaic arrangements composed entirely of dry substances, Ritter, of Munich, invented an instrument, which, indeed, did not possess the power of developing electricity by its own action, but was capable of receiving a charge from the voltaic pile, so as to acquire for a time all the properties of the pile. This instrument has been denominated the *secondary pile of Ritter*. It consists simply of a column formed of discs of copper and moistened card, placed alternately. When a pile of this description is once charged, it loses its electricity very slowly when there is no direct communication between its two poles. But if this communication is made by a good conductor, a discharge of the electricity accumulated in the exterior plates immediately takes place, which, as in the Leyden jar, produces an instantaneous shock. To this effect a new state of equilibrium succeeds, and the discharge may be repeated a considerable number of times, but of course with continued diminution of power, until they at length cease to be sensible.

This apparatus produces, with diminished intenelaborate work, in which those infant sciences will be amply treated of.

To the consideration of *thermo-electricity*, also, we regret that we cannot afford sufficient space. The fact of the development of electricity by inequality of temperature is highly interesting, as tending materially to aid in the explanation of terrestrial magnetism. Thermo-electric batteries are at present constructed of antimony and bismuth. By a small apparatus, composed of those metals, a spark may be obtained, by the aid of a coil of copper wire or ribbon, on immersing one extremity of the battery in a freezing mixture, and applying heat to the other.

If we solder a copper wire to each extremity of a plate of tinned iron, and connect the wires with the cups of the galvanascope, on placing a piece of cotton wool, or sponge, on one end of the plate, and moistening it with sulphuric ether, the development of electricity will be manifested by an immediate and very perceptible action of the current on the needle, which, in the galvanascope we have already described, was permanently deflected 6° 5. On heating the other extremity merely with the hand, the deflection was increased.

It is probable that if one of the extremities of the plate is made to terminate in the form of a vessel for containing water, we might form a thermo-electric battery, whose action would be constant, and subject to very trifling variation. By causing the water to boil, we could maintain the temperature of that extremity of the plate nearly uniform; sponge, cotton wool, or a little tow, moistened with ether, being placed on the opposite extremity.

The tin plate which we used in the experiment above alluded to, was eight inches in length, and two and a half inches in breadth.

We trust that we have now placed before our readers the leading facts connected with the development of electricity, and its various accompanying phenomena, in a point of view sufficiently clear to enable those who have not previously attended to the subject, to perceive the importance of electricity as connected with the various phenomena which are continually occurring around us, and to understand the *modus operandi* of that all-pervading and subtle fluid in the production of those phenomena.

We have shewn that the equilibrium of the electric fluid is disturbed by the most trifling action, either chemical or mechanical; nay, during the process of respiration, a quantity of electricity is probably evolved, which, if concentrated, might prostrate the "knarled oak," and rend asunder the adamantine rock. It exists in all substances; its presence is manifested in the air—on the earth's surface—in its dark caverns—in the ocean, in which animals exist, which, from their peculiar anatomical structure, are enabled to wield the artillery of the skies beneath the waters of the mighty deep. The waving of a lady's fan, the vibrations of the wings of the humming insects, are sources of electrical excitation. The zephyr of the tranquil summer's evening, the howling and bitter blasts of winter, alike awaken from its slumber this mighty agent; the genial breath of spring, the opening beauties of the young flower, woo it from its inert state. Autumn comes, and death triumphs in the forest and in the field, but it exists; and while flowers are fading, and blighted leaves falling around us, it is still active in its unceasing and unerring operations—unerring, because its limits and its laws have been assigned to it by that same OMNISCIENT BEING who said to the deep, "thus far shalt thou come, and no further."

If, indeed, there were no sacred volume to guide erring mortals heavenward—were the evidences of the existence of a GREAT FIRST CAUSE less manifest than they are in the wondrous works of the creation—the study of the nature and operation of this subtle but mighty agent would alone be a cure for infidelity, and an antidote against scepticism.

When we reflect that above, beneath, and around us, there exists, in a state of unceasing activity, a vast ocean of the electric fluid, compared with which the lightning of the summer's storm is but as a drop in proportion to the ocean, our only wonder is that the earth has existed until its moss-grown rocks bear the marks of time on their rugged forms: our only surprise must be that the world has not, ages ago, ended as it began, in chaos, or been resolved into elements so etherial that perchance the inhabitants of another distant world might have breathed the wreck of a planet that once appeared to them as a star.

It is highly probable, also, that the operations of this mighty agent extend even to the regions of boundless space; and that the electric fluid is, in fact, the cause of that species of attraction which is termed gravitation, of which the other kinds of attraction are merely modifications. We have seen that by its power of attraction electricity is capable of producing varieties of motion—that, under certain circumstances, intense light and heat are evolved by its agency. Finding, then, that this one imponderable element is possessed of these three distinct powers or properties, it is nôt, perhaps, an unwarrantable inference that to its influence may be referred the motions of the heavenly bodies, as well as the various effects of which we have already treated. What greatly tends to strengthen such an opinion is that, as we have proved by experiment, electricity is capable of acting upon matter in two very different modes; in the one of which it exhibits an attractive power on bodies at a distance, which may be called *electro-attraction*—in the other it only influences the *atoms* of matter when they are in close approximation. Its action, in the latter instance, may, perhaps, with propriety be termed *electro-polarity*; and hence probably arise all those interesting actions which are called chemical; hence, also, that power which is called the attraction of cohesion. For if it is true that every substance in nature contains its natural quantity of the electric fluid, it must also be true that every atom of that body has its natural share; that, consequently, the atom has a *tendency* to assume polarity when its resident fluid becomes disturbed by the approach of another atom of a dissimilar kind. Herein we may perhaps discover the reason why electricity is capable of effecting either the composition or the decomposition of bodies. In the latter case, an electric energy is essential which is capable of overcoming the attraction of cohesion: in other words, an electric current is required, whose force is adequate to the reversing, or perhaps the destroying, of the polarity of the atoms. That this is true has been demonstrated by Dr. Faraday in reference to water, and it may be inferred that the law equally applies to all other bodies*.

But this is a subject the full consideration of which would of itself occupy a large volume; a subject, too, which demands for its elucidation and development an extensive series of careful experiments.

In reference to the subject of gravitation, and the motions of the planets, and their probable influences upon each other, no one will attempt to deny that our earth, and probably the other heavenly bodies, are in a constant state of strong electrical excitement. Now, we have seen that around all bodies electrically excited, an *electric atmosphere* exists, partaking of the forms of the excited bodies. It is probable, therefore, that the earth, and all the

* It is deeply to be regretted that the researches of this indefatigable philosopher have not been reprinted from the various sources in which accounts of them have appeared, so that scientific inquirers generally might avail themselves of the valuable information which they convey.

heavenly bodies, possess electrical as well as aerial atmospheres; and, as it has been shewn that electricity moves with facility through a vacuum, the electrical atmosphere extends far beyond the confines of the atmosphere commonly so called. Hence it is far from unlikely that the electrical atmosphere of one heavenly body may frequently interfere with that of another, particularly when such interference is favoured by certain relative positions of those bodies; as, for instance, in conjunctions, oppositions, &c. It will thus often occur that that portion of a planet *opposite* to the sun may be in one state of electricity, and may be opposed to the portion of another planet in a different position as regards the sun, and in an opposite state of electricity. In such a position, and under such circumstances, we presume that no electrician will hesitate to admit that interchanges would take place between the two electrical atmospheres. Hence may arise many of those disturbances in nature which remain to be accounted for; hence, perhaps, the origin of that beautiful but unaccountable phenomenon, the aurora borealis, which might readily be produced by such an electric action between two distant bodies, the fluid becoming visible to the inhabitants of the earth upon its entering our atmosphere. The peculiar appearance of the light, and its coruscations, precisely resemble the phenomena which we are enabled to produce artificially, by discharges of electricity between two bodies in a receiver, through a medium of highly rarefied air. This opinion is very much strengthened by the observations of my friend, Lieutenant Morrison, R. N. of Cheltenham, a profound astronomer and meteorologist, from one of whose interesting letters to me, dated 27th July, 1837, I beg leave to give the following extract:—"Your observation respecting the aurora is quite correct. Electrical phenomena have prevailed in the air to an immense extent: there have been numerous long, light clouds in the day, *ranging themselves in the meridian line,* and coming to a point either on the south or north *punctum* of the horizon. At night they take a fleecy, aurora-like character. Yesterday they were numerous, and a change of weather has followed. I believe that these clouds are formed by the discharges and currents of electricity, which, when they are more *decided,* produce auroræ. There was a conjunction of Venus and Jupiter last evening. The position you drew, [in one of my letters to Lieutenant Morrison] was that of an opposition of the sun and a planet, when we see the sun in one direction, and the planet in the opposite one. *When Mars* is so situate with the sun, *there are always meteors, or lightning, auroræ, &c. &c.; in winter, frosts; in summer, lightning, &c.*"

The subject, indeed, of the "agency of electricity," is so unlimited, opening before us, as it does, a boundless field of inquiry of the deepest interest and the highest importance, that it is impossible, in the course of an elementary essay to do more than briefly allude to many important natural phenomena, in the production of which electricity is concerned.

We are now about to enter into the consideration of electrical influence on the functions of animals and plants, and we approach the subject with a full conviction of our inability to treat it in the way which its importance demands. If, however, we should succeed in awakening the attention of a master-mind to its importance—if a perusal of this essay happily arouse from their slumber the latent energies of genius—we shall rest satisfied with the conviction that, so far as in us lies, we have done our duty, and shall anticipate a day, perhaps not far distant, when those natural phenomena whose causes are still involved in obscurity, will be enlightened by the rays of genius; when the night of darkness, which our humble efforts have not tended to illuminate, even by the faintest spark, will be rendered bright as the cloudless noon-day of summer, by the radiance which the increase of knowledge will shed over the wide world; when the power, also, of that mighty engine shall enable us to remove every barrier in the paths of science, how insurmountable soever the obstacles may at present appear.

And, surely, no subject is more worthy of our time and labours than that the investigation of which will enable us, under the blessing of Providence, to ameliorate the condition, and alleviate the sufferings of our fellow-creatures, and which may place in our hands the power of averting the shaft of disease, or, at least, of rendering its deadly poison in some degree innocuous.

The much that remains to be done, ere we can expect this "consummation" so "devoutly to be wished," we willingly and joyfully relinquish to hands more able than ours. Let the electrician and the physiologist unite their efforts. A field in its barrenness, yet by its rich and fruitful soil offering a cheering promise of fruitfulness, lies before them. What shall be sown therein, generations yet unborn shall reap, with hearts overflowing with gratitude to those by whose labour it was first cultivated.

END OF PART I.

Part II.

AGENCY OF ELECTRICITY.

CHAPTER I.

Influence of peculiar Electrical States of the Atmosphere on the Functions of Animals and Plants ;—Instances.

THAT the state of the air, independently of the degrees of moisture or density, has an influence upon our health, is an opinion which is strengthened by innumerable facts. Who has not at times experienced that painful depression of spirits, accompanied with unpleasant sensations of chilliness, and other "nervous" feelings, on one of those gloomy days without rain, and when the wind is easterly? The sensation of cold, at such times, is attributable to some peculiar atmospheric influence, for there is no corresponding depression in the thermometer. But we find a sufficient solution in the fact that on such a day as we have described, the electroscope invariably indicates a negatively-electrical state of the atmosphere.

The peculiar effects of changes in the state of the atmosphere are constantly observable in their influence upon the functions of animals and plants. Dogs, for instance, grow drowsy before rain, and in these animals, as well as in cats, which are peculiarly sensible to atmospheric influences, a disease of the ears has been observed.—(See *Forster's Atmospheric Phenomena:* London, 1833.) A leech in water indicates atmospheric change by its quiescence, or by its rapid motion. That the bee is not insensible to such influence, see Virgil, Georg. Lib. iv. 194. The web of a spider, if destroyed in the morning, will not be repaired, if rain impend.—(*Kirby and Spence's Entomology.*) The effect of a coming storm is noticed by Pliny—" Boves cœlum," &c. He also instances the activity of ants—" *Formica concursantes, aut ova progerentes,*" &c. Homer noticed the frequent immersion of water-fowl before rain. Horace, Claudian, and Lucan, celebrate the " crow prophetic." " As clamorous as a parrot against rain," saith Shakspeare; and the *Georgics* abound with the result of Virgil's observations on similar subjects.

But as regards man, these influences have been little attended to; for other causes are generally searched after, though rarely discovered.

These peculiar effects of the atmosphere are not observable in such animals only as may seem to be more immediately exposed to their influence; for moles, and other subterranean animals, are also affected. They operate likewise upon the waters, aquatic animals being alike sensible of their action. The angler may in vain expect to entice the silver trout when a thunder-storm is impending. Then, also, the eel may be observed to come forth from his lurking-place beneath the stone, not in search of food, but indicating, by his peculiarly restless motions, that he is ill at ease. When dolphins play about the surface of a calm sea, Pliny says, (Lib. xviii. c. 35,) wind may be expected from the quarter whence they come. Before storms, according to Foster and Bewick, the porpoise, dolphin, and grampus, approach the shore in large bodies. So also says Aratus of the Erodius.

The following are additional instances of this invisible precursor of bad weather. The mistletoe thrush (*Turdus viscovorus*), has acquired the name of the *storm cock*, from the circumstance of its singing particularly loud and long before rain; indeed, even during a lull in the tempest, the song of this bird frequently affords a striking and pleasing contrast to the jarring of the elements. The stormy petrels (*Procellariæ pelagicæ*) betake themselves for shelter under the wake of a vessel, and thus warn the mariner to "have an eye to his reefing tackle." On the island of St. Kilda, says Pennant, in his *Arctic Zoology*, the fulmar (*Procellaria glacialis*) forebodes the direction of the wind. When these birds return to the land in numbers, there will be no west wind for a long time; when, on the contrary, they return to the ocean, a zephyr is expected.

Thus, then, ere yet the way-worn traveller is warned by the cloud, or the low murmurings of the yet distant tempest, if he is an observer of nature, he may know when to seek for shelter by the sure indications afforded to him in the display of the instinct of those animals, which are thus affected by the first faint breathings of the storm.

Nor are the effects of a change in the state of the atmosphere observable in the vegetable kingdom less remarkable than those which we have instanced amongst animals. Those frail, but beautiful children of the spring and summer, which clothe the earth with loveliness, and whose silent and sweet breathings purify the air which the breath of the animal has polluted with poison, discourse to us in other language than that with which the poet delights to invest them,—the gentle and tender language of love. The naturalist reads the words of warning, which he detects in the folding leaves of the tender flower—"the cloud cometh."

There are numerous instances of this folding of the leaves upon the approach of rain, or during the partial obscuration of the sun by a passing cloud. It has been beautifully and poetically termed the "sleep of plants."

Visit your favourite haunts in the still evening, you will see the daisy—

> "That wee, modest, crimson-tipped flower,"

recumbent on the earth, and the pond-weed reclining on the surface of the water. Return in the morning, you will find that the "wee, modest" thing has unfolded its beauties to the sunbeam, and that the nymphæa has raised its head from its watery pillow. In the words of Mr. Murray, in his *Physiology of Plants*, "the electro-chemical solar stimulus is necessary to arouse the dormant resilience of the fibre, which had lost its power of elongation by the absence of such stimulus."

To these may be added the chickweed, the trefoil, the *Amagallis arvensis*, and the pimpernel. There is, however, a solitary instance, to which the above explanation will not apply. Amongst other prognostics of bad weather, Mr. Foster mentions that afforded by the Siberian sow-thistle remaining open *all night*, which, he says, indicates rain on the succeeding day; and in Loudon's *Magazine of Natural History*, vol. iii. p. 486, a correspondent states that the flowers of a crocus have been expanded by the action of the light of candles. Upon this Mr. Loudon's correspondent remarks, "Some flowers and leaves seem to be affected by the light, and others by the heat of the sun: if, however, they receive either too intensely, they suffer, and are withered. Instead of a temporary cessation of their vigour, as is the case before rain, it is an injury which only a refreshing shower and darkness can recover. Again, many plants are most active in growth, and most completely expanded during the night, and some, from the extreme delicacy of their structure, seem only fitted to blow in darkness or twilight." A striking instance of the last-named circumstance is to be met with in the "night-flowering ceres," whose beautiful, delicate flowers expand, bloom, and perish, between sun-set and the dawn of morning; affording an impressive example of the short-lived nature of beauty.

That the electric fluid, artificially employed, influences the growth of plants, is a fact which we state on the authority of Cavallo. The experiments he mentions were performed on several sweet balsam plants, and it was found that the growth of those which had been subjected to the action of electricity was accelerated. If, however, care be not taken—if, for instance, the shock is too strong, the plant is at once deprived of life.

In its operation upon animals the nerves are the parts which are most powerfully affected. Mr. Singer informs us that a charge sent through the head of a bird injures or destroys the optic nerve. A similar shock, given to a larger animal, is said to produce a general prostration of strength, with trembling and depression. A strong charge, directed to the diaphragm, is frequently followed by involuntary sighs and tears. The first effect, when a jar is fully charged, is a sudden effort made by the lungs, followed by a loud shout. If the charge is slight, it never fails to produce a violent fit of laughter. A charge passed through the spine produces a degree of incapacity in the lower extremities, so that if a person be standing at the time, he sometimes drops on his knees, or falls prostrate on the floor.

Such, then, being the wonderful and powerful effects of electricity upon the nervous system, we may surely infer that the electrical state of the atmosphere must also strongly influence the functions of men and other animals, as well as those of plants—a fact indeed, which the instances adduced tend to establish: and the circumstance of its acting through the medium of the nerves seems to favour the conjecture that in numerous instances the nervous system is first affected by disease, which is then, by induction, communicated to other parts. Hence a diseased state of the stomach may not always, as is alleged, be the *cause* of derangement in the nervous system, but actually the effect of a previous derangement of the latter.

These electro-atmospherical influences may, perhaps, throw some light upon the obscure subject of epidemics, a subject which will be fully considered in connexion with the electro-physiological theory, which we shall attempt to explain in a subsequent chapter.

As the lower animals and plants are first influenced by atmospheric change, so the fading of the summer flower ere yet autumn hath breathed upon it, and the ravages of disease and death amongst cattle and other animals, invariably precede epidemics which attack man. At length he, too, becomes affected, and "behold! at eventide trouble, and in the morning he is not."

with the conviction of its extreme subtlety, is it not natural to infer that it plays a part in the more mysterious functions of our frames? Those who deny this will place themselves in a dilemma, for, since the equilibrium is invariably disturbed during chemical action, and since the processes of respiration, digestion, &c. &c. as before observed, are strictly chemical, they must be prepared to point out a path by which the constant supply of the fluid may be conducted quietly from the body. What, then, are its duties? First, it aids in the supply of heat. And in what mode does it thus act? Simply thus: by its being transmitted from the nerves, the most perfect conductors in the body, to other parts of the frame, and finally to the surface, through less perfect conductors. The result as regards caloric, when electricity is thus transmitted from good conductors through others of inferior conducting power, is too well known to every electrician to require the waste of space for a list of illustrative experiments, for it will readily occur to him that it is by checking the rapid progress of the fluid by means of imperfect conductors, that we are enabled to inflame combustible substances, to fuse wires, &c.

Again, in the course of the nerves, there are a number of knots, termed ganglions. These, probably, serve to accumulate a quantity of the electric fluid; so that from its passage from these reservoirs along nervous fibres of extreme minuteness, an increase of temperature will result. Dr. Munro's opinion of the use of these ganglions favours this idea. He supposes them to be "new sources of nervous energy."

Since, then, during every moment of our lives, by means of the various electro-physiological processes continually going on, there is a new supply of electricity, the question naturally occurs,—is there a regular circulation of the electric fluid through the whole nervous system, as well as a circulation of the blood through its proper channels? Having shewn, in a former chapter, the extreme sensibility of the nerves to the action of electricity during peculiar electrical states of the atmosphere, how much more powerfully must they be affected when exposed to the more direct influence of that fluid! This leads us to the consideration of a subject of the highest importance, that of the "*nervous principle*," as some authors have termed that intermediate something between the body and the soul, by means of which the mind acts upon the material part of our frame, giving rise to the phenomena of thought and perception, and imparting motion to those muscles which are under the control of the will. But let us not approach such a subject with a mind disposed to speculate, or imagine; for, if there is one species of inquiry throughout the wide-extended field of philosophy, in which, more than in another, the imagination is apt to assert its independence of the control of the judgment, it is, perhaps, in that upon which we now presume to enter.

Let us, then, for a moment, turn our attention to the results of the researches of the celebrated

Magendie, and then proceed to apply them to the foregoing theory, and to that under the head of "Animal Heat." He states, then, that the origin of motion and that of sensation are totally distinct, although their connexion, in the healthy state, is so very intimate that the two phenomena seem one and the same. In his memoir, read before the Académie des Sciences, in Paris, on the 22d June, 1823, he remarks—"It must be borne in mind that all the nerves in the body originate from the spinal marrow; that two distinct orders of roots are observable, some taking their attachment from the anterior, the others, on the contrary, emerging from the posterior portion." Now, is not this precisely such an arrangement of the nerves as would be best calculated to promote such an electrical circulation as above mentioned? Again—"I have," adds Magendie, "fully demonstrated that the spinal marrow is, as it were, formed of two distinct cords in juxtaposition, the one of which is endowed with exquisite sensibility, whilst the other, almost completely unconnected with this property, seems to be reserved for *motion*, and that this separation exists through the whole extent of the spinal cord." Such being the fact, it is highly probable that there is an ascending current of the electric fluid, along one portion of the cord, to the brain, affecting the organs of sensation, and a descending current through the other half, influencing the organs of motion; or, perhaps, that there is a negative and positive portion of the cord, the former constituting the agent of sensation, the latter that of motion. Magendie himself suggests the following fact as an additional argument in favour of the electrical hypothesis, viz. that, "it is at the *surface* of the organ that its properties, as far as regards motion and sensibility, are the better unfolded." This fact is worthy of remark, for electricity is said to move only along the *surface* of conducting bodies; and Magendie also found that so far from the respective properties of those parts being more striking in the *interior* of their substance, the *central* part of the marrow is quite insensible, and, by stimulating it, no motion whatever can be produced. Lastly, it is probable that the *modus operandi* is partly thus :—First, with regard to motion. The *will* to move a particular organ, and the act of motion, are simultaneous. The same effort (if effort it may be called) that acts upon the mind, at the same instant, causes the formation of a circuit, by means of which the fluid, in an accumulated state, is instantaneously transmitted to the nerves connected with those muscles which are required to be brought into action.

CHAPTER III.

Digestion ; Action of the Muscles ; Respiration ; Sensation and Perception ; &c.

One of the most important facts, having considerable weight in the support of the opinions we have presumed to advance, is the very remarkable one, that the electric fluid has been found capable of supplying the place of "the nervous influence." Dr. Wilson Philip, by incisions in the necks of several living rabbits, divided the eighth pair of nerves distributed to the stomach, and subservient to digestion. The digestive process was suspended, the parsley which the animals had eaten remaining unaltered in the stomach. Death took place, apparently through suffocation, after the animals had suffered much from difficulty of breathing. But when, in other animals, similarly treated, the electric fluid was transmitted along the nerve, below its section, to a disc of silver placed in close contact with the skin of the animal, opposite to the stomach, no difficulty of breathing occurred ; and the action being kept up for twenty-six hours, the rabbits were then killed. The parsley was as perfectly digested as that in other rabbits fed at the same time, and their stomachs evolved the smell peculiar to that of a rabbit during digestion. These experiments were several times repeated with similar results, and were afterwards tried upon dogs with the same success. These results were confirmed by Dr. Clarke Abel, of Brighton.

Dr. Wilson Philip, in his earlier researches, endeavoured to prove that the circulation of the blood and the action of the involuntary muscles were independent of the nervous influence. In this view he concluded that he was correct, from the result of the following experiment. Rabbits being rendered insensible by a blow on the occiput, the spinal marrow and brain being removed, and the respiration kept up by artificial means, the motion of the heart and the circulation were carried on as usual, contrary to the opinion held by Le Gallois, the French physiologist. This, however, is by no means conclusive as to the correctness of Dr. Wilson Philip's opinion. The motion of the heart being carried on after the removal of the brain and spinal marrow, seems only to prove what was already known, and nothing further, viz. not that such action does not depend upon the nervous influence, but that it is independent of that part. (the brain), through the medium of which the mind acts. And it certainly appears to afford a strong argument in favour of the electro-physiological theory; for the involuntary muscles must be immediately acted upon by the electric fluid, not through the medium of the brain. This is satisfactorily proved by Dr. W. Philip's experiments, the supply being kept up by the chemical action going on during respiration. It is evident that the action of such muscles could not have been involuntary, if it had depended upon the presence of the brain or spinal marrow.

That the renewal of the respiratory process after death can also be effected by the agency of the electric fluid was satisfactorily proved by the result of one of the interesting experiments instituted by Dr. Ure, of Glasgow, at the suggestion of Dr. Jeffrey, the professor of anatomy. The account is too long for insertion, but we shall give the result as described by Dr. Ure. After detailing the preparatory steps, and the manner in which the conducting wires were directed, he says, "full, nay, laborious breathing, instantly commenced. The chest heaved and fell, the belly was protruded and again collapsed, with the relaxing and retiring diaphragm. This process was continued, without interruption, so long as I continued the electric discharges. It was thought by many scientific gentlemen who witnessed the experiment, that the phenomenon of the circulation of the blood might also have occurred, had the body not been previously pretty well drained, and the spinal marrow severely lacerated."

It has been stated that many of the nerves are furnished with ganglions, the use of which, in part, we have already attempted to explain. Now, a fact which seems greatly in favour of the electro-physiological theory is this: that the nerves of motion are destitute of those ganglions. For it is evident that, if such knots had existed in them, the various motions which they were destined to influence could not have been performed with that wonderful facility which is frequently requisite. For the electric fluid is, as it were, so averse to circuitous routes, that it invariably prefers a direct passage—a fact with which electricians are perfectly familiar.

Nor is the fact that the nerves of sensation are provided with ganglions less corroborative of the truth of the theory, than is the absence of such ganglionic masses in the motive nerves. This will become evident, when we reflect upon the phenomena of the nervous system, bearing in mind, at the same time, the order in which they commonly occur. The sentient extremities of the nerves are so situated as to be exposed to the action of certain external bodies, whilst the medullary substance is divested of the enveloping membranes from the *pia mater*. To these extremities, then, thus so admirably constituted and situated for the purpose by the unerring wisdom of that Being whose works alone are perfect, the first impulse is imparted by the action of external bodies; then arises thought, or perception, (termed, at its origin, sensation,) which again, variously modified, gives rise to volition, or the willing of definite ends to be attained by certain motions of the body, and, finally, volition causes the contraction of muscular fibres; thus producing motion in the part required. Now, conceiving these ganglions, to use the expression of Dr. Munro, to be so many "new sources of nervous energy," or, to adapt the phraseology to the electro-physiological theory, considering them as so many reservoirs of accumulation for the electric fluid, it appears that many difficulties in this mysterious department of science may be removed, and many phenomena that appeared unaccountable, readily explained. Who, for instance, has not experienced that peculiar, that indescribable sensation, which accompanies the process of intense thought, whilst engaged in the study of some abstruse subject? Do we not feel that, during the first efforts, the brain seems, as it were, to be scarcely at all acted upon? By degrees, we become sensible of the influence of some new power, or at least we are conscious of an increase in the intensity of the perceptive faculty, until, at length, we are enabled to overcome the difficulty by which we were so long baffled. And, what is remarkable, this result occurs frequently, if not invariably, with almost a startling suddenness, the truth flashing upon the mind with the velocity of light, and we then begin to wonder at the tedious perceptive process which has thus enabled the "mind's eye" to see more distinctly. The electro-physiological theory furnishes us with a ready explanation even of this phenomenon. During the first efforts but a small portion of the electric fluid is transmitted to the brain: gradually the ganglions become charged with it, until the accumulation is such that the brain is immediately and intensely acted upon: hence the result, as above described, in the increased perceptive power. Again, we may explain why it is essential that the process must be kept up. If, whilst engaged in intense thought, we are interrupted, and our attention diverted, even for a moment, to any extraneous subject, we frequently labour under greater difficulty in arriving at the point which we had attained previous to the interruption, than we originally experienced, for the sentient extremities of the nerves then become differently acted upon; the electric fluid, in its partially accumulated state, either becoming dissipated, or having its course diverted into a different nervous channel. This supposition may also aid in explaining the phenomenon of dreaming; the action upon the sentient nerves which have been most excited during the day, probably being renewed by the residual electricity, which is then increased by the supply obtained, as suggested in a former chapter, during chemical action. Facts, well authenticated, prove that tasks which to an individual, during his wakeful moments, appeared replete with difficulties, have been accomplished by him with astonishing facility and correctness during sleep.

It has been urged in objection to the electro-physiological theory, that the nerves exhibit no signs of "spontaneous electricity." Nor ought we to expect such a phenomenon; for the nerves must be considered, not as springs from whence the electric fluid flows, nor yet as bodies capable, of themselves, of exciting electricity, but simply as conductors;

and no conducting body, with which we are acquainted, ever exhibits signs of "spontaneous electricity." It has also been asserted that feeling is occasioned by "vibration." The nerves are too inelastic and too soft to admit of such an hypothesis: indeed, their situation and connexion are proofs of the fallacy of the vibratory theory.

CHAPTER IV.

Objections answered.

In the Library of Useful Knowledge, (title "Animal Mechanics," Part ii., p. 49), the author observes, "Another mistake which some philosophical inquirers entertain is to fancy that the principle of life is of galvanic nature." All that has hitherto been contended for in this work is that the electric fluid forms part of the mechanical contrivance in the animal economy. The observations and reasoning, however, of the author of the treatise in question, tend so materially to assist in proving that there is a very intimate connexion indeed between galvanism and vitality, that one or two extracts from that treatise will be found not inappropriate under this head. The author has, indeed, been particular in distinguishing the mechanical adaptation of parts from the co-operation of the vital principle residing in the several parts; but in his overstrained zeal to preserve that distinction, he has entirely lost sight of the moving power, and has thus placed himself in the situation of one who, in attempting to explain the mode of action of the steam-engine, should omit to state that the vapour of water is the material agent which constitutes the motive power, leaping at once from water to caloric, and informing us that, since we cannot tell what caloric is in a separate state, our inquiries must be limited solely to the action and co-operation of the various levers of the machine. In reference to the experiments at Glasgow (alluded to in the last chapter), he observes, " experiments without reason are equally delusive with hypothesis; those who will not give themselves the trouble of thinking, desire to witness striking phenomena," &c. And he thus continues: " A calf's head is made to yawn, or a man cut down from the gallows to move like a figure of cards pulled with strings!" [Here we cannot but rest for one moment to admire the very close analogy between the movements of a pasteboard figure pulled with strings, and the motions of the muscles, as effected, through the medium of the nerves, by means of galvanism!] He proceeds thus: " The jaws move and the eyes roll, and this is done by conveying the galvanic shock to the nerves: here it is supposed that nothing less than the principle of life can work such wonders, and that galvanism is this principle." The principle of life (taking the expression, not certainly as employed by the author, but in its most limited sense), will probably remain, as it is, a mystery. All that can be done towards elucidating the phenomena of vitality, is to endeavour to arrive at the ultimate effect which is produced in subordination to the cause. Indeed, all that can be arrived at in any department of science is an ultimate effect; the cause being inscrutable to mere human reason, which, compounded as it is of that which is immaterial with that which is material, can only, of course, investigate the phenomena of mind and matter in their mysteriously united state, and not separately, so as to detect the mode of action the one upon the other. It need not be observed that we are here referring to vitality as regards man. To use the writer's own words, "experiments without reason are equally delusive with hypotheses." True. But, on the other side, to theorise without reference to facts proved by experiment, is, to say the least of it, equally unphilosophical. The author ought to have shewn that there are other stimulating agents which can effect all that the galvanic fluid has effected, *not only in the living, but in the dead* animal. He says that "the whole phenomena resulting from galvanism transmitted through an animal apparently dead, are fairly to be attributed to its being a high stimulus conveyed through the moist animal body, and exciting the powers which remain insulated in the several parts." But let it be asked, what sort of stimulus is that which can thus excite the "insulated powers" in an animal apparently dead? Let it further be asked, can any other stimulus excite those powers, under similar circumstances? Can the processes of digestion and of respiration be renewed by any other stimulus? Or by any other influence than that of galvanism can the muscles be brought into play? In Chapter IV. of the treatise, the author ingeniously proves that which in Chapter II. he views as ridiculous. At p. 58, we find, in speaking of the changes in the material of the animal body during life, this statement: "We make a moderate assumption, when we declare these changes to be under the guidance of the living principle. In a seed, or a nut, or an egg, we know that there is life, and from the length of time that those bodies will remain without change, we are forced to acknowledge that this life is stationary or dormant, and limited to the counteraction of putrefaction, or chemical decomposition; but no sooner does this principle become active, than a series of intestinal or internal changes are commenced, which are regularly progressive, without a moment's interruption, while life continues." But what takes place from the moment of the insertion of the seed in the earth? Decomposition commences in those parts which protected the embryo plant; and we must again bear in mind the established fact that no chemical action can take place without a disengagement of electricity. Again, at p. 61, he says, "There is a living principle, which is permanent, while the material changes." This alteration in the material again all depends upon chemical action. "And this principle," he continues, "attracts and arranges, dissolves and throws off successive portions of the solids, shapes and limits the growth of every part," &c. &c. Those who are sufficiently acquainted with electricity will readily admit that that subtle fluid is capable of thus attracting and arranging, dissolving and throwing off, successive portions of the solids. That it is also capable of influencing the forms of bodies, has, we trust, been already proved. The very dust upon the pavement assumes a regular form during a highly electrical state of the air, of the truth of which any person may convince himself at the time a thunder-storm is impending.

We have thus attempted to glean proofs of the truth of the electro-physiological theory from the pen of one who has ridiculed the very idea of the connexion of galvanism with the vital principle; and, if we have also been bold enough to advance a step further than his limit would prescribe as proper in such researches, we trust that the motive for doing so will not be misunderstood. But to explain: it is indisputable that the same Almighty Being who created, also continues to uphold all created things, and to direct all the changes produced by the operation of those unerring laws which have regulated those changes from "the beginning." To this conclusion we must come, let us pursue our investigations to what depth soever we may. And no mortal can claim the right to say such is my limit to all inquiry—a limit which no one must presume to overstep; as if, in all our inquiries into the phenomena of nature, we shall not always find in the deep another deep yet more profound. It may fairly be asked whether the very idea that a man can by any possibility be subjected to such a limitation, does not imply a supposition either that the mind of man is, or may become, infinitely perfect, or the atheistical notion that the First Great Cause can ever be understood, or even in idea approached, by a finite being. It has been truly observed that all our knowledge only serves to teach us that we know nothing.

CHAPTER V.

Theories of Galvani and Dr. Wilson Philip.—Agreement of the Theory of an Electrical Circulation with Anatomical appearances, &c.

Upon the discovery of galvanism, Galvani supposed that the nervous influence was of a galvanic nature; but that philosopher was not aware of the development of electricity during chemical action, or at least he had entirely lost sight of that fact, and hence was under the necessity of assuming that the fluid was called into action in the same manner as its liberation is effected in an artificial galvanic combination. Thus he considered the entire nervous apparatus a galvanic battery. Dr. Philip also, and, we believe, all other authors who have entertained opinions favourable to the identity of electricity and the nervous influence, have had recourse to the same upposition. But upon this assumption, even admiting it, the phenomena of the separate functions of the nervous apparatus cannot be explained. For, if the entire apparatus is a galvanic battery, all the functions must have been equally under the control of the will. Again, there is not any arrangement in the nervous system analogous to that of the dissimilar plates in a galvanic apparatus. It is evident that we must have such an arrangement as will admit of the action of involuntary muscles, at the same time that such actions are so far affected in common with those which are voluntary, as to be influenced by the passions, which act upon the whole nervous system.

The distinction between the theories must, there fore, be borne in mind. In the theory of Galvani, the nerves themselves were considered as wholly, or in part, concerned in the production or excitation of the electric fluid. In the circulatory theory, as before stated, the nerves are to be viewed merely as conductors, and as being no more necessary to the liberation of the fluid, than the arteries and veins are concerned in the formation of the blood; the electricity being excited solely during the chemical changes which are continually going on in the system.

"Those parts which are under the control of the will, and which convey to the percipient organ the impressions they receive from without, are supplied with nerves which arise from determinate portions of the brain and spinal marrow. Between these definite portions of the brain, and the organ to which they correspond, the communication is simple and direct; each particular nerve being a fasciculus of smaller cords running parallel to each other, and communicating distinctly between the two extremities.

Every fibre of the body which is under the dominion of the will, is thus placed in relation to a definite spot in the brain or spinal marrow, and volition may be conceived to operate upon it, through an action concentrated exclusively on that point."—(*Morgan's Philosophy of Life*, p. 176.) It was suggested in a former chapter that volition might operate by causing the completion of a circuit, and thus the "concentrated action" alluded to in the foregoing extract may be explained. Let us next proceed to an examination of the difference in the construction of those nerves, and that of the nerves of the sympathetic plexus, which were destined to influence organs removed from the control of the will. This plexus is "a network of nerves uniting with each other in every possible variety, and also with numerous ganglions, which appear to perform the functions of so many nervous centres. This system of nerves unites with the brain, and with every portion of the spinal marrow, by numerous communications, and may therefore be considered as receiving impulses from all these points, and consequently as being susceptible of the joint influence of all, without being subjected to any specific action from each."—(*Ibid.*) Thus, the parts to which these organs are distributed, although emancipated from the dominion of the will, are subjected to the influence of the passions and other causes, which act upon the whole nervous system. It would not, perhaps, be a difficult matter to trace these influences specifically; but of this hereafter. Thus, as Bostock remarks, (*Elements of Physiology*, vol. iii. p. 258,) particular organs seem to feel the effect of particular mental emotions; fear and joy act upon the heart, surprise appears more particularly to affect the respiration, and grief the digestive organs; and Parry adduces evidence of certain mental emotions producing a peculiar effect upon certain secretions.—(*Pathology*, § 666.)

CHAPTER VI.

The Existence of a Nervous System not essential to the circulation of the Electric Fluid, as in Plants, &c.

Dr. Bostock, in his remarks on the "nervous hypothesis of secretion," and more particularly in allusion to the interesting experiments of Dr. Philip, admits that the reasoning employed by that gentleman, and the facts adduced by him, are very impressive, and, at first view, almost unanswerable. But, in order to shew that there is not any necessary connexion between "the nervous influence" and the action of the glands, and further that the series of changes which are produced are not essentially dependent upon such a connexion, but that they may be deemed merely incidental, he refers us to examples of the production of secretions, where there can be no intervention of nervous influence. *Ex. gr.* in the case of all the various classes of the lower tribes of animals, in which no nervous system has been detected. This seeming difficulty is entirely obviated by substituting the circulatory theory for that in which it is necessary to assume that the electric fluid is generated by means of the nervous apparatus. For this purpose a "nervous system" is by no means necessary: it is sufficient that the circulation of the fluid, generated during chemical action, should be favoured by a certain disposition of conducting tubes or fibres, of which we shall find an abundant provision, not only in the lower orders of animals, approximating to the vegetable kingdom, but even in the latter kingdom itself. So that the question is reduced to a mere matter of dispute as to the propriety of the expression "nervous influence." It cannot be too frequently repeated that all which appears requisite is a proper adjustment of conductors, be their technical terms what they may; for we might, by a process of reasoning similar to that above alluded to, deny that there is a circulation in vegetables, merely upon the ground that the vessels adapted to that purpose are not precisely similar to the arteries and veins of animals which convey the blood through the system*. —(*Vide Bostock's Elements of Physiology*, vol. ii. p. 413, *et. seq.*)

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* These remarks were published in the "*Atlas*" newspaper, in the latter part of 1835, and we can now avail ourselves of the observations of the justly celebrated Magendie, in his Lectures on the Physiology of the Nervous System, delivered in the College of France, in 1836. To the following extract from these lectures, we particularly request the reader's attention:—"*The phenomena exhibited by the nervous system, when in action, have often been compared with those of the electric and galvanic fluids.* There are certainly many points of analogy; *but without pushing the comparison too far, or giving way to exaggeration, I may affirm, that the result of the various experiments*

It may, perhaps, be questioned by some whether a sufficient supply of the electric fluid can be obtained during chemical action to keep up such a circulation. Dr. Faraday has demonstrated that a single grain of water contains as much electricity as an ordinary flash of lightning! Thus, then, the little dew drops, from which the poet has derived so many sweet images, may suggest to him ideas of a more elevated and sublime nature. What countless tempests repose upon the green bough, or, in silence and in beauty, pillow themselves upon the delicate petals of the drooping flower! Yes: even upon a dew drop he may gaze until he is involved in speculations the most deep, curious, and interesting, and until those speculations again become absorbed in wonder, and in admiration of the works of that Almighty Being, who thus teaches him at once to love and to fear through the medium of objects apparently the most insignificant. The gem that decks the leaf, and whose very beauty consists partly in its silent repose, may, ere another sunset, play its part in the strife of conflicting elements—its breath the whirlwind,—its voice the thunder,—its spirit the lightning—rending, perchance, the time-worn trunk of some stately monarch of the wood, upon whose foliage it had slumbered in peace, a glittering thing of beauty.

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which I have made on the spinal marrow, proves that SENSIBILITY, AT LEAST, IS CONNECTED WITH THIS PORTION OF THE NERVOUS SYSTEM, EXACTLY IN THE SAME MANNER AS THE ELECTRIC FLUID IS CONNECTED WITH THE METALLIC CONDUCTORS WHICH ARE DESTINED TO TRANSMIT IT."

We are almost induced to believe that we have no word in our language synonymous with the "*anima*" of the ancient philosophers, as applied to what are termed inanimate bodies; and, in studying the properties of matter chemically, and detecting in its composition an agent of so subtle a nature as the electric fluid—so subtle, indeed, as to lead the inquirer to doubt even its materiality, the idea cannot but occur to the thinking mind that we have in this fact another argument, for the over-learned, (who call for argument in support of innate proof), of the existence of a soul. For analogy would almost teach us that since in the physical world there is a chain whose connecting links between the several kingdoms are so nicely adjusted as to lead to disputes where one kingdom terminates, and another commences, and resident in each a subtle element, whose materiality with some is almost a matter of speculation, so both in the physical and the intellectual world more etherial links may exist, so subtle as to be beyond the reach of our vision, both physical and mental, progressing towards perfection, from minerals upwards to vegetables and animals, and finally to man, who, being distinguished above all other animals by the possession of an immortal spirit, forms the connecting link with the spirits of a better world; for "man was made only a little lower than the angels."

CHAPTER VII.

Application of the Electro-physiological Theory in elucidating the Phenomena of Disease;—Inflammation, &c.

Perhaps it may be thought that we are entering upon this important part of the subject somewhat abruptly; but, since a proper introduction would probably occupy a complete volume, we shall at once proceed to attempt to point out how particular diseases may arise upon the principle of this theory. Having attempted to shew that a close connexion exists between electricity and vitality, we shall now proceed to point out in what manner the electric fluid probably produces disease. And this it may do, either by increase or diminution in its natural quantity, by being diverted by natural causes, or by accidental circumstances, from its natural course, or by having its course completely reversed in diseased parts of the system. In thus treating the subject, we are only proceeding upon the maxim, that the principal sources of disease must be sought amongst those agents which most materialy contribute to life. We must first premise a few facts which it will be necessary to bear in mind. For instance, strictly speaking, diseases are all either functional or organic, although the functions of a part are rarely disturbed without some degree of organic affection, and organic disease cannot long exist without the functions becoming affected; but particular diseases, for the most part, bear more decidedly upon one or other of these actions. As examples of this distinction, two diseases of the lungs may be adduced—catarrh, and tubercular consumption: the former a functional affection, readily relieved; the latter an organic disease, and how certainly fatal is but too well known. Again, diseases may be confined to the parts to which the morbid stimulus is applied, or the whole system may be deranged. They are further distinguished into acute and chronic, according to the time they consume in performing their natural course. The rapidity of the disease must, however, be estimated in comparison with the rapidity of the customary actions of the part affected, rather than by its absolute duration. *Ex. gr.*—Inflammation in the cellular substance of a muscle will pass through all its stages in a few days, while in that of a bone it will occupy as many months to arrive at its termination. Yet both, relatively to the ordinary movements of the parts, may be considered acute diseases. Now, here we have an instance in which the electro-physiological theory is applicable. Upon the supposition that acute diseases are owing to a disturbance of the equilibrium of the electric fluid, by means of which an accumulation takes place, and an increased action in its circulation is induced, the difference in the 'rapidity of the progress of the diseases of bones and of cellular substance is attributable to the greater degree of resistance with which the fluid meets in the one case than in the other, the bones being the least perfect conductors in the body.

If we take two brass balls of equal dimensions, the one hollow and the other solid, insulate, and charge them with electricity, we shall find that the latter will contain precisely the same quantity of the fluid as the solid ball, shewing that accumulated electricity does not pervade the substance of conductors, but tends towards their surface. Now inflammation. wherever seated, is always more violent on that side of the inflamed part nearest the surface, and shews a constant tendency to work its way externally, rather than internally. This law applies equally to the thorax, to the abdomen, and to parts which lie close to the different outlets of the body. And its operation has appeared so inexplicable, that authors have actually brought it forward as an "incontrovertible proof" of the existence of an "instinctive remedial power (!) existing in the part affected! This fanciful idea may, perhaps, be highly agreeable to some minds, but, in a philosophical point of view, it is most absurd. That it is so, facts of daily occurrence sufficiently prove. Is it an instinctive remedial power that causes adhesion of serous membranes, thus interrupting the movements of the viscera they cover? Is it such a power that chains the lungs to the ribs, or which binds the heart to the pericardium, and so interrupting the functions of those important viscera, that dissolution ensues as the consequence of the efforts of this "instinctive" faculty? Is it this *vis medicatrix* which induces suppuration in tubercular consumption, by which one purpose only is served—that of hurrying the patient more rapidly along the path to the tomb? Let us discard such vain dreams of the imagination. Let them be blotted for ever from the pages of science. But we shall now at once proceed to shew how disease, and the operation of this *vis medicatrix*, may be otherwise accounted for. To commence, we shall first inquire into—

The nature of Inflammation. — How little this subject is understood is evident when medical writers are under the necessity of endowing the affected part with another attribute of mind. We are told that inflammation generally commences in a small point, and spreads by means of the sympathy of the neighbouring parts. This is a most convenient term, but it fails to satisfy the judgment. It explains nothing. Upon one point the agreement seems to be general, viz. that the capillaries are the immediate seat of the inflammatory action; but while some have contended that increased, others have as strenuously maintained that diminished action, takes place in those vessels. Boerhaave's *lentor* and Cullen's spasm were found equally insufficient to explain the cause of inflammation. Where is the difficulty? It consists in this:—the combination of a state of increased action with distension of the vessels. To account for this, we must suppose an obstruction in some form or other. And have we not a ready solution upon the supposition of an accumulation of electricity in the affected part? We have already satisfied ourselves that electricity accelerates the motion of fluids through tubes of small diameter. We have now only to find an explanation of the distension of the vessels. The same agent will effect this, by the well-known action of electricity upon the fibrin of the blood, imparting to it a disposition to coagulate. It is to this coagulation (owing to increased resistance) that the distension of the vessels is due.

Inflammation is characterized by redness, attended with a greater or less degree of heat, pain, tumefaction, and fever. Now Ritter, in the course of his researches in medical electricity, found that the positive pole augments, while the negative diminishes, the actions of life; that tumefaction of parts is caused by the former, depression by the latter. We are not aware that his experiments have been repeated, and therefore shall not dwell further upon this point than merely to remark that, if inflammatory action is induced by an accumulated state of the electric fluid, the remedy is of easy application. If the electro-physiological theory is correct, we ought to find that an increased action in one part causes diminished action in another. This is the fact, and for such an effect a most curious cause has been assigned—that of sympathy, a word which is much in vogue with medical authors to aid in the explanation of many of the phenomena of disease. What new light breaks in upon us on our being informed that disease in one part produces disease in another by means of sympathetic action? Not one faint ray, assuredly; nor shall we be much more edified by the perusal of the many pages which have been devoted to the subject of the sympathetic production of disease. In fine, sympathy is a term which, in the sense it has frequently been applied, is well worthy of being classed with the *vis medicatrix*, or instinctive remedial power, and others *hujus generis*. But let us examine the statements of authors upon the subject of what is termed "sympathetic action," and we shall discover a contradiction in terms ere we have perused many pages of any account which may fall in our way. For instance, we are told that sympathy is owing to the connexion subsisting between different parts; that its influence evidently depends, in some cases, upon mere contiguity, in others upon a direct vascular or nervous communication, and that it may frequently be referred to association. Then, in the very next sentence, we are informed that there are some instances in which none of these causes seem to be applicable, where the parts are distant from each other, where there has been no repetition of the actions, so that they cannot have acquired an association with each other, and where there seems to be no direct communication through the medium either of the vessels or of the nerves; that, although the phenomenon cannot be thus explained, authors are disposed to think that it must be referred to the operation of the nervous system. Yet the difficulty still remains in explaining the *modus operandi* of sympathetic action between parts connected, although that connexion depends upon neither contiguity nor communication; for such is the contradiction in the above attempted explanation. Now, it is not a little singular, that what has always appeared to constitute the barrier between the phenomenon and its explanation, is, on the contrary, the very tact which prompts a ready solution, viz. the absence of any peculirr or especial nervous connexion. As, for instance, in some of the affections which are ordinarily termed sympathetic, and from amongst which the following are enumerated by Dr. Bostock, (*Elem. of Physiol.* vol. iii.):—"The general uniformity in the motion of the two eyes; the secretion of milk; the convulsive contraction of the diaphragm, which produces sneezing, as caused by the irritation of the nerves belonging to the mucous membrane of the nostrils; pain of the head, occasioned by a certain condition of the stomach; imperfect vision, from a morbid state of the intestinal canal; and vomiting, from the irritation of a biliary calculus in the duct of the liver—effects which could not have been predicted or suspected, but which are well-authenticated matters of fact." The explanation which the electro-physiological theory affords is this—a positive state of one organ or part of the frame induces a negative state in another part. And when we bear in mind to what an extent this inductive action may be carried, we shall be the more ready to admit this explanation of what has been termed "sympathetic" influence. It is, moreover, an explanation with which facts are in the strictest accordance. *Ex. gr.* when action is increased in one part, it is, to a certain degree, diminished in another. When the liver is inflamed, or has its action increased, the stomach is weakened, and dyspeptic symptoms take place. If, on the contrary, the stomach is weakened, then the action of the liver is increased, and an inordinate secretion of bile results. When the brain is injured, and its action much impaired, as in compression, inflammation and suppuration have been often known to be occasioned in the liver. It were needless to multiply instances of a like nature. Now, if there is such an influence as that which has been called sympathy, we should expect that its *modus operandi* should be very different. An increased action in one part ought invariably to induce increased action in another—weakness in one, should produce a corresponding affection in another organ. But, as has been stated, and as facts fully demonstrate, the reverse is the case. When, however, inflammatory action suddenly disappears from one part, it will frequently speedily occur in another: to use the words of medical authors, "in that organ which sympathises most with the part which was originally diseased." Hence, and from the facts before enumerated, has sprung into use another term of high sound, but little meaning, viz. the "sympathy of equilibrium." It is not a little strange that the terms thus so commonly used should be so directly applicable to the electro-physiological theory. For it is not too much to assert that all the actions and reactions which are observable during the progress of certain diseases, may be attributed to the influence of a something that has a constant tendency to regain its state of equilibrium, when a condition of unequal distribution has been induced. What is that something? Who that is acquainted with the various modes of action of the electric fluid will be at a loss for a reply to the question? The very language employed by medical authors is that which is precisely adapted to signify those modes of action; and the reason why the unmeaning terms "nervous influence," "instinctive remedial process," "sympathy," and others equally absurd and unphilosophical, have been thus freely used, is attributable to the study of electrical science having been neglected in medical education, or, at least, but little attended to. We have another instance of this in the following extract from Sir T. C. Morgan's *Philosophy of Life*: "Every action which takes place in the organization is the necessary consequence of the adjusted balance of causes operating upon the living principle." What follows is still more obscure:—"If the disturbing force be not so great as to master the permanent and ordinary principles of motion, the balance of function must, in the end, be necessarily restored; and certain corresponding phenomena must inevitably accompany the successive stages of the progress by which the violence impressed on the machine is neutralized and absorbed in the periodic movements." Now this ambiguous attempt at explanation, and other explanations, which are a strange mixture of truisms vaguely worded, and conjectures, are far from being satisfactory—if, indeed, they are intelligible.

CHAPTER VIII.

Of Fever, &c.

Having attempted to shew that the proximate cause of disease generally has never been satisfactorily explained—that its extension to other parts than those which were first attacked, has never been accounted for, excepting upon the assumption that the organs are separately endowed with a species of sympathy, or instinct, and that the cure of disease is not, in any instance, owing to the operation of the imaginary "instinctive remedial power"—we shall now proceed to the consideration of the phenomena of fever, since they have been supposed more particularly to evince the existence of the last-named hypothetical principle. The symptoms of febrile disease teach us (we are told), that "there is a derangement in the balance of nutritive functions, which influences to a greater or less extent those also of the relative organs." Here is the effect of an effect, but nothing more. How or whence arises the derangement in the balance of nutritive functions? For we surely cannot conceive the derangement of a balance without the instrumentality of some disturbing cause: and this cause, moreover, must be one of considerable force, since a return to health only occurs after an extended series of re-actions; or, to use the words of medical authors, "the return to health is accompanied by many '*oscillations*' (!), producing the recurrence of the phenomena in a regular series." First, then, with respect to the "derangement of the balance of nutritive functions." Whatever may be the cause of this, it must be something that is possessed of various modes of action; for, although it is supposed that fever is not long in forming (seldom more than twenty-four hours), still, in some cases, the assault is very abrupt, from sudden occasional causes, and this, too, in every diversity of constitution. Hence it is evident that this "derangement of balance" may be produced, comparatively speaking, either gradually, or the "balance" may be at once destroyed. In either case electricity affords an explanation, for, by its subtlety as well as by its intensity, it may either insidiously undermine the nervous system, producing a gradual derangement, or its assault may be sudden and violent. It were easy to point out in what mode and under what circumstances the electric fluid would operate, either by the one or the other of these modes of attack; but the more minute inquiry into this subject may be properly reserved until we proceed to the consideration of epidemic diseases generally, and their causes. Secondly, then, with regard to the (so called) oscillations. A series of re-actions are said to take place. These re-actions are probably owing to the continued inductive process, which goes on either until the equilibrium of the fluid is restored, or the constitution of the patient sinks under the disturbance which is produced. As might be expected, if re-action occurs suddenly, and with a degree of force proportionate to the violence of the disturbing cause, the result will be fatal. This also may be explained by the sudden induction and accumulation of electricity upon the brain, or some other important organ. Again, fever exhibits a disposition to observe regular periods. In our own country marked changes are looked for on the seventh, fourteenth, and twenty-first days of the malady. The cessation of fever on one of these days is accompanied by some notable increase of secretion, particularly of perspiration. Now it is evident that the matter of perspiration is capable, owing to its composition, of materially aiding the efforts of the electric fluid to regain its equilibrium, owing to its conducting power. That it is a good conductor, may be inferred from its composition, as given by Thénard, who states that it is composed of a great deal of water, a small quantity of acetic acid, of muriate of soda and potash, a small quantity of earthy phosphate, an atom of oxide of iron, and a trace of animal matter. The matter of perspiration has been more recently examined by Berzelius, whose results are considerably different from those of Thénard; but the difference does not affect it as a conductor of electricity, he, too, supposing it to contain free acid; only, instead of the acetic, he conceives it to be the lactic acid, accompanied with the lactate of soda, together with the muriate of potash and soda, and a minute quantity of animal matter. Now it is not a little singular that in a deranged state of the health of those animals in which there is no secretion of this perspiratory matter, the hairs or feathers of their bodies may frequently be observed to stand erect and apart from each other, precisely in the same manner as they would do if electrified. Hence, when this occurs, it is not improbable that a process is going on similar to that above mentioned, viz. that the restoration of the equilibrium may, in such cases, be effected by means of the pointed hairs and feathers of those animals. In birds this erection of the feathers is often observable, and even in some of those animals which secrete the perspiratory matter in abundance, the same peculiarity has often been noticed; for instance, in the horse; and grooms sometimes detect it as being the first indication of indisposition which the animal has afforded. In order, however, to discover how far the phenomena of febrile diseases have been already accounted for, let us proceed to examine the various theories of fever, and we shall soon find that the subject of the nature of fever is overshadowed with as dense a darkness as that of inflammation. In a modern work, now lying before us, we are presented with a view of several theories, each the fashion of the day at the time of its promulgation, each anon falling into disuse as its novelty wore away, or its defects began to be perceptible. In what the various theories are appropriate, in what they are deficient, the author clearly points out; but nothing more is done than to shew that the plausibilities of the various opinions are not very plausible, and that the deficiencies still remain unsupplied. And we have this conclusion to his labours:—"The result of the whole is, that we know little or nothing of the proximate cause of fever, or the means by which its phenomena are immediately produced. In the language of Lieutaud, applied to the subject before us, they are too often *atrâ caligine mersæ;* nor have any of the systems hitherto invented to explain this recondite inquiry, however ingenious or elaborate, answered the purpose for which they were intended." And again, in the words of Dr. Good, "Upon this subject a great deal of learned dust has been raised, and a great deal of valuable time consumed. Ancient speculations have been overthrown, and modern speculations, in vast abundance, erected upon their ruins, which, in rapid succession, have also had their day, and expired."

We shall proceed to give, as briefly as possible, the various hypotheses that have been generally received, so that whenever any particular theory is afterwards more expressly alluded to, the non-medical reader can refer to any work wherein a full account of the hypotheses may be perused.

The conjecture that the proximate cause of fever was to be sought for in a morbid change in the composition of the blood, gave rise to various hypotheses that rank under the common division of the *humoral pathology.* In the supposition that the cause consisted in a morbid change in the tone or power of the living fibre, other hypotheses originated, appertaining to the common division of the *fibrous* or *nervous pathology*. The first two of the following hypotheses belong to the former, and the remainder to the latter of those divisions :—

I. That of the Greek schools, founded on the doctrine of a concoction, and critical evacuation, of morbific matter.

II. That of Boerhaave, founded upon a peculiar viscosity, or *lentor* of the blood.

III. That of Stahl, Hoffman, and Cullen, founded on the doctrine of a spasm on the extremities of the *solidum vivum*, or living fibre.

IV. That of Brown and Darwin, founded on the doctrine of accumulated and exhausted excitability or sensorial power.

V. To these may be added the hypotheses of Dr. Clutterbuck and Professor Marcus, who identify fever with inflammation.

There appears to be more or less truth in each of these hypotheses, how different soever they may appear. Not any one of them, however, will account for all febrile phenomena, nor will a mixed theory, erected from portions of each, form a fabric of greater stability. Perhaps, indeed, such an edifice might shew the ingenuity of the architect; but designs so various, and materials so dissimilar, could in no wise be united so as to form a whole that would not offend by its want of harmony.

Theory of Hippocrates.—The doctrine of the Greek schools is not only highly ingenious and plausible, but is in perfect unison with several of the phenomena peculiar to fever; whilst, however, it was found to derive strong support from the general history of febrile diseases, it was weighed in the balance, and found wanting in an explanation of the proximate cause of those species of fever in which there is no specific eruption. Galen supported the views of Hippocrates with all the medical learning of the day; and this, for the long period of three thousand years, is the only explanation of fever to be met with in medical writings. At length, a new theory was constructed, which triumphed over the hypotheses of the Greek schools—that of

Boerhaave—who attempted to explain the phenomena by his *lentor* and *error loci*, alluded to in a former chapter, under the head of "Inflammation." His system consisted of an elegant and ingenious combination of all the doctrines of corpuscular physiology; but it also, in its turn, gave place to the more philosophical theory of

Stahl—who first attributed febrile action to a spasm on the extremities of the nerves, produced by a torpor or inertness of the brain. Boerhaave, with that candour so truly characteristic of a great mind, in his latter days admitted the agency of the nervous power, although the doctrine struck at the very root of his own system. Stahl's hypothesis, as modified and improved by Hoffman, formed the basis of

The Theory of Cullen—which is styled by Dr.

Good, "a stately and elaborate structure;" "and if," he continues, "it be at this moment crumbling into decay, it is certainly not falling prostrate before any fabric of more substantial materials, or more elegant architecture." Upon the plea of such a statement, by one whose opinion is entitled to attention and respect, we presume to crave the reader's attention while he enters with me, with yet more marked attention than we have devoted to the former hypotheses, into an examination of that of Cullen; and we trust we shall be able to shew, by the aid of the electro-physiological theory, that many of those parts in the architecture which have been pointed out as defects, constitute, in reality, its chief beauties; and that those parts which have been deemed weak and unstable, on the contrary contribute mainly to its strength. Before, however, we come to his opinion upon the proximate cause of fever, it is necessary that we should have in view the more elaborated principles of the Cullenian system, which are as follow:—The human body is a congeries of organs, regulated by the laws, not of inanimate matter, but of life, and superintended by a mobile or conservative power or energy seated in the brain, but distinct from the mind or soul; acting wisely, but necessarily for the general health; correcting deviations and supplying defects, not from a knowledge and choice of the means, but by a fore-established relation between the changes produced and the motions required for the restoration of health, and operating, therefore, through the medium of the moving fibres, upon whose healthy or unhealthy state depends the health or unhealthiness of the general frame: which fibres he regarded, with Stahl, as simple nerves, the muscular filaments being nothing more than their extremities, and by no means possessed of an independent *vis insita.* Upon this hypothesis the brain is the *primum mobile,* but it closely associates in its action with the heart, the stomach, and the extreme vessels. We shall now proceed to his explanation of the proximate cause of fever, which he attributed to a collapse or declination of the energy of the brain, produced by the application of certain sedative powers, as contagion, miasm, cold, and fear, which constitute the remote causes. This diminished energy extends its influence over the whole system, and occasions a universal debility, but chiefly over the extreme vessels, on which it induces a spasm, and in this spasm the cold fit is supposed to consist. "However," to use Cullen's own words, "such is the nature of the animal economy, that this debility proves an indirect stimulus to the sanguiferous system." Now this has been pointed out as the most glaring defect in the Cullenian hypothesis; for medical authors have made a stumbling-block of the contradiction that debility can be made, by any means, a cause of strength, although, after all, the meaning of Cullen has been much and unfairly strained, in attributing to him any such absurd proposition. But we shall not quarrel with words. As we have already instanced in regard to what have been erroneously termed sympathetic actions, so we trust we shall be able to shew, by the aid of the electro-physiological theory, with reference to febrile phenomena, that apparent anomalies are transformed into natural and reconcileable results, and the greatest seeming difficulties converted into facilities of solution.

"All nervous power," says Cullen, "consists in a motion beginning in the brain, and propagated from thence into the moving fibres, in which a contraction is to be produced. The power by which this motion is propagated, we name the *energy* of the brain, and we therefore consider every modifications of the motions produced as modifications of that energy." But in what this energy consists, whence it is derived, or how produced, or called into action, or in what manner the motions are thus propagated along the moving fibres, could in no wise be explained without the supposition of the existence of "*a vital fluid*" sent forth by the brain. And this vital fluid Cullen supposed to be not a secretion, but an inherent principle, never exhausted, and that never needs renewal. This can scarcely be said to be consistent in itself, or with facts.

If, then, in the place of an imaginary vital fluid, we admit the constant generation of the electric fluid in the animal frame during the various chemical actions that are at all times going on (an admission which no chemist will hesitate to make), we may find a ready explanation of the phenomena of fever, as well as of those of inflammation. But this is a division of the subject of too much importance to be passed lightly over. We therefore presume to crave the attention of our readers to the following propositions :—

I. That there is (as stated by Cullen) a peculiar energy in the brain, not, however, as he conceived, an inherent property, but dependent upon some material power or agent.—Because it is capable of being diminished or exhausted, and of being again replenished by food and rest, often with an accumulation of power.

II. That a diminution in the quantity of this vital agent in the brain accelerates the circulation.—Exemplified by numerous actions, erroneously termed by authors "sympathetic."

III. That a contrary effect is often produced by an accumulation of fluid in the brain.—Instances of which are also to be met with in the same actions.

IV. That fever may be produced by either of the two electric conditions of the brain, viz. by an accumulation of, or a diminution in, the quantity of the fluid.—As in inflammatory and typhus fever.

V. That we are not acquainted with any material agent whose *modus operandi* can explain such opposite effects, excepting the electric fluid.—*Ex. gr.* Negatively electrified bodies induce positive electricity in others, and *vice versâ.*

The "energy" of the brain cannot be an inherent property, as it was supposed to be by Cullen; for if, as he states, all nervous power consists in "a motion beginning in the brain, and propagated from thence into the moving fibres," we cannot conceive in what way such a motion can be produced in the first instance; for there can be no motion without an impulse. Even if we could only thus far satisfy ourselves, and admit the propagation of such a motion in such a manner, another difficulty presents itself. When the inherent energy is diminished, or (as is sometimes the case) totally suspended, how are we to account for the restoration of its power, without involving ourselves in the mazes of a problem similar to that by which we should attempt to prove the possibility of producing a mechanical perpetual motion? For it is evident that this supposed "energy" must constitute at once the moving power and the moving material; in short, must be both cause and effect. We are also involved in the absurdity of assuming that a given motion is the cause of its own motion; and further, that it is capable also of suspending its own motion, and of reproducing it.

What is chiefly deficient, then, to perfect the hypothesis of Cullen, is a material agent upon which the energy of the brain depends—an agent whose peculiar modes of action are fully adequate to the explanation of all febrile phenomena, whether they be dependent upon an increased or diminished energy of the brain. Let us suppose, then, the electric fluid to be this material agent, bearing in our recollection the statement in a former chapter, that there is probably a constant circulation of the electric fluid through the nervous system. Now it must be evident to every one acquainted with the structure of the brain that a great extent of conducting surface is afforded, so that a large proportion of the circulating fluid must be continually confined to that important organ in a healthy state. That portion may be properly termed its natural quantity. We must next proceed to shew by what means this natural quantity may be diminished, and how the altered electrical condition of the brain can so operate as to give rise to increased action, or, in other words, produce an accumulation of the fluid in other organs more or less remote, and conclude by explaining the *modus operandi* of the series of inductive actions which constitute the phenomena of fever.

CHAPTER IX.

Electro-physiological Theory of Fever continued.—Influence of Fear.—Contagion.—Epidemic Diseases.

In pursuance of the plan proposed in the last chapter, we have to proceed to shew in what manner the natural quantity of electricity in the brain may be diminished, and how the altered state of the brain may affect other organs. It has been before advanced that there is probably an ascending current of electricity to the brain, affecting sensation, and a descending current from the brain, influencing the nerves of motion. Hence, whatever affects the irritable fibres, must, in many instances, also, (in however slight a degree,) either increase or diminish the quantity of fluid in circulation, according to the nature of the stimuli by which they are acted upon. What we have first to attend to is the diminution of the fluid in the brain. Inordinate exercise, which requires a great determination of the nervous fluid to those nerves that are connected with the muscles brought into play, must of necessity diminish the sensorial quantity. And we have many instances of fever consequent upon excessive fatigue, produced by muscular exertion, either of too violent a nature, or too long continued. The converse, also, will go a great way towards proving the truth of this statement. Exercise, for instance, wherein there is only a moderate degree of muscular exertion, and which is continued only for a limited time, not only does not diminish the sensorial energy, but often increases it; because, although there is still a determination of the fluid to the requisite nerves, the loss is more than supplied during the increased chemical action consequent upon moderate exercise, respiration being rather accelerated, and the digestive process conducted with greater energy. When, on the contrary, the exercise requires immoderate exertion, the demand towards the nerves is much greater than can be adequately supplied. Indeed, another effect takes place, which tends to diminish the quantity usually generated. Respiration becomes so hurried, that the important changes which the blood undergoes during that process, are, in all probability, very imperfectly performed; so that there are other sources of loss—the superabundant supply required for the excessive muscular exertion, and the decrease in the quantity generated, owing to diminished chemical action, as above explained. Upon this hypothesis, the sense of fatigue, and the extreme debility by which inordinate muscular action is followed, are readily and satisfactorily explained. It were needless to multiply instances. But we must not pass over in silence other powerful causes which greatly influence the sensorial power, diminishing or temporarily increasing its energy, in some cases to such a degree as to place the life of the individual in imminent danger: we mean, the passions. Let us consider, for instance, the influence of *fear,* which is one of the several remote causes of fever. Let us attentively examine some of the phenomena connected with this passion, and we shall find further confirmation of the truth of the electrical hypothesis. We have before observed that those motions which are involuntary must be immediately and directly influenced by the fluid, as in the case of the heart, by means of the peculiar formation of the *sympathetic plexus.* Whatever, then, suddenly and violently affects the sensorial power, decreasing the natural quantity of the fluid in that organ, ought to influence the involuntary muscles. What is the case with the depressing passions, particularly that which we are considering—fear? The sensorial power is, of course, first affected. A perception received by the eye or the ear, combined with some previous idea of danger, excites the passion of fear. But the effects of this passion are particularly manifested on the heart and arteries; the pulse becomes irregular, throbbing violently, or being nearly suspended, according to the degree of the emotion or the mental feeling immediately connected with it. The extent to which this action may proceed is absolutely indefinite; we have numerous instances, in which the effects produced upon the circulation, by mental excitement, have remained during life; and to such an excess has this excitement been occasionally carried as to have caused instant dissolution.—(*Bostock's Phys.* iii. 257.) When the passion reaches this height, it is evident that voluntary motion is completely suspended, whilst there are peculiar derangements of the organic functions over which the will has no control. Hence it may be inferred that there is either an undue increase, or a great diminution, of the sensorial energy, which, of course, immediately affects those involuntary organs; and this effect must be proportionate in degree to the loss of power in the voluntary muscles, thus proving that there must be some material agent concerned in the production of nervous phenomena. It is singular, too, that the last attempts at voluntary motion leave the individual almost statue-like—the personification of the passion under the effects of which he is suffering. In fear, for instance, the hands remain uplifted, the legs in a strange position, which almost denotes a vibration of volition at the moment of the impression, between an advance and a retreat, the tongue cleaves to the roof of the mouth, &c. But one of the most singular effects is the erection of the hair of the head. The last is a phenomenon which it is impossible to produce voluntarily, and which cannot, we conceive, be otherwise explained than upon the supposition of a state of extreme electrical excitement causing the hairs to exert against each other a repellent power.

"Fear," says Morgan, "makes the heart palpitate, drives the blood from the surface, and acts violently upon the intestinal canal;" and Galen reduces all the passions to two movements; one from the circumference to the centre, and another from the centre to the circumference. The first embraces fear, sorrow, and the debilitating passions; the other includes the opposite affections of anger, joy, &c. a notion which is also adopted by Dryden:—

> "These heats and colds still in our breasts make war,
> Agues and fevers all our passions are."

We shall pass over the other propositions, since electricians, bearing in mind the inductive influence of electricity, will be fully able to apply the observations upon the first and second propositions to those also which follow. It will be evident that another subject naturally forces itself upon our attention, as connected, not only with the phenomena of fever, but with those of contagious diseases generally, viz.

Contagion.—It is necessary to premise that we make use of this term in its general signification—as a generic term embracing all those "poisons," as they have been called, which communicate specific diseases. This we could not avoid, as the term, by misapplication, has become synonymous with others having very different significations. Perhaps medicine is the only science in which we are so lavishly supplied with a variety of causes for one effect, and those causes, too, differing materially from each other in their nature. Decidedly in no other are we told that there can be an effect without a cause. When we hear or read of an assertion that some diseases arise spontaneously in the economy, can we conceive that the statement implies any thing less than that disease is self-generating? Time was, when corruption itself was invested with a creative power, and we read marvellous accounts of the "spontaneous production" of insects, or rather of their larvæ. There was a time, too, when such marvellous stories were credited. When, therefore, we hear of a disease for the origin of which many various causes are assigned, we may rest assured that the real cause has escaped detection; and when we are told of a disease arising spontaneously, we must immediately suspect that the cause is still a sealed mystery, not so much as dreamed of.

It may fairly be questioned whether there be a subject connected with medicine upon which opinions are so various and so numerous as upon that of epidemics. We read of subtle poisons, held in solution by the atmosphere; of noxious effluvia, arising from marshes, or from decaying animal and vegetable substances; but these supposed poisonous particles have never been detected by our most able chemists. Even admitting that matter, undergoing decomposition, may, in the first instance, affect an individual, it remains to be explained in what manner the propagation of the disease from one individual to another, or to a number of others, can be effected. Whatever disagreement of opinion, however, may exist as to the specific cause of epidemics, the idea that it exists in the atmosphere is generally entertained. Now, it is material that we should bear in mind that the composition of the air is not only constant in the same place, but in all regions, and in every latitude. Whether collected at the summit of Mont Blanc, or Chimborazo, or in the lowest valleys, its elements are invariably the same, and in the same relative proportion. Berthellot has examined the air of Egypt, and he found it to be similar to that of France. Gay-Lussac brought air from an altitude of 21,735 feet above the earth, and found its composition the same as that collected at a short distance from its surface. Hence the idea that the healthiness of the air, at different times, and in different places, depends upon the relative quantity of oxygen gas, has been exploded. Even in the miasmata of marshes, and the effluvia of infected places, there is no deficiency of oxygen, so that their noxious qualities must be owing to some principle of too subtle a nature to be detected by chemical means. Nay, more, in the infectious atmosphere of an hospital, the odour of which was almost intolerable, Seguin could not discover any appreciable deficiency of oxygen, or detect any other peculiarity of composition. Perhaps some of our readers may not be aware how very small a proportion of any foreign ingredient can be detected; if so, the following experiments will satisfy them upon this point.—A single grain of iron, dissolved in nitro-hydrochloric acid, commonly called aqua regia, and mixed with three 3,137 pints of water, will be diffused through the whole mass; by means of the ferro-cyanate of potassium, which strikes a uniform blue tint, every portion of iron may be detected in every part of the liquid. This experiment proves the grain of iron to have been divided into rather more than twenty-four millions of parts; and if the same portion of iron were still further diluted, its diffusion through the whole liquid might be proved by concentrating any portion of it by evaporation, and detecting the metal by its appropriate tests. Again, starch is so delicate a test of the presence of iodine, that, according to Stromeyer, a liquid containing 1-450,000th of its weight of iodine, receives a blue tinge from a solution of starch. These facts are mentioned to show how very greatly diluted those poisons must be which the air is supposed to hold in solution, when they thus baffle the endeavours of the most scientific chemists to detect them. And we can scarcely be so credulous as to conceive that existing as they must (if, indeed, they exist at all except in imagination), in a state so diluted, and consequently so very widely diffused, they could be capable of producing the powerful, and, in many instances, the sudden effects which have been ascribed to them. We have, therefore, perhaps sufficient grounds to justify us in rejecting the notion of a "poisoned atmosphere" being the cause of epidemics, as unphilosophical, inasmuch as it is devoid of even the shadow of proof.

CHAPTER X.

Epidemics attributable to the Electrical State of the Atmosphere.—Spasmodic Cholera, &c.

——— The salutary art
Was mute; and, startled at the new disease,
In fearful whispers, hopeless omens gave.
Armstrong.

We shall add yet another observation to show upon how slight a foundation rests the opinion that epidemic diseases are occasioned by a "poisoned atmosphere." If such were the fact, they would not be so sparing in their ravages; for all constitutions are nearly equally susceptible to the influence of poisons, whatever may be their nature. For the same reason they cannot be owing to the intermixture of any foreign body of a gaseous nature, inasmuch as all gases, whatever may be their specific gravities, possess the property of blending uniformly with each other, so that, if this were the cause, the effect, as in the case of other poisons, would be more general. Having, therefore, briefly attempted to show to what causes epidemics can not be attributed, we shall now endeavour to point out the real cause of their production—a cause possessing the double advantage of affording a solution not only of the phenomena of the epidemic itself, but an explanation of that peculiarity of constitution which has been termed predisposition to disease. That cause is the peculiar electrical state of the atmosphere. That epidemics are chiefly attributable to such a cause, we have the less hesitation in asserting, inasmuch as we are convinced that the more the subject is inquired into by those who are intimately acquainted with the varieties and peculiarities of electrical action, we shall only be furnished with an additional number of facts and arguments in support of the opinion. We shall first draw the attention of our readers to the meteorological peculiarities which were observable for some time previously to the visitation of our shores by that dire pestilence which has been termed the *Asiatic*, or *Spasmodic Cholera*. During the autumn, at the close of which this disease first made its appearance at Sunderland, thunder-storms were more than usually frequent and violent. And, what is remarkable, a very short time before the irruption of the disease, it was observed that the nights were characterised by a highly electrical state of the atmosphere, and by the incessant discharges of the electric fluid in that form which has received the appropriate term of "silent lightning," owing to its being unaccompanied with thunder. The fact was observed, and remarked upon at the time in one of the Newcastle journals, by (we believe) Dr. Greenhow, of Shields. Those phenomena, also, which are commonly called "shooting stars," were abundant almost every night. It must also be remarked, that the month of October is unusually late in the season for such an electrical condition of the atmosphere.

Again, during the whole of the season, the aurora borealis was also a frequent source of wonder to multitudes, many of whom had never before witnessed the appearance of that phenomenon, and none of whom had ever known it to assume the splendour which distinguished it at that time. Now, bearing in mind these facts, it is interesting to notice particularly one peculiarity in the disease—we mean the circumstance of its having persevered in its route from India, in a north-western direction; so that, if a line be drawn upon the globe, Sunderland, upon whose inhabitants the first of the scourge was inflicted, will be found as nearly as possible to be the point which it might have been expected to strike. The manner of its first attack, too, plainly indicated that its cause was atmospherical. It broke out in the workhouse, and several individuals, in different parts of the building, were almost simultaneously attacked. From Sunderland the ravages of the disease extended to Newcastle-upon-Tyne, and from thence, be it observed, not to places situate upon the line of the great north road to Edinburgh, and between which and Newcastle there is a daily, nay, an hourly intercourse, but still persevering in a north-western direction, it visited Hexham, exhibiting in this instance the same peculiarity which has marked its progress elsewhere, viz., that of following the course of rivers. It is also worthy of remark that it spreads, and advances more rapidly, and manifests the greatest degree of virulence, in the vicinity of rivers and large bodies of water. Thunder-storms exhibit the like peculiarity, as regards the direction of the clouds. But ere we proceed further with the subject, it may be as well to make a few observations upon the electricity of the atmosphere. And first, we shall turn our attention to the electrical state of—

Clouds.—And surely the very word suggests matter for a volume. For we must not be content to look upon clouds as objects having no definite use assigned to them in the economy of nature; we must not view them as objects which merely vary the face of the heavens—now depicting (in mockery of the artist's pencil), a scene of loveliness and of peace, as they flit lightly and proudly in their borrowed beauty, and through whose fleecy forms even the distant stars are seen—now mantling the wide expanse of the firmament in the gloom of the coming storm, and almost compelling us to believe, as we gaze upon their dense and sombre volumes, that darkness itself is a very element, and not a negative property; anon throwing over the earth and the waters a robe of mourning, denying to the little flower the pastime of its sport with the sunbeam it loves so well—and anon, as if in recompense, decking the descending sun with robes of purple and of gold—at times, almost baffling the ingenuity of the beholder to tell whether he is gazing upon the face of heaven, or upon the bosom of his own world, rising into, and presenting the appearance of, a range of mountains, their rugged sides representing huge abrupt rocks and "precipices dire," thus emulating the grandest and most sublime of the world's imagery; at other times, again, so varied are their protean forms, imitating earth's more lovely and more peaceful scenes—

> Detach'd in ranges through the air,
> Spotless as snow, and countless as they 're fair,
> Scatter'd immensely wide from east to west,
> The beauteous semblance of a flock at rest.
>
> *The Farmer's Boy*—WINTER.

The Abbé Bertholon seems to have entertained some faint notion of an office performed by certain clouds, which recent discoveries have ascribed to the curl cloud.—(*Berth. de l'Elect. Met.* tome ii. p. 113.) He speaks of them as "vehicles of the electric fluid, and as being useful in conveying the matter of lightning, which would be otherwise oftener embodied in large clouds, and strike the earth with terrible violence." Thus, then, their office is as gentle as their forms are beautiful. It is this species which Bloomfield has so admirably depicted in one line, in the painting of poetry. Perhaps, in our language, there is not a poetic picture more beautiful, and at the same time more true to nature, than that of the well-known poetic painting of moonlight by our immortal Shakspeare. The name of the cloud will, perhaps, be sufficient to indicate to the reader its form and appearance. It is frequently the first cloud that is discernible after a continuance of clear weather, sometimes continuing visible for many hours, or even days together, without any material change in its appearance; but, at other times, in peculiar states of the atmosphere, its figure undergoes changes so rapidly and continually, that, unless the eyes of the observer are kept upon it, he might be unable to identify it as the same cloud. Yet, under what form soever the curl cloud may appear, it is always to be considered a conductor of the electric fluid; and in what mode it acts in this capacity we shall soon be enabled to judge by a consideration of the varieties of the curl cloud. In dry weather, its texture is more fibrous than when the air is saturated with moisture. And under what form soever it appears, its extremities invariably consist of fine points. The reason of the former of these facts is thus readily explained:—The air, when perfectly dry, is a non-conductor; hence, if the electricity is to be equalized between two remote parts of the atmosphere, the cloud will be extended to a greater length, and will be divided, or drawn out, as it were, to a greater number of transmitting points. The explanation of the second fact depends also upon the circumstance of the curl cloud assuming that form which is best calculated to transmit or to receive the fluid, viz.—that possessing linear and pointed terminations. Now, it is perfectly clear, that when the cloud is surrounded with moist air, the fluid is readily conducted from all sides of it, moist air being a conductor, and hence, as there is no necessity for those pointed transmitting or receiving terminations, there is very little, if any, well-defined fibrous texture. The pointed extremities above alluded to frequently indicate the direction of an approaching breeze; but a circumstance that has not a little puzzled meteorologists, is, that the subsequent wind frequently blows from a direction opposite to, instead of in that of the point. This is doubtless owing to a current from another distant cloud. And it must be remembered that it is immaterial whether such terminal points are transmitting or receiving electricity, since, in either case, a current of air will proceed from the point. We shall have occasion to refer to this explanation, in the subsequent observations on epidemics. In the *Phil. Trans.* vol. xlviii. is related a curious instance of a violent gust of wind, which succeeded a flash of silent lightning, and proceeded from the same quarter as the fluid.

It is impossible to describe intelligibly the endless varieties of clouds without the aid of the artist's pencil, or without having recourse to technicalities that are only known to those who have paid considerable attention to meteorology; at all events, the attempts to do so would occupy more space than can be devoted to it in this essay. We shall, however, have abundant occasions of recurring to the subject in connexion with that of epidemics, and we shall therefore at once resume the subject of—

The Spasmodic Cholera.—We have selected this epidemic in particular, owing to its having claimed such general attention by its novelty and its extreme malignity.

Our talented friend, Mr. Dunn, of Norfolk Street, has kindly directed our attention to an essay on this disease, by Mr. Orton, formerly a surgeon of the 34th regiment of foot—a work which is doubtless in the hands of our professional readers. It contains a mass of evidence tending to prove that the disease is occasioned by a peculiar electrical state of the atmosphere.

—————— The circumambient heaven
Involved them still; and every breeze was bane.
Armstrong.

At page 196 of this work, Mr. O. quotes an observation of the late Dr. Heyne's (author of *Tracts in India*):—" All epidemics in this country are preceded by uncommon heavy rains and severe lightning. Such was not only the case in the epidemic fever of 1809-10, but also before the appearance of the present cholera morbus in Bengal, and now at Madras." And Dr. Lind states, that " shoals of large and ravenous sharks, crowding into the harbours, a dark thick cloud to the southward, with thunder and lightning slowly approaching, foretel the coming on of the sickly season," &c. We may here remark that the appearance of such a cloud as that described by Lind, was, in itself, a sure indication of a highly electrical state of the air, most probably negative. Again, Dr. Adam, in No. cclxxxiii. of the *London Medical Journal*, states—" As far as observation goes, the prevalence of the disorder appears, in some degree, connected with a certain state of the atmosphere, and cases were most frequent on any change of weather. Dense detached clouds were common precursors of the cholera." Although the description of the clouds, as given by Dr. Adams, is too indefinite to enable us to determine their species, still the combined characters of their being dense and detached are sufficient to justify us in classing them amongst those which accompany, (and which, indeed, are perhaps a cause of) the negative state of the atmosphere.

CHAPTER XI.

Epidemics continued; their Remote Causes, &c.

Of all the causes which tend to deprive us of that blessing, health, there are decidedly few which can be compared to those of epidemical diseases. History affords us many instances of the effects of these visitations. We have already slightly alluded to the spasmodic cholera, and shall return to the subject. But we must first direct our attention to an inquiry into the cause of epidemics in general. For a great number of years the world has providentally been comparatively free from some of these disorders in their highest degrees of virulence, and our knowledge of them is, happily, only obtained from the records we possess of their unsparing ravages. And, although other diseases have successively sprung into existence, not less fatal in their effects, still the periods of their prevalence are by far more limited. Whether, however, the pestilence visits us in the form of the plague, which has in former times rendered the city a solitude—when the pageantry of the glittering chariot hath given place to the heart-sickening sight of the dead-cart, all noiseless in its course, as it slowly and solitarily rolled over the green grass and the rank weeds in the once busy thoroughfare — or in what other form soever the visitations may descend upon us, we must admit that they are owing to some physical causes proportionate in magnitude to the effects. A knowledge of these causes in all probability would lead to some decisive means of prevention and cure ; for true it is that *viæ ad scientiam atque potentiam humanam conjunctissimæ, et fere, eadem sunt.* Knowledge is truly power. It has taught man to range the heavens, and has made him familiar with the motions of the orbs of light, which, isle-like, adorn the boundless ocean of space : their relative distances, their forms, their dimensions, are not unknown to him. The laws which regulate the very power that urges them onwards around their centres are not beyond his cognizance ; in short, it is that power which has civilized, elevated, ennobled him, and which is gradually advancing him to that degree of superiority which it was intended he should attain by his Almighty Creator. The powers of the mightiest engines he can calculate by the most simple rules ; the velocity of the swift wind he can ascertain ; the air he can weigh in the balance ; of the power of water, in its liquid form, as it imparts motion to his engines, he can form a correct estimate, or of its resistless force in the state of vapour. The subtle fire, too, he can submit to accurate admeasurement ; so that it also may be rendered subservient to his purposes as a ready and willing servant, to obey his bidding. But of the resources of that mighty agent which has enabled him to effect all this, and which will yet empower him to accomplish much more, he is as ignorant as the babe in its innocence, ere yet the day-dawn of reason has lit its vacant eye with a glance of intelligence. Here, indeed, is a problem, the solution of which will for ever baffle the skill of the most patient mathematician. He may circumscribe, until the earth itself becomes too small a field for his operations, in the vain attempt of being able to say, "here, within this circle, are its limits." He may yet persevere, and extend his circles into the realms of endless space itself, until, at length, throwing aside the rule and compass, he will be compelled to admit that he is lost in perplexity as great as his circles are illimitable. Who, in short, can check—who can even control, the advance of knowledge? He only who can arrest the lightning as it flashes between heaven and earth! Who shall presume to limit the power which it wields? who shall submit it to the nice rules of calculation? He who can grasp earth, moon, and stars, and stay them in their courses—he only who can fathom eternity!

Let us not, then, despondingly conclude, that because many of the operations of nature are yet involved in the clouds of obscurity, they shall not be revealed to our sight; but, in endeavouring to investigate the causes of those operations, let us not ourselves increase the impending darkness by adding to it the gloom of mystery. Let us not have recourse to the imagination, invoking to our aid agents that never had existence. Let us enter upon the subject with minds unprejudiced, so that our judgments may be unbiassed. Thus prepared, let us compare the mode of operation of the laws of those agents with which we are already acquainted, with the effects to be accounted for. Let us thus proceed with patience, perseverance, and in the true spirit of inductive science.—Having premised these observations, we shall now proceed to a consideration of *the remote causes of epidemics in general.*

"The operation of some *general agent,* inducing a disposition to become affected by contagion, or other existing causes of disease, would appear to be the principal cause of the predominance of epidemics. The contagion of small-pox and scarlet fever perpetually exists among us, yet it is only at particular times that those diseases attack so many individuals as to be called epidemic. The principal plague years of the seventeenth century were 1603, 1625, 1636, and 1665, in which the number of deaths, from the plague in London, were 36,000, 35,000, 10,000, and 68,000 respectively; but so far was the disease from being extinct in the intermediate periods, that from the year 1603 to 1667, the Bills of Mortality exhibit only three years entirely free from the plague. It is obvious, therefore, that the presence of infectious matter, or other exciting causes, is not alone sufficient to produce an epidemic disease."—*(Rees's Cyclop.* art. Epidemic.) We have already seen that chemistry does not appear to have thrown any light upon this dark subject. Sydenham speaks of the "hidden constitution of the air.' But the constitution of the air, as has already been stated, is now no longer a matter of speculation. What, then, must we conclude? That it is owing to some peculiar condition or state of the air. A late ingenious American writer (Mr. Noah Webster) supports such an opinion, and endeavours to show that epidemics are owing to a certain principle which is contained not only in the atmosphere, but throughout the whole physical world, and produces not only those, but nearly all the other great disturbances of nature." Mr. Webster appears to have grasped at the shadow, and missed the substance. We shall endeavour to shew that this general agent, which he termed the "pestilential principle," is, in fact, the electric fluid; but, in the first place, we shall briefly notice Mr. Webster's observations.

Mr. Webster's work is filled with evidence which he believes goes far to prove the existence and operation of some general agent, which, as we have already stated, he termed the pestilential principle. To this agent he ascribes the origin of earthquakes, and volcanoes, and meteors, and he considers it the medium by which comets affect the earth, producing tempestuous seasons, great heats and colds. The historical account which he gives of the various epidemic and pestilential visitations on record, contains a chronological view of the appearance of comets, the eruptions of volcanoes, the commotions of the earth, and the various atmospherical phenomena which authors describe, in order to prove this coincidence. "All the comets," he says, "which have approached the earth in their passage to and from the sun, especially those which have passed very near us, have been preceded by and attended with most extraordinary effects; as great heat and drought in summer, severe cold in winter, deluging rains, violent tempests, and unusual tides. They occur so uniformly with the appearance of those bodies, and for some months preceding and following, as to leave no room to question the influence from which they proceed." He quotes Aristotle, Pliny, and Seneca, to shew that great heat, tides, and winds, are the usual concomitants of comets, and adduces a number of records in support of the opinion that there is a connexion between earthquakes and epidemics—an opinion which many writers have adopted. It appears, however, that great pestilences, even when occurring within a short period of earthquakes, have generally preceded those commotions; thus, after the plague in London in 1665, shocks are said to have been felt on the continent. Mr. Webster believes that pestilence and earthquakes depend upon one common cause; but he supposes the "action or fermentation of the internal fires" may precede for months, or even years, the explosion in earthquakes.

"In all the great plagues which have affected the human race, the lower animals, and even vegetables, have borne their share in the general calamity; the 'pestilential principle' has extended to every principle of life." "The beasts of the field perish with deadly epidemics; the fish at the bottom of rivers and the sea die, or become sickly, while corn is blasted on the most fertile plains, and the fruits in gardens and orchards wither, or fail to arrive at their usual perfection." (Vide *Rees's Cyclop.* art. EPIDEMIC.) We find also, in the *Edinburgh Review*, in a very able article, an account of an epidemic fever which prevailed to a great extent in the British Isles, during the very time that India was afflicted with cholera. The author of the treatise alluded to remarks, "For our parts, from attending to the history of health and diseases during the succession of seasons, we are persuaded that changes of mighty importance take place in the air we breathe, without their being at all appreciable by either our eudiometers or hygrometers; and this," he adds, "we must at present be satisfied to receive as an ultimate fact, for which we cannot account." Again, "What this peculiar state or constitution of the atmosphere favourable to epidemic is, we know not: yet we cannot help believing that it exists; and that the occult quality, whatever it may be, has no relation to the thermometrical or barometrical conditions of that fluid. Whether it is at all connected with its electrical states, it would be fruitless to conjecture." We have already called attention to these facts in a former chapter, and have shewn how peculiarly susceptible animals and plants are of certain atmospheric influences totally unconnected with the density, temperature, or hygrometric state of the air. There is, however, an instrument which is sensibly affected during such peculiar conditions of the atmosphere, viz. De Luc's column, or aerial electroscope, which ought to be in the hands of every meteorologist. The result of observations made with this instrument renders it no longer a matter of fruitless conjecture, whether or not these peculiar atmospheric effects upon animals are occasioned by a disturbance of the equilibrium of the electric fluid. It is much to be regretted that not one of the meteorological tables with which we are so abundantly furnished, contains observations of the electrical state of the air, upon which depend so many important phenomena, which, perhaps, will never be understood until observations with the instrument above alluded to, and also with the electrometer, are taken with the same care and regularity as those with the meteorological instruments in common use. It is, indeed, singular, that the acknowledged cause of so many of the effects which are so carefully and diligently recorded, has never had a column allotted to it. Until this deficiency is supplied, meteorological tables will continue to be of the same use as they have hitherto been, and that is little, if any more, than as constituting records for the curious, of certain effects, noticed on certain days, at certain hours, without any reference to, or connexion whatever with, the cause of those effects. Besides the deficiency above alluded to, there is yet another, and a very material one—the omission of a column for the prevailing diseases. It is rather a matter of reproach to our learned societies that these deficiencies have been so long allowed to continue unsupplied, possessing as they do the means as well mental as pecuniary. But we must return to Mr. Webster's "pestilential principle," from which we have been drawn into a slight but not an unnecessary digresssion. And first, the term itself is one which causes a revulsion in the mind, conveying, as it certainly does, an idea that a merciful and benevolent Creator had called into existence a specific agent, whose express *modus operandi* was to be diametrically opposed to the divine command, as delivered at the creation, and totally at variance with the blessing at the same time pronounced by the Creator. What! can we for one instant credit the operation of a principle, solely existing for the specific purpose of filling the fair earth, the works of His hands, with desolation? But Mr. Webster's "pestilental principle" is not confined to our earth. It exists, it operates, throughout the whole physical world! That there is existing throughout the whole physical world a subtle fluid will scarcely be called in question. The immortal Newton entertained an opinion of the existence of such fluid, which he termed Æther.—(Vide *Newton's Optics.*) That this universally diffused fluid is concerned in the production of all the phenomena of the physical world, we have reason to believe; and that some irregularity of action, or a state of unequal diffusion of that fluid, may cause apparent deviations from regular laws, which are sometimes observable, is also probable. But that there exists a specific cause such as is implied by the term "pestilential principle," is an idea so repugnant to our notions of the benevolence of the Creator, that, if the opinion were supported by any degree of evidence, even the most slight—were countenanced by the merest shadow of proof, which it is not—we might still hesitate to assent to such a doctrine. We are aware that some will term this cant. Be it so. We are not the less convinced that no species of philosophy that is at variance, in any degree, with that holy volume, at which it is too much the fashion of the present day to cavil, will bear the test of examination.

In a former chapter allusion was made to some observations by Dr. Greenhow, of North Shields, on meteorological peculiarities which were observed in the north of England, previously to, and about the period of, the irruption of the malignant cholera in this country. A paper by that gentleman, "on atmospheric influence in the production and modification of disease," appeared some months ago in the *London Medical Gazette*, in which he urges the necessity of medical gentlemen recording the prevailing diseases in connexion with the meteorological condition of the atmosphere at the time of their prevalence. He adds, "it is a subject of somewhat difficult investigation, but I think much useful information might be gained, were every medical man to observe and record the weather and temperature, the moisture or dryness of the atmosphere in connexion with prevailing diseases, and the mode of treatment he found the most successful. In this way such a mass of medical statistics would gradually be acquired as might ultimately produce very important results in the knowledge and treatment of disease." But we must again repeat that meteorological observations are very far from being perfect, and that they never will afford satisfactory results, until recourse is had to the use of instruments for shewing the electrical state of the air in addition to those which are in common use. It is obvious that our present instruments indicate only the extent of certain effects—certain changes which have taken place. It ought to be our object to arrive at a knowledge of the cause, and to detect the precursory signs of these changes. Much, perhaps even more than can be calculated upon, towards effecting this purpose, may be accomplished, by diligently and carefully noticing and recording the electrical variations of the atmosphere, in connexion with the usual observations, and also, as we before suggested, with the prevailing diseases. For the perpetual electricity of the air is no longer a mere matter of conjecture, the existence of that subtle fluid and its continual agency in the atmosphere having been ascertained by numerous clear and decisive experiments; and it certainly must be admitted to be a fair inference that this fluid cannot exist in the atmosphere without exerting a certain influence on all matter within the sphere of its action, and principally upon organized bodies. We have, indeed, such a thorough conviction of the importance of the nature of the investigation which we have presumed to suggest, that although we have entertained the opinions advanced in this essay for some years, we have hesitated to make them public, feeling that their publication by an unknown individual would have little influence in drawing the attention of the scientific to the subject, and at the same time being fearful that the cause which we should vainly attempt to advocate might be injured rather than advanced by our inability to place its importance in a point of view sufficiently prominent, and to treat a subject embracing topics in variety so infinite in a manner in any degree adequate to its extent and importance. And if, at length, we have presumed to advance our opinions in the best shape that our humble abilities enable us, we must rest content with the conviction that the time will arrive, and is, perhaps, not far distant, when the subject will be pursued with that intelligence—will be treated with that ability, which it demands, by those who are, in every way, better qualified for the task. This we assuredly venture to predict; but we will yet go further; we will be bold enough to predicate, that if the investigations we have presumed to suggest be instituted and pursued in the proper spirit, the result will shew that the subtle fluid which is so universally diffused throughout the physical world is subject to laws as regular as those which are peculiarly adapted to preserve the existence and constant harmony of the universe; and that those apparent irregularities that are sometimes observable, are, in reality, part of a series of regular actions. The law of force, which constitutes the actions and reactions of matter with matter, equally subserves the maintenance of the wonderful order and beautiful and unvarying motions of systems of worlds, and to regulate the various changes and modifications which bodies and atoms are destined to undergo, in their connexions and combinations with each other; if, indeed, all these operations are not to be referred to the operation of the same general agent, which we have attempted to prove. The same wisdom is evidenced in the variety of the atoms of matter, and the proportions of each kind; none are in defect, none in excess; and from the nature of their constituent forces, there is a constant tendency to preserve the established order of things, according to an all-wise and infinite design. It is this tendency that we must particularly keep in view as we pursue our path through the widely extended field of investigation upon which we have entered; for it certainly follows that if matter be acted upon according to laws so regular in their operation, the agent which influences those actions, must, itself, be subject to regular and unvarying laws. This agent we conceive to be the electric fluid, effecting by its operations not only those changes which inorganic matter undergoes, but those also to which organized bodies are subject. Upon this supposition, then, we are naturally induced to inquire whether its presence is indicated, during such changes in organic substances, by those signs by which it is peculiarly characterised. This is an inquiry which can safely be answered in the affirmative, since electricity is invariably disturbed by all actions upon matter, whether chemical or mechanical. The next question is with reference to organized bodies. We have stated that disease, but more particularly the prevalence of epidemics, is owing to some peculiar state of the atmosphere; that that peculiar state depends upon its electrical condition. We ought, therefore, to inquire whether the presence of the fluid is indicated otherwise than by the destruction of animal life. Let us, then, carefully examine the nature of the evidence which has been collected respecting the Asiatic cholera; as our principal hopes of success must depend on ascertaining the meteorological occurrences which have been observed to accompany any epidemic, and comparing them with the phenomena of the disease itself.

The first fact that claims our attention is, that the slight attacks of mild, or the common cholera of this country, have been observed to be connected with remarkable changes of various kinds in the weather. Sydenham observes that heavy falls of rain are frequently attended with these visitations. It was also observed in India, that unusually heavy rains prevailed in that country for several years previously to the appearance of the malignant cholera. And now we shall meet with an instance of the truth of our observation, that our common meteorological observations are of no use whatever in leading us to the cause of changes in the weather, however accurately they may enable us to record the changes that actually take place. The opinion became general that those rains were the cause of the epidemic. The idea did not seem to occur that these rains were themselves only effects of atmospherical peculiarity not appreciable by our usual instruments for meteorological observations. It was afterwards found that if the disease originated with heavy falls of rain, it also ceased under similar circumstances. Therefore, the above opinion was speedily abandoned, as being void of foundation. Again, it was afterwards remarked that attacks of the epidemic frequently preceded the heavy rains. It follows, then, that the cause is not attributable to the changes of weather, but to the agent by which those changes are effected. *Ex. gr.*—The severe attack experienced by the Bengal and Madras troops at Nagpore, occurred at the end of May 1818. On the 10th of June the rains appeared with great violence, when the epidemic abated, and immediately afterwards ceased.

Mr. Orton (in the work before alluded to) states that he had been personally informed by an intelligent officer, who witnessed the different attacks of the malignant cholera in Brigadier-general Smith's force at Seroor and other places, that they were always accompanied by a cloudy, overcast state of the sky, sudden showers, composed of large drops of rain, resembling those of a thunder-shower, and a thick, "heavy" state of the atmosphere, giving it a whitish appearance; and whenever the weather cleared up the disease disappeared. He particularly observed that the epidemic was invariably preceded and accompanied by a large black cloud hanging over the place; and states that this had been universally remarked; so much so, indeed, that the appearance had even received the name of the *Cholera Cloud*. Mr. Orton adds, that these remarks were made without any questions or suggestions from him that could influence their tendency. Caius Britannicus has the following coincident observations regarding the "sweating sickness." He states that "some thick clouds, and fœtid, unwholesome fogs, brought by the wind from the county of Salop, spread this epidemic over all England. For from its origin, both a strong noisome smell preceded the distemper, and a black cloud was seen to move from place to place, as it were at the pleasure of the wind, and the pestilential disorder was observed to follow exactly the route of the cloud."—(*Swieten's Comment*. vol. xvi. p. 21.) Van Swieten also quotes an author, who alleges that he had himself observed a similar phenomenon "over a town, which was shut up on account of the plague, and that both the inhabitants and guards affirmed the cloud was always there." He quotes similar observations from other writers.

The cholera appeared in Brigadier-general Pritzler's force at Hoobly about the middle of August; and Mr. Scarman, the staff-surgeon to the Force, thus writes:—"The disorder has appeared in the camp, while a strong wind prevailed from the southward, with heavy clouds and rain." The disorder appeared for the first time in his Majesty's 34th regiment (excepting one case,) on the 21st September, and committed dreadful ravages before night. It is, therefore, of great importance to notice the state of the atmosphere on that day. Mr. Allardyce, the surgeon of the regiment, thus reports to the Medical Board:—"During the whole of the day of the 21st the weather was unusually close, and excessively oppressive, with a clear sun. At ten P. M. we had a violent thunder-storm, with two hours' heavy and incessant rain. It rained again heavily the whole night of the 22d. The 23d was hot and close. It rained again on the morning of the 24th, and very heavily the whole of that night. On the 25th the disease abated remarkably, and in three days more entirely disappeared. Mr. Orton was not particularly informed of the state of the weather after the 24th, but says it was generally mentioned that "it became fine when the disease disappeared." Again, Mr. Duncan thus reports from Arcot:—"This dreadful malady, which appeared in the depôt on the 14th of October, broke out on the same day that the wind changed to the monsoon quarter, the north-east. The weather was variable, with sudden squalls of wind, and torrents of rain; the sun very seldom made its appearance, and there was a peculiar chilly sensation from the atmosphere, although the thermometer did not fall lower than 74 deg. in the middle of the day. No abatement took place in the disease until the 23d, the day following a dreadful gale of wind, accompanied with rain, which blew from the south-west." We must here request attention to two facts of importance recorded in this report, so fully demonstrating the highly electrical state of the air. The one is the sensation of cold, unaccompanied by a corresponding depression in the thermometer. If we refer to Chapter I. it will be found that particular allusion was made to the same peculiar condition of the air referred to in Mr. Duncan's report, accompanied with the remark that under such circumstances the electroscope invariably indicates a negative state of the atmosphere. The other fact demanding attention is the opposite quarters of the wind at the commencement, and upon the disappearance, of the epidemic; in connexion with which we must bear in mind what has before been advanced respecting the restoration of the equilibrium of the electric fluid between two distant points in the atmosphere. Mr. Searle personally informed Mr. Orton that during the whole of the six days in which the disease prevailed at Manantoddy, in Wynaad, "the weather was dark and overcast, and extremely dispiriting and oppressive to the feelings;" and that at the conclusion of that period a considerable fall of rain took place, after which the atmosphere became clear, bright, and exhilarating, and the disease disappeared. In the same chapter allusion is also made to that peculiar depression of the spirits which Mr. Searle describes as accompanying a negative state of the air, and which, it appears from his account, had been particularly noticed during the prevalence of the cholera. Mr. Mackenzie, surgeon to the governor's body guard, observes, in a report to the Board, (13th of October)—"Notwithstanding the protracted prevalence of the epidemic in various parts of India, it is a question as yet undetermined what its predisposing causes are. Various opinions have been given, but all of them admit of unanswerable objections. That, however, some peculiar state of the atmosphere has influence as an exciting cause, is generally admitted. In this part of the country one circumstance has struck all classes of people—the very great change in the state of the weather which has marked the present year. From June to October thirty inches of rain are stated, from good authority, to have fallen, when during the same period, in former years, from three to five inches have been the average quantity. Added to this material change in the seasons, the atmosphere has, during the same time, been charged, in a greater or less degree, with electric fluid, and thunder-storms have succeeded each other almost in nightly succession. The thermometer has shewn, during the year, a greater alteration in heat and cold than has been known for a long time. Mr. Orton states, that during a fine season of three or four months, the epidemic appears to have been extremely rare; and the next attack of it which he records evinces its connexion with disturbed states of the atmosphere, still more strongly, if possible, than any of the preceding. It occurred in a part of the 84th regiment under Mr. Orton's charge, whilst marching in the southern Mahratta territory. The weather in that part of the country, for the preceding four months, had been uninterruptedly serene; for during the whole of that time he had not (to the best of his recollection) witnessed a single shower of rain, or a cloudy day, and certainly not more than two cases of cholera. On the forenoon of the 14th of March, 1819, the first attack of the epidemic occurred, and was followed by others in the evening; in the afternoon of the same day the sky became obscured with black clouds, and in the evening a considerable quantity of rain fell, accompanied with thunder and lightning. During a continuance of the same kind of weather for the next two days, numerous cases occurred; the fourth day was fine, with a steady, strong breeze, but still cloudy about the horizon, and on this day the epidemic ceased. This statement fully corroborates the truth of the opinion that epidemics are owing to the cause of changes in the weather; for it will be observed that the first case occurred in the forenoon, that not even a cloud was visible until the afternoon, and that it was not until the evening that the rain descended, and the thunder-storm occurred. About a month afterwards, General Pritzler's force suffered another very severe attack at Gudduck. The weather is stated to have been "cloudy and cool," the air moist, "as in the monsoon," and this, too, during what is termed the hot and dry season. Thunder-storms were of frequent occurrence in the evenings.

CHAPTER XII.

Atmospheric Influence continued; Thunder-storms, Earthquakes, &c.

A MUCH greater mass of evidence may be collected from Mr. Orton's work, to which we beg leave to refer those of our readers who feel interested in the subject. But from all that is stated in that treatise, only one conclusion can be arrived at, viz. that previously to, and during the prevalence of the Asiatic cholera, the atmosphere was in a highly electrical state, and that the cause of the atmospheric irregularities was also the cause of the epidemic; for the epidemic frequently preceded the marked changes in the weather, and ceased with the rain, or with the tendency to rain. Indeed, common observation points out occurrences analogous to those during a thunder-storm. Previously to the storm, we feel oppressed and anxious, and that frequently before any indication of its approach. After the storm, we are relieved from those painful sensations, and the atmosphere generally becomes remarkably clear, indicating the presence of an unusual quantity of electricity, for in serene weather the electricity of the air is always positive—a fact established by the observations of all who have attended to the subject of atmospherical electricity; amongst whom may be named Beccaria, Cavallo, Franklin, Saussure, &c. Mr. Crosse, also, who has made numerous observations with a remarkably extensive apparatus, infers—"That, in the usual state of the atmosphere, the electricity is invariably positive: whenever the negative electricity is observed in the apparatus, it is certain that there is either rain, snow, hail, or a mist, in its immediate neighbourhood, or that a thunder-cloud is near."—(*Singer's Elements of Electricity.*) It is evident, therefore, that the appearance of clouds, and the fall of rain, indicate a deficiency of electric fluid in portions of the atmosphere; and as those phenomena have been shown to attend, in an unusual degree, the prevalence of the epidemic cholera, it is also evident that the disease is likewise accompanied by a negatively electrical condition of the atmosphere.

It is commonly imagined that, during thunder-storms, the atmosphere is highly charged with electric fluid. This is a natural, although an erroneous idea. We have the strongest evidence, on the contrary, that, at such periods, the air is deficient in its natural quantity of free electricity. Dr. Franklin infers, from his long and able researches, that "the clouds in a thunder gust are most commonly in a negative state of electricity, but sometimes positive; the latter, I believe, is rare. For the most part it is the earth that strikes into the clouds, and not the clouds into the earth. Those who are versed in electrical experiments will easily conceive that the appearance will be nearly the same in both cases." He also mentions that "in many observations made by Mr. Kinnersley, the clouds were constantly in the negative state, with but one exception."—(*Letters on Electricity.*) Mr. Morgan also contends that the deficiency of electricity which causes the explosion, always exists in some part of the atmosphere, and never in the earth.—(*Encyclop. Brit.*) Hence it is evident that on the occurrence of thunder-storms large portions of the atmosphere possess less than their natural share of electric fluid; and we find that many of the most destructive attacks of the epidemic have been attended by violent thunder-storms, and that its ravages have ceased after the restoration of the electrical equilibrium.

We have now to proceed to the consideration of another phenomenon, which, although it may at first appear not closely allied to the subject, will be found to be intimately connected with the meteorological portion of our investigation—viz. that of earthquakes.

It has been long and generally believed that earthquakes either precede or accompany severe epidemic diseases. But we shall find that if there be, indeed, any connexion between those phenomena and the prevalence of epidemics, they are both, in point of fact, referable to the operations of one cause, and that the diseases are by no means effects of the earthquakes—that, in short, the same meteorological disturbances which produce the one, give rise also to the other of these visitations. Since, however, it has been stated by those who have spent much time and labour in endeavouring to ascertain the cause of epidemics, that those phenomena usually precede or accompany the pestilence, it is our duty to examine the nature of the evidence adduced with an unprejudiced mind, and, setting aside all preconceived notions and favourite speculations, to inquire into the question in all its bearings, endeavouring to base our theory upon incontrovertible facts, rather than attempt to raise a visionary structure, with theory for our foundation, and vague hypotheses for the superstructure.

We have been induced to make these remarks in consequence of the extraordinary nonchalance with which some authors view the unwearied and unceasing labours of others, conceiving, it would almost appear, that a few moments' consideration will suffice to enable them either to support with the full weight of their ability, or to prostrate, by a single blow, the work of years of close application and unwearied toil. If our readers have perused the treatise on Epidemics, in Dr. Copland's *Medical Dictionary*, they will probably recollect a brief allusion to a work we have already quoted, (that of Mr. Webster.) And from that allusion they might infer that Mr. Webster's work is a pamphlet of some few pages, whereas it is one of two volumes; and since the general facts upon which Mr. Webster's opinion is founded are not called in question, it is presumed that it is the inference from these facts which is objected to.

All that Mr. Webster attempted to show was, that earthquakes usually accompanied great pestilences, and that they both depended upon one common cause; that this cause was generally diffused throughout the physical world, and was termed by him the pestilential principle. It will be recollected that we deprecated the notion of the existence of any specific pestilential principle, and undertook to attempt to show that the effects attributed by Mr. Webster to this supposed principle, might, in fact, be satisfactorily accounted for by referring them to the agency of the electric fluid. It remains for us, then, to show that, admitting the accompaniment of epidemics by earthquakes as a fact, they both depend upon the same cause. And, although the whole question is undeniably one that must be set at rest by observation and experiment rather than by argument, it is our wish to meet fairly every possible objection that can be urged against the electrical theory, inasmuch as an objection advanced by one whose opinion is justly entitled to consideration, might be the means of deterring other inquirers from a course of investigation, by the pursuit of which they might be induced to form an opinion of their own. It is for this reason that we now allude to Dr. Copland's objection to the electrical theory of epidemics. And to what does his objection amount? Does he attempt to deny the effect of certain electrical states of the atmosphere upon the functions of organized beings? No. It is admitted that certain effects may be produced. Does he essay to disprove the mass of evidence which has been collected in reference to the connexion between a highly electrical condition of the air, and the prevalence of epidemics? No such attempt is made. Is it denied that animals suffer the painful sensations, and that even plants indicate the effects of the peculiar atmospheric influences to which we have before frequently adverted? Of these facts not the slightest notice is taken. What, then, is his objection? Why, simply this: that we can employ electricity artificially without any effects being produced to justify us in entertaining the opinion that epidemics are attributable to the agency of electricity. The experiments of Ritter and others have shown otherwise. But, even admitting that such were the case, does the writer of the treatise alluded to seriously intend to institute a comparison between our philosophical toys (for such, comparatively speaking, they are) and the sublime apparatus in the laboratory of nature? He assuredly does not imagine that nature works with a plate or a cylinder of glass, in order to produce her magnificent phenomena, or that she employs a series of zinc and copper-plates, in Wedgwood-ware troughs!

Van Swieten, in reference to the opinion of plagues arising from earthquakes, says—"On the contrary, when the plague raged at Oczakow, on the very day the distemper began to abate a violent earthquake happened. *Quære*, did any thing exhale from the earthquake antidotal to the contagion of the plague?" (*Commentaries*, vol. xvi. p. 36.) In many other instances, adduced by various authors, we find that the epidemics preceded the earthquakes. Now, admitting the connexion between those phenomena and the diseases, one of two conclusions must be arrived at, viz. either that the earthquakes were the causes of the epidemics, or that they were both merely effects of a common cause. And since, as we have seen, earthquakes have rather the effect of removing than of producing epidemics, the latter of these conclusions is indubitably the more rational. What, then, is the cause of earthquakes? Decidedly the most satisfactory theory of earthquakes that we possess is that which ascribes them to the agency of electricity. It has been universally observed that the lower animals evince signs of extreme uneasiness before earthquakes, being affected in the same manner as before storms. Both Dr. Priestley and Dr. Stukely favour the electrical theory of earthquakes. The former imitated the tremulous motion of the earth by means of electricity, and the latter has furnished various arguments in support of the opinion. He states, that "previous to the earthquakes in London, in 1749 and 1750, the appearance of the aurora borealis had been very frequent, and a very short time before the earthquake, exhibiting unusual colours, and its motions were to the south, contrary to its usual direction. During this year, too, fire-balls, lightnings, and coruscations, had been common; and on the night preceding the earthquake coruscations were frequent. From these circumstances an earthquake was predicted by the Italians, and others who had been accustomed to the appearances that precede them. Before the earthquake was felt, a black cloud suddenly covered the atmosphere to a great extent.

Another argument in favour of the electrical theory is drawn from the effects of the earthquake on the state of the weather at the time, and on persons of weak and nervous constitutions. To some those disorders proved at the time fatal; and its effects in general were similar to those of artificial electricity."—*(Encyclop. Brit.)* Another strong argument is drawn from the simultaneous occurrence of the same shock at very distant places. Dr. Stukely observed that a portion of earth in England, one hundred miles in length, was pervaded, as far as could be learnt, in an instant. M. De Humboldt informs us that "frequently, on the coasts of the South Sea, the action is almost simultaneously communicated from Chili to the Gulph of Guayaquil, a distance of six hundred leagues." It has been a matter of general remark (uninfluenced by theory), that the earthquake of the 16th of June, 1819 took place over the whole of India at the same moment. Here, then, it is seen that an instantaneous throe is felt over twelve or thirteen hundred miles of the earth's surface, from a given point of greatest agitation—and this extent of surface is moved in all directions, in the twinkling of an eye, by—what* ? Can we seriously entertain the opinion which supposes earthquakes to be occasioned by the formation of steam, or some analogous

* Orton on cholera.

process, by which an elastic gas is generated? Granting this, it is necessary to suppose that the action originally takes place at a single point, whence the effect is communicated, by vibration, through the earth to distant places. It is impossible. Sound itself, in travelling twelve or fifteen hundred miles (if that were possible), through the elastic air, would require about two hours. Can we, then, suppose that an analogous motion could be propagated through the solid, and infinitely less elastic earth, in so short a period? Again, the escape of steam has never been observed to attend earthquakes, nor has a single proof of the irruption of any kind of gas been afforded. In short, what power in nature, except electricity, can we suppose to be capable of agitating the whole of India in an instant? Electricity alone is equal to produce such an effect; its velocity and power, so far as our knowledge of that fluid extends, being alike incalculable. Do lightning and the aurora borealis disturb the direction of the magnetic needle? The same effect is produced by earthquakes.—*(Encyclop. Brit.* title *Variation.)* A hissing noise and a sulphurous smell are alike accompaniments of earthquakes and of electrical discharges. A circumstance has also been occasionally noticed which cannot be accounted for except by means of the electrical theory, viz. that of two or more distant places suffering severely from a shock which is scarcely felt in an intermediate portion of the earth. This is undoubtedly owing to the different degrees of conducting power of different strata. The electrical theory also accounts for earthquakes being communicated along rivers, sea coasts, &c. and for their influence being indicated much more extensively by water than by land; vessels at sea sometimes receiving a sudden shock, as if they had struck on a rock. A few words will suffice to explain this. Water is a much better conductor of electricity than the earth. Beccaria supposes that "the electric matter to which these phenomena (earthquakes) are owing, is lodged deep in the earth, and it is this matter, discharged from the earth to restore the equilibrium between it and the air, that occasions earthquakes." If this opinion be correct, a change in the electrical state of the atmosphere ought to take place during an earthquake. And that such a change actually takes place we state upon the authority of M. de Humboldt, who says that "often when violent shocks succeed each other, in the space of a few hours the electricity of the air sensibly increases at the moment that the ground is most agitated."—(Vide an account of the electroscopical experiments made in Piedmont, in the vales of Pelis and Cluson, in 1808, *Journal de Phys.* tom. lxi. p. 292; *Personal Narrative of Travels in South America,* vol. ii. p. 238.)

We might have entered more fully into the question of the cause of earthquakes, but as it was intended to consider the subject solely in reference to its connexion with the cause of epidemics, perhaps it has already occupied too much space. It was, however, necessary to dwell a little upon it, inasmuch as it has been asserted that great pestilences and earthquakes usually accompany each other, and that the former are caused by the latter. But it will be seen by the evidence which we have adduced, and the arguments drawn from that evidence, that there is no other connexion between those phenomena, farther than that they are both effects of a common cause, and that both are attributable to the agency of electricity. Indeed, an earthquake may not be inappropriately termed a subterranean thunder-storm.

FURTHER REMARKS ON ELECTRICITY, AS CONNECTED WITH METEOROLOGY.

We are indebted to our friend Lieutenant Morrison, R.N. for the following additional facts, which he obligingly communicated to us in a letter from Cheltenham. During the whole period of the prevalence of the malignant cholera in Liverpool, in the fall of the year 1832, the magnetic needle (adapted with collecting wires so as to be deflected east or west, accordingly as the atmosphere was positive or negative) continued steadily to point about eleven degrees west of north, thus indicating a constantly negative state of the air. And from Lieutenant Morrison's own observations it appears that the apparatus he employed invariably indicated a negatively electrical state of the air at the time of the irruption of the more ordinary forms of epidemia; as sore-throats, influenza, &c. From all that has been advanced, then, the importance of connecting meteorological observations with those of prevailing diseases must be evident. And it is to be hoped that, in proportion to the increase in the number of inquirers, possessed of the means, and favoured with the opportunities to investigate the subject experimentally, we shall be supplied with an additional number of facts, which will doubtless lead to important results connected with medical science, tending to point out the extent, and probably the definite nature, of the action of the peculiar electrical conditions of the atmosphere on the functions of animals. Let us first, however, turn our attention to some of the facts with which we have already become acquainted. It has been before observed, that the atmosphere, in serene weather, is invariably positive; but it differs in degree, and the first fact, therefore, that now claims our attention, is that of *the regular fluctuations in the density, and in the electrical state of the atmosphere.*

From M. Saussure's observations at Geneva, it appears that the electricity of the air is pretty strong at 9 A.M. It then gradually diminishes until six in the evening, when it reaches its first minimum. After this it increases until eight, when it attains its second maximum.—(*Encycl. Brit.*) It is, however, probable, that the time of its increase and decrease will be influenced by the season. In Europe, according to M. Schubler, the electricity, in calm and serene weather, is constantly positive, but subject to two daily fluctuations. It is at its minimum a little before sunrise; it then gradually accumulates, and reaches its first maximum a few hours afterwards (eight o'clock, in May); at this period it begins to diminish until it has descended to its second minimum. The second maximum of atmospherical electricity occurs in the evening, about two hours after sunset; it then diminishes, at first rapidly, and next in slower progression, during the whole of the night, to present again, on the following day, the same oscillations. These regular fluctuations may be observed throughout the year, more easily in fine than in cloudy weather, and of longer duration in summer than in winter, and they are not influenced by temperature.—(*Journal of Science and the Arts*, No. 4.) The barometer manifesting similar fluctuations, perhaps the mean results of a comparison of these two series of phenomena will be interesting. The barometrical variations are the mean of the observations of Horsburgh, Humboldt, and Balfour: the electrical fluctuations are the mean results of the observations of Read, Saussure, and Schubler. The results are as follow:—

	1st Maximum.	1st Minimum.	2d Maximum.	2d Minimum.
Density . . .	10 A.M.	4–5 P.M.	10–11 P.M.	4–5 A.M.
Electricity . .	8–9 A.M.	4 P.M.	9 P.M.	6 A.M.

M. Saussure has given very minute details of the meteorological phenomena occurring during three days at Geneva.—(*Encycl. Brit.*) The following are the observations on the barometer and electrometer for the first day, which was perfectly serene:—

	Barometer.	Electrometer.
9 A.M.	26 6. 7.	2—
11	26. 6. 5.	1—6
2 P.M.	26. 6. 1.	1—1
5	26. 6. 4.	1—1
6	26. 6.	1—0
7	26. 6. 2.	1—8
8	26. 6. 3.	2—
9	26. 6. 3.	1—8
10	26. 6. 1.	1—2
11	26. 6.	1—5
12	26. 5.15.	1—2

In nine of the eleven observations, the barometer and electrometer were both rising and falling, or stationary together. In one instance only the electricity is increasing, while the density of the air is decreasing. These coincidences are striking, and evidence a connexion between the density and electricity of the air. Mr. Wilkinson has also alluded to this subject—(*Electricity of Galvanism*, ii. 279.) He informs us that "Volta and Read have observed a coincidence between the daily changes of the barometer and the state of atmospheric electricity. As the barometer is higher in the morning and evening than in the middle of the day, so likewise has the atmosphere at these times been observed to be more electrical."

When the earth is positive and the atmosphere negative, the electric fluid, in endeavouring to restore its equilibrium, would cause a motion amongst the particles of the air in a direction from the earth towards the higher regions of the atmosphere; for air being a very imperfect conductor, the particles near to the earth's surface can only convey electricity to the more remote particles by such a motion. This would, in effect, partly diminish the downward pressure of the air which is due to its actual density; consequently the barometer would fall, and continue to do so, as long as the action continued. When, on the contrary, the earth is negative, and the air positive, this motion of the particles will be reversed, thus increasing the pressure towards the earth, and producing the same effect as if the air had actually increased in density. Then of course the mercury in the barometer will rise, and the rapidity and degree of change will be proportioned to the extent of the difference in the states of the earth and air. Thus, before violent storms, the mercury frequently sinks very suddenly, and it has before been shown that the air at those times is invariably negative. We merely presume to offer this as a conjecture, the variations in the "density" of the atmosphere never having been satisfactorily accounted for.

CHAPTER XIII.

Further Remarks on Atmospheric Influence, &c.

An objection has been made to the opinion of the influence of electricity in producing epidemic diseases, upon the ground that every individual would be attacked, if that opinion were correct. But if we consider for a moment the nature of that peculiar variety of action which has been termed *induction*, we shall soon perceive that such an objection is totally inapplicable to the electrical theory of epidemics, at the same time that it possesses great weight in opposition to the truth of all other theories. This has been already shewn, in allusion to the cause of epidemics generally, and it was pointed out that their reference to "subtle effluvia," to a "pestilential principle," or to a "poisoned atmosphere," merely left the subject in the same obscurity as before, the only advance towards elucidation consisting in contriving a name for something that might or might not exist, and whose actual existence it appears not to have been deemed at all necessary to prove. And even if the existence of such a poison, or effluvium, had been proved, it would require considerable ingenuity to explain why every individual should not be attacked in some form in a greater or less degree of violence; and a much greater share of sagacity to discover the reason why epidemics so frequently spare the inhabitants of extensive tracts of country which intervene between two points of attack. How can this peculiarity be explained upon the "pestilential," or "poison" hypothesis? And how simple and satisfactory is the explanation derived from a knowledge of the varieties of electrical action, by means of the phenomenon of electrical induction!

When an electrified body is brought near an unelectrified body, so as to be within the sphere of the electrical influence, without being sufficiently near directly to receive any portion of the electricity of the electrified body, it too becomes electrified, but in an opposite state, at that end which is next to the excited electric. If, for instance, we suppose A B

A ———— B C ——————— D

E F G H I

to represent an excited glass tube, and C D an insulated metallic cylinder, with rounded ends—suppose, further, that this cylinder is furnished with suspended pith balls at E, F, G, H, and I—if the cylinder is brought near to the excited tube A B, the pith balls will all diverge, excepting those about the middle of the cylinder at G; those at E and I will diverge most, the degree of divergence diminishing from both ends towards the centre G, which is termed the plane of neutrality. The end near to the excited tube (which of course is positively electrified), will be negative, the other end positive. The pith balls also at F and H diverge; those at I, of course, with negative, and those at H with positive electricity, being situated at different sides of the neutral plane. It is necessary also to state that the position of this neutral plane may not be in the centre, for it varies according to the distance of the electric, and the relation which that distance bears to the body itself. There are other modifications of effect which might be noticed; but it is merely intended to explain, as briefly as possible, the nature of the inductive influence of electricity, in order that its application to account for epidemic peculiarities may be more readily understood. Another modification only must be referred to as necessary to assist us in the explanation; that is, if we employ a series of conductors, by joining them endwise, so that they may act as a single conductor when placed near to the excited tube, each of the conductors will be electrified in the same state throughout its whole length, but each pair of adjacent conductors will be in opposite states to each other, with the exception of the central one, which constitutes the neutral plane; or rather that conductor will constitute the neutral plane which is situated centrally as regards the point and extent of electrical action. We shall now see how this applies to some of the peculiarities in epidemic diseases, by referring them to *electrical induction in the atmosphere.*

It is evident that a large portion of electrified air will exert an inductive influence on another portion;

and the latter, again, will affect a more remote part, so that the atmosphere above a certain tract of country may be positive, whilst at the distance of a few miles it will be negative; and between these two oppositely electrified portions, or rather at some central point, we shall have a plane of neutrality as above explained. Again, it is necessary to remark that all, or at least many bodies upon the earth's surface, upon which the air in a certain electrical state impinges, will be subject, in like manner, to the inductive influence, becoming either positive or negative, according to their various natures as electrics or conductors. The effect of this, again, will be a reaction upon the air in the neighbourhood of those bodies, re-inducing a positive or negative condition, accordingly as adventitious circumstances favour the one result or the other. Thus, even in a small apartment, one individual may be exposed to the influence of a positive, whilst another, at the same moment, may be exposed to a negative atmosphere. And we shall now very readily see how it can happen that the inhabitants of one town or village may be free from the ravages of an epidemic disease, whilst those of other neighbouring towns or villages are suffering more or less from the effects of the visitation—why, even in the same town, some particular localities will be more free from the attacks of disease than others—and why, again, a certain tract of country, having, for a brief period, escaped, should still be visited by the pestilence, after, perhaps, the lapse of a few weeks, the neighbouring parts being then as free from the epidemic as that tract was at the time of its raging in parts around it.

In all other hypotheses respecting the nature and origin of epidemics, great stress has been laid upon a certain state of the body, termed a predisposition to the disease. In the electrical theory, it is much less necessary thus to suppose the existence of a condition constituting a state favourable to the reception of the disease. That, however, there is such a predisposition can admit of little doubt, although to an extent much more limited than is imagined; for although many are attacked whose peculiar idiosyncrasy might have led us to infer the great probability of an attack, a very great number fall victims in whom no existing predisposition was at all apparent, or even in the least suspected. But if it be required to be shewn in what consists that predisposition, we might rest satisfied by merely quoting the words of a thousand authors, that it is owing to debility, the consequence either of a natural decay, or the sure result of intemperate habits. But let us not be content to stop here. Let us inquire further. Debility is owing to a diminution of the vital energy. The question, then, is, in what does the vital energy consist? Now it has already been shewn that there is a close connexion between the electric fluid and the "vital principle," and that indeed they are probably identical. When, therefore, the functions are impeded or suspended by organic defects or derangement, there is a proportionate decrease in the quantity of electric fluid which is disengaged (as has been shown) during all chemical action. Consequently the effects occasioned by exposure to a negative atmosphere can be less readily counteracted. Again, in the aged and debilitated, the nerves probably lose much of their conducting power—an inference which we draw from the fact that the charge of a Leyden jar which would affect a young individual across the chest, will scarcely be felt by an aged person above the elbows. Thus we have the following concurrent and co-operating causes:—a diminution in the natural quantity of electric fluid generated in the system, during the more feeble chemical action—exposure to a negative atmosphere—and an impaired conducting power in the nerves.

CHAPTER XIV.

Atmospheric Influence, concluded.—General Remarks.

For our ability to furnish our readers with the following additional evidence, we are indebted to the kindness of Dr. Clanny, of Sunderland, who has obligingly forwarded to us a copy of his valuable work on the Malignant Cholera. Respecting the irruption of that disease at Sunderland, Dr. Clanny says, (p. 2) "The commencement of the epidemic cholera was, according to my personal observation, about the beginning of the month of October; and I find by my memoranda of cases that on the night between the 2d and 3d of November much lightning occurred; and it is worthy of remark, that exactly at this time our first five fatal cases were drawn up, and reported to the Board of Health in London. Upon the 2d of November we had no new cases, nor upon the 3d, 4th, and 5th; but upon the 6th we reported six cases and two deaths; and upon the night between the 6th and 7th we had continued flashes of lightning during the whole night, an unusual phenomenon at this season of the year." Again, at p. 49, Dr. Clanny states, that many medical men of Sunderland are impressed that our first attack of epidemic cholera was directly owing to atmospheric temperature ; but how or when that state of temperature commenced no man can say. It appeared to me that we all felt this atmospheric influence one way or other." (*Hyperanthraxis, or the Cholera of Sunderland.*) Here, again, we must regret that we cannot be furnished with a record of the atmospheric electrical variations.

We trust that sufficient evidence has now been adduced to prove that epidemic diseases are occasioned by peculiar states of the atmosphere, and that its electrical condition constitutes that peculiarity. We ought now to proceed to explain the manner in which the disease is induced by the action of the atmosphere in certain electrical states upon the system. But, before entering upon that portion of the subject, we may perhaps be excused if, in our anxiety to apply the test of truth to the proposed theory, we think it necessary to preface that explanation by a few observations somewhat in the nature of a recapitulation of the evidence that has been adduced in the preceding chapters ; to retrace, as it were, the paths along which we have progressed, so that we may be enabled to detect any point of deviation, where we may have been led away from, in place of approximating, the truth. We trust the result of that test will be favourable; and we also presume to hope that where we have been so venturous as to strike out a path for ourselves, it will be admitted that we have not been allured from the beaten track by any of those *ignes fatui*, which, by dazzling the imagination, serve only to mislead the judgment, and which, withdrawing their uncertain light as suddenly as it was first bestowed, leave us overshadowed by the darkness of doubt, and bewildered in a maze of error, but that, as it was the voice of Nature that first invited us to pursue those paths, so her light also has been our guide.

We trust, also, that we have never once lost sight of those rules which ought ever to be our guides in investigations of this nature. We are not to multiply causes, nor to admit of any that the necessity of the case does not demand. Instead of multiplying causes, we have endeavoured to shew that many phenomena, which have not been explained without the aid of various causes, some of which were ideal, may, in fact, be referred to the operation of *one* cause, which, in itself, is amply sufficient for their production; and that cause not imaginary, but its existence as a fact and a principle well established. Neither have hypotheses been framed, inasmuch as the whole theory is founded upon deductions from phenomena, and inferences from facts that are indisputable. Nor has any thing been arbitrarily assumed as a principle.—But a truce with what has *not* been done in a speculative way. A multitude of facts have been brought forward in various branches of natural philosophy, apparently not more diverse in their nature and origin than the different explanations that have been given of them; and for all of which it has been attempted to account by a very few, and very simple principles, which, again, were derived not from an ideal agent, with imaginary properties to suit, but from our knowledge and experience of one actually existing element, and its well-known peculiar varieties of action. And if these principles be found (to say the least) at all events equally as applicable as when the various phenomena have been made to depend upon various causes, and upon the influence of a multiplicity of agents, some of which exist only in the imagination—causes conjured into existence for the sole purpose of explaining the effects, and ideal agents invoked to aid in the construction of theories—they must, at least, be admitted as being probable, rational, and entitled to some slight degree of attention. Further, these principles are not only exceedingly simple, but their application is easy and self-evident. And it will surely be admitted that it is not complexity, but simplicity, that characterises the operations of nature in all their multiplicity, diversity, and grandeur. Her causes are few, yet the effects depending upon them how innumerable! Her course is the easiest and shortest possible, and her means the fewest that can possibly bring about her ends. In fine, the more fully and deeply we enter into an inquiry of the wonderful processes, which, with a constancy and uniformity which cannot fail to excite our admiration, are continually presented in nature on a grand scale, the less shall we deem it necessary to search for causes and powers as diversified and numerous as the effects we witness; on the contrary, we shall be only the more fully satisfied that the simplicity of the first principles is as much calculated to excite our astonishment as the infinity of the results. With the conviction of this truth upon our mind, it is scarcely probable that we should have dared to exercise the little ingenuity we possess, in framing useless hypotheses. We have not attempted to mystify that which appeared difficult of explanation, but, on the contrary, it has been our aim simply and clearly to trace and point out the relation between cause and effect; to shew that the cause referred to was adequate to the production of the effect; and that the various phenomena that have been noticed, and some of which have hitherto been referred to the operation of imaginary causes, to which specious names have been assigned, and upon which wonderful properties have been bestowed, adapted with an ingenuity most admirable, so as to be applicable to particular cases, are, in fact, readily explained upon the theory of the universal agency in nature of the electric fluid. That we have been ardent in the pursuit of the investigations which form the subject of this essay we hesitate not to admit; but we trust that our ardour has been equalled by the caution with which the conclusions are drawn; and that, if imagination has at all bestowed her aid wherein our judgment was at fault, still there will be found infinitely less of the visionary in the proposed theory than in other theories to which we have alluded; and that the peculiar properties and modes of action which the imaginations of some have bestowed upon ideal causes, are, in fact, the characteristic attributes of that subtle element whose universal agency it has been our aim to attempt to prove.

Our next step, then, is to inquire whether the theory advanced in this work falls short of what may be strictly termed scientific truth. Scientific truth is founded on facts with which we have become acquainted through the medium of close and accurate observation; upon analogy, by which similar facts are connected; and upon experimental results, by which we are furnished with new facts. Thus, "in the progression of knowledge, observation, guided by analogy, leads to experiment; and analogy, confirmed by experiment, leads to scientific truth*." First, then, we shall refer to the following facts:—

The electric fluid pervades all known bodies—all substances containing a certain portion of the fluid, which has been called their natural quantity; the slightest disturbance, by the mechanical or chemical action of one substance upon another, or of one element upon another, destroys the equilibrium of the fluid, and disengages it from the body in which it previously existed in a latent state. The mere contact of two metals, or other dissimilar bodies, the sifting of a powder through a sieve, the evapora-

* Sir H. Davy.

tion of water and of ether, may be instanced as occasioning considerable divergence of the gold leaves of an electroscope*.

Analogy suggests that since, during chemical action, electricity is always disengaged, it is also set free during the processes of digestion, respiration, and all the other chemical processes that are continually going on in the system. Another fact is, that the electric fluid invariably prefers the most perfect conductors, when its route along them is not very circuitous; and it also being true that the nerves of animals are the most perfect conductors in the system, analogy guides us to the inference that

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* It appears exceedingly probable that during the contact of the metals or other bodies, as well as in the process of evaporation above alluded to, slight chemical action takes place. All bodies are continually undergoing a gradual change; the process of decay is ever active, although in many instances the change is too minute and gradual to be perceptible. Hence we know not but that the feeble electrical effects produced by the mere contact of two dissimilar metals may be due to a very slight oxidation of one of the metals; and when other bodies than metals are employed, it is questionable whether a very minute degree of combination does not occur between the external particles of the substances thus brought into contact. But at the same time it is by no means demonstrable that the development of electricity depends upon chemical action. On the contrary, it is much more probable that chemical action between electro-positive and electro-negative elements is owing (supposing the form of the atoms to be spherical) to the currents in the former flowing from the centre to the circumference, and in the latter from the circumference to the centre.

they first receive the fluid generated during chemical action—that, consequently, as they receive a renewed supply every instant, the fluid circulates through the nervous system as regularly and constantly as the circulation of the blood is continued through the arteries and veins; that it constitutes, in fact, that ideal something which authors have termed "the nervous influence," or "the nervous fluid," or the "nervous energy." Then, again, experiment has shewn, in a most decided manner, that the place of this imaginary "nervous fluid" can be supplied artificially by the substitution of the electric fluid; that by its agency digestion can actually be carried on after the division of the nerves subservient to that process. It is unnecessary to dwell upon the experiments of Dr. Ure, of Glasgow, and of Dr. Wilson Philip, they having been already particularly referred to. It is to be regretted that both, in some instances, have been unfairly attacked, not by statements of antagonist results of similar experiments, but by the substitution of ridicule in the place of argument: and, as respects the latter-named gentleman, by unfounded assertions respecting the inaccuracy of his experiments—charges which, however, he has himself satisfactorily rebutted.

It is also demonstrable that electricity, in its passage along imperfect, or even along perfect conductors, whose diameters are, in any part, disproportionate to the quantity and intensity of the transmitted fluid, elicits a quantity of caloric capable of fusing such transmitting bodies. Hence, analogy again suggested an idea of the cause of animal heat being partly attributable to electric agency, inasmuch as in the passage of the electric fluid from the nervous centres, whose surfaces are of considerable extent, through the exceedingly minute nervous filaments, which present a small extent of conducting surface, heat must necessarily be evolved, in consequence of the retarded transmission of the accumulated fluid. And here. too, another source of the supply of caloric is to be found. The fluid not meeting with perfect conductors of sufficient capacity for its free transmission, would partly persevere in its progress towards the surface through less perfect conductors, the effect of which, again, would be the evolution of caloric. Then, experiment has shown that in a negatively electrical state of the atmosphere we experience an unpleasant sensation of cold, which an inspection of the thermometer at once convinces us is not attributable to the state of the air as regards temperature.

It has likewise been demonstrated that electricity greatly facilitates the motion of fluids through tubes of small diameter; hence, analogy suggested an explanation of the mode in which inflammation is produced. And it was shewn that the extension of inflammatory action was readily accounted for by the inductive influence of elec icity.

Again, it is demonstrable that positive electricity produces negative, and, *vice versâ*, negative electricity gives rise to positive, by means of what has been termed induction. To these two states, or con-they first receive the fluid generated during chemical action—that, consequently, as they receive a renewed supply every instant, the fluid circulates through the nervous system as regularly and constantly as the circulation of the blood is continued through the arteries and veins; that it constitutes, in fact, that ideal something which authors have termed "the nervous influence," or "the nervous fluid," or the "nervous energy." Then, again, experiment has shewn, in a most decided manner, that the place of this imaginary "nervous fluid" can be supplied artificially by the substitution of the electric fluid; that by its agency digestion can actually be carried on after the division of the nerves subservient to that process. It is unnecessary to dwell upon the experiments of Dr. Ure, of Glasgow, and of Dr. Wilson Philip, they having been already particularly referred to. It is to be regretted that both, in some instances, have been unfairly attacked, not by statements of antagonist results of similar experiments, but by the substitution of ridicule in the place of argument: and, as respects the latter-named gentleman, by unfounded assertions respecting the inaccuracy of his experiments—charges which, however, he has himself satisfactorily rebutted.

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Again, it is demonstrable that positive electricity produces negative, and, *vice versâ*, negative electricity gives rise to positive, by means of what has been termed induction. To these two states, or conditions, which are diametrically opposed, it is difficult to apply appropriate terms, inasmuch as the words excitement and depression, whose signification approaches nearest to the idea, cannot with propriety be used in reference to inanimate bodies. However, by analogy, we are led to infer that diseased action in animated beings is referable to an agent whose *modus operandi* is similar, inasmuch as the effects are analogous. Excitement, for instance, in one part of the system, occasions depression in another. On the other hand, depression in one organ induces excitement in another. This, also, has hitherto been referred to sympathy; and it is not unworthy of remark, that this word has been so used, or rather abused, by writers upon physical science, as to have acquired a meaning directly the reverse of that which is attached to it by writers on moral science. By the latter it has been used as applicable to that feeling which causes us to experience emotions in accordance with the feelings of our fellow-men; which impels us to rejoice with the happy, and to grieve with the mourning; to participate, in short, in the pleasures, and to experience, in part, the pains of those with whom we may come in contact:—a feeling which is one of the greatest privileges bestowed upon us by the Creator,—which irradiates the clouds of life, and even adds brightness to its noon-sunshine. But, in this sense, it is used to express the idea of mental sensations, corresponding, (so far as they can do so in imagination), to a definite feeling of joy or sorrow, of pleasure or pain, in another. A kindred chord is, as it were, struck, which excites sensations allied to the joyous or to the sorrowful, somewhat similar to the major and minor keys in music, which by peculiar harmonic combinations are capable of awakening, in the inscrutable recesses of the bosom, feelings either of delight, in its ecstacy allied to wildness, or of sadness, which in itself would almost reach the confines of insufferable pain, were it not owing to the inexplicable and mysterious pleasure we experience in thus being privileged to feel. But medical authors are less excusable for the very different signification which it has acquired by their adoption of the term sympathy. If the energy of one organ is increased, and that of another diminished, the effect is said to be produced by sympathy! Thus, then, we have hitherto been furnished with no explanation whatever of the *modus operandi* of the inductive process of disease. Sympathy, if applicable at all, is only so in reference to the moral sentiments. For "nothing has tended more to mislead the mind in scientific investigation than the habit of attributing the properties of life to inanimate substances, and of transferring the conceptions of the mind to things external, thus elevating mere fancies and analogies into real existence."

CHAPTER XV.

General Observations, and concluding Remarks.

THE field of inquiry upon which we have presumed to enter is unlimited, and the prospect is so boundless, that the horizon is invisible even to the telescopic eye of the philosopher. And now that our little volume is drawing to a conclusion, we find that we are compelled to relinquish our labours, before we have been able scarcely even properly to introduce the subject of the universal agency of the electric fluid in the operations of nature.

Other subjects of scientific research are more or less circumscribed; and it too frequently happens that the inquirer is rather more ready to pluck the laurels from the brow of a fellow-labourer, than to take the trouble to win them for himself. Envy and petty jealousy shrink into utter insignificance, and are lost in the vastness of the subject of the "agency of electricity;" for there are distinct paths for every individual—intersecting each other, indeed, in an infinity of directions, and tending to one definite point as the limit of their journey, but each requiring all the pains—all the energies—and all the talents of the philosopher to explore.

There is a path for the astronomer which conducts him to the regions of boundless space, where the secret springs of the actions and reactions of planetary systems on each other may be unfolded to his view, and their connexion with, and dependencies upon, the great centres of their systems may be revealed to his mind's eye.

To those who limit their inquiries to the earth which we inhabit, there are millions of untrodden paths. The parent of the storm is yet unknown to the meteorologist; the cause of the various affinities which exist between the different elementary bodies is a mystery to the chemist; if, indeed, he may be said even to know what an elementary body is. On the influence that penetrates the solid rock, and veins it with the glittering metal, which decorates the dark cavern with the crystal, and forms the glittering gem, a glimmering light has, indeed, already been shed, but as yet resembling only the dawn of a winter's morning.

The connexion between, if not the identity of, the imponderable elements, as they are termed by chemists, invites the attention of a thousand inquirers to experimental investigation. The subject of magnetism alone is one of the highest importance, and of the deepest interest, and more especially so to us as a maritime nation. But for the directive power of the magnet how many distant countries might have remained unknown, whose riches have been borne over the trackless deep to our shores, until our land has become the treasury of the world—respected, although envied and feared by the despot—the pride and safeguard of the free. To that property, in a great measure, is also attributable the rapid progress of religion and civilization throughout the world.

The much which we imagine has been effected, even in our own times, sinks into nothingness when we reflect upon what remains to be done. We may be said to be still only at the threshold of the temple of Science; but we trust that the day is not far distant when its gates will be unlocked, and we shall be enabled to admire the beauties and wonders of its interior. Nothing will tend more to hasten that event than a diligent and careful investigation of electrical phenomena, and of their connexion with the varied operations and phenomena of nature. The universal agency of the electric fluid may be suspected from its diffusion throughout all matter. It may be inferred from, if not demonstrated by, the impossibility of any motion, either chemical or mechanical, taking place, without being accompanied by a disturbance in the equilibrium of the electric fluid. Whether, indeed, the development of electricity during chemical action is the cause of, or only an effect depending upon that action, is with many matter of doubt: but we humbly submit briefly the following questions and observations to those who contend that the liberation of the electric fluid is an *effect* arising from chemical action.

What is chemical action? If it is owing to the different affinities existing between different elements, what is affinity? Is it the preponderance of attractive power between the atoms of two elements over those of another? If so, that attraction is due to a power by which motion is produced, and it must therefore be the effect of some material agent capable of causing such motion. Is it owing, in part, to a repulsive force? If so, let it be proved that there exists such a power as repulsion. And even admitting its existence, since repulsion also implies the exertion of some *force* or *power*, we must either again call to our aid some material agent in which the attractive and repulsive force resides, or be content to rest satisfied with the explanation, that particles attract and repel each other, because they do so attract and repel. In fine, what is the cause of chemical action? And is it not more reasonable to suppose that electricity is that cause, than that it commences voluntarily, instinctively as it were, and thus produces electricity?

We cannot conclude without offering a few remarks on the subject of gravitation, the operation of which (excepting at sensible distances) seems to have been discarded by philosophers. But it is probable that gravitation, cohesion, and the other species of attraction, are all modifications of the attractive power of electricity, which is alike capable of acting upon bodies at a distance, and upon the ultimate atoms of matter. In the former case, as we have already observed, the effect may be considered as being due to *electro-attraction* ; in the instances in which the particles are in close approximation, the attraction is probably owing to *electro-polarity*. First, then, in reference to gravitation. If the sun is in a state of high electric excitement, conceive the extent to which the electrical atmosphere would extend around a body whose diameter is computed at 822,148 miles! Even calculating from the imperfect data afforded to us by our very imperfect instruments, as, for instance, founding our calculation upon the distance at which a brass ball of only half an inch in diameter, attached to the conductor of an electrical machine, will sometimes affect light conducting bodies—we shall obtain a result which will satisfy us that the direct electro-attractive influence alone of the sun would extend to the verge of that system of which our globe is one of the smallest bodies. But to this direct electro-attractive influence must be added the attractive power due to the mass of that immense body. As connected with this subject let us turn our attention to the following series:—

Mercury.	Venus.	Earth.	Mars.		Jupiter.	Saturn.	Uranus
0,	3,	6,	12,	24,	48,	96,	192,
4,	4,	4,	4,	4,	4,	4,	4,
4	7	10	16	28	52	100	196

"The series denotes the relative distances of the planets from the sun. There is a deficiency of one term between Mars and Jupiter, and nearly at the proportional distance of 28 from the sun. This planet was named Ceres; and since, three others have been discovered, Pallas, Juno, and Vesta, all of which have their orbits so near to each other as to induce the belief that they are fragments of a large planet which had been shattered to pieces by some internal explosion, or the shock of a comet."

The law was known as far as one hundred years before the discovery of Uranus, and the distance of that planet being found to correspond, affords a very remarkable confirmation of its truth. Hence it would appear that the same law of definite proportions which regulates the actions and reactions between the atoms of matter, extends in its operations also to bodies in their mass, suggesting the inference that gravitation and chemical action are in all probability due to the operation of one mighty and universally diffused material agent, capable of these two modes of action.

Secondly, in regard to electro-polarity. We frequently hear the remark, that the elements of the composition of the other planets in our system must be very different from those of which our earth is composed; but we confess we do not see the necessity for such an assumption. We see no reason why water should not be composed of hydrogen and oxygen in the planet Mercury, as is the case on our earth; for we conceive that the degree of force with which an atom retains its electro-polarity on any of the heavenly bodies, will bear some exact ratio to their distance from the sun. Hence the same degree of heat may be required in the planet Mercury to fuse a given body, which is necessary for the conversion of the same body into the fluid form on our earth, owing to the greater force of cohesion which must exist between the atoms of bodies so much nearer to the sun; for, assuming gravitation, cohesion, &c. to be due to the agency of electricity, it is obvious that, in a body which (comparatively speaking) is very near to the sun, every atom of which that body is composed must contain a quantity of natural electricity (as it is called) proportionally greater than that contained in an atom of a body which is at a greater distance; so that the greater degree of heat and the superior force of cohesive attraction will exactly neutralize each other.

But these are speculations in which we will not for the present further indulge; and we merely offer these observations that the astronomer and the mathematician may examine them, and apply to them the test of truth. As we draw nearer to the conclusion of our essay, we find that subjects crowd the more thickly upon us; that our memory seems to awaken as from a slumber of years, and from her inscrutable recesses to pour forth showers of facts, all tending to prove the existence and constant operation of some general principle, on whose action all the phenomena of nature are dependent; facts, which may be learned, not in the laboratory of the chemist, nor from the perishable pages that are consulted by those who are content to learn their lore from books alone, but in that imperishable volume, whose every page and every word bear the impress of truth—the book of nature. Therein we may peruse, engraven in characters indelible on the adamantine rock, the history of the physical revolutions which our earth has undergone at different epochs—every leaf, every stone, every dew-drop, nay, every particle of dust, is a volume; and they who are gifted with the poet's soul, and with the poet's ardent and enthusiastic love of nature, need not the aid of fiction in their paintings of nature's wonders.

How strange soever many of the statements in this essay may appear, few will hesitate to admit that, in the physical, as well as in the moral world, truth is frequently "strange,—stranger than fiction."

A deep and attentive study of nature is no less necessary to the philosopher than to the poet: not that kind of study which bears upon us with the heaviness of a task, but the study to which we are impelled by an ardent and inherent love of nature; by that longing and unquenchable thirst of the very soul for the waters of the fountain of knowledge of Nature's works; for

—— - – ——— "Nature speaks
A parent's language; and in tones as mild
As e'er hush'd infant on its mother's breast,
Wins us to learn her lore."

PROFESSOR WILSON.

THE END.

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