ON THE

MEDICAL USES OF ELECTRICITY:

A CLINICAL LECTURE.

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THE MEDICAL USES OF ELECTRICITY.[1]

SOMEWHAT more than two thousand years ago, Thales, the great Ionian philosopher, discovered that a piece of amber rubbed with a dry woollen cloth attracted to itself any light objects in its neighbourhood. He concluded that amber had a soul, an *anima* or vital principle, which was nourished by what it was able to attract to itself.

This soul or anima we know as little about as Thales did, and we call it ELECTRICITY, in memory of the amber—*electron*—from which that old philosopher first obtained this mysterious agent, which numbers among its phenomena the mild radiance of the aurora borealis, the destructive force of the thunderstorm, and the fibrillation of a muscle, not to speak of its many marvellous applications in the world of arts, which are daily being multiplied and extended.

The simple experiment of Thales remained barren and unfruitful for rather over two thousand years, till the time of Queen Elizabeth, when her physician, Gilbert, made a trifling advance by showing that sulphur, wax, glass, etc., possessed properties similar to those of amber. In another hundred years Otto von Guericke invented the electric machine, and ere the close of the following century Galvani and Volta had given to the world those wonderful discoveries which, in their fuller development, have revolutionised society, and put a girdle round the earth more wonderful than Puck's, laying on the breakfast table of the New World the details of the coming day's business as it has just been transacted

[1] This lecture is published at the request of some of those who heard it some two or three years ago, and in the hope that it may be useful to others in want of a concise statement of the more important facts of medical electro-therapeutics.

in the Old, and which are now about to light our streets and houses, and it may be to propel our cars and cook our food.

It would have been strange, indeed, if an agent at once so manifold in its manifestations and so powerful in its operation had not been turned to use in medicine as well as in the arts. But progress in this direction was marred, as it so often has been in others, by preconceived theory. The shade of Thales dominated the physician; electricity was held to be an *anima*, a vital principle or form of life, and therefore more likely to benefit if administered in a vitalized condition. Patients were consequently made to hang their numb and palsied limbs in a tub containing electric eels (Gymnotus electricus); and even in recent times the electric discharge of the torpedo has been employed by the Arabians as a sovereign remedy in fever. But though amongst ignorant people such views may still prevail, they have long since been discarded by more enlightened practitioners. The very latest phase of this vitalistic idea—that, namely, which Galvani was the first to propound, that electricity is identical with nervous force—having been quite readily disproved by the simple expedient of passing a ligature round a nerve, or by cutting it; either procedure at once arrests the passage of the nervous force; but so long as the parts remain in contact, electricity passes readily, and produces all its usual effects.

We are as ignorant as Thales was as to what electricity really is, but we know a great deal more than he did as to the conditions of its development and its modes of action; and we also know it to be a remedy of proved value in the relief of pain, in the diagnosis and prognosis of various forms of paralysis, and in their treatment. In medicine we employ three so-called forms of electricity, named, after their discoverers, Franklinic, Galvanic, and Faradic; terms which do not, however, indicate three actually different kinds of electric fluid, but merely three conditions in which the same fluid may exist, and which possess properties varying more or less materially from one another.

Franklinic or frictional electricity is that form of electricity discovered by Thales, and which continued to be the only one known down to the end of last century. When employed in the present day, it is used as developed by some one of the various modifications of the electric machine invented by Otto von Guericke in 1671. Electricity so obtained possesses certain peculiar properties. It exercises more considerable powers of attraction and repulsion than any of the other forms of electricity; it is usually in a state of great tension, that is, it has a powerful tendency to escape from any place where it is confined, or, as we might otherwise put it, from any body in which it is contained, so that it is either spontaneously dissipated or else shatters any jar in which it is being over-accumulated; it is also small in quantity. Faraday has calculated that to produce electricity enough to decompose a single grain of water, the great Leyden battery of the Royal Institution would require to be charged 800,000 times.[1] If this charge of the battery were concentrated into a single spark, it would resemble a great flash of lightning, and yet the actual quantity would be so small as only to equal that developed in about five seconds by a single pair of Grove's battery. Faraday has also estimated that the quantity of electricity in action during a severe thunderstorm would correspond to the amount set free by the chemical action of one grain of water on four grains of zinc.[2]

Frictional electricity is, as we can readily understand, both troublesome and difficult to handle, yet it was the only form available for medical use down to the beginning of this century, and it did good service then, as it does still in appropriate cases. There are several modes of employing frictional electricity; one of the best probably is the so-called electric bath. In taking this the patient is insulated, by being placed upon a stool with glass feet; he is then connected to the machine by a metallic chain, and is thus charged with electricity. If the patient be connected with the prime conductor, he becomes charged with positive or vitreous electricity; if with the cushions of the machine, he gets charged with negative or resinous electricity. This form of electric bath has been found extremely useful in relieving neuralgic pains and muscular spasms and tremors, as well as flutterings of the heart dependent upon abnormal innervation. Charging the patient in this way sets his hair on end, but produces no disagreeable sensations whatever. The moisture naturally existing in the atmosphere carries off electricity rapidly; and to keep the patient charged he must not only be very carefully insulated,—that is, separated by a non-conductor from the earth,—but the operation must also be performed in a room as warm and dry as possible, and the plate must be kept in constant rotation. If it be thought desirable to localize as far as possible the escape of the electricity along the course of any particular nerve, this is very readily done by means of a hair brush passed slowly in the required direction close to, but not quite in contact with, the skin. A series of rapid, successive, and minute discharges of electricity take place between the body of the patient and each successive bristle, generating a feeling as of the passage of a current of cold air.

As electricity is neither life nor nervous force, it is probable that it only modifies vital phenomena by modifying the chemical constitution of the agents producing them. In this respect it must be remembered that if frictional electricity, owing to its small quantity, possesses but little power of chemical decomposition, it must, from its high state of tension, have some mechanical advantages. In the form of an electric bath it permeates every tissue in the body, and may exert its influence with effect even in the central

[1] *Experimental Researches in Electricity.* Vol. I., § 861. London, 1839.
[2] *Op. cit.*, § 873.

organs of the nervous system, where trifling alterations may be fraught with momentous consequences. From this point of view it seems probable that of late years static or frictional electricity has been too much neglected, though the main reason for this has undoubtedly been the cumbrous nature of the machine for generating it, as well as the difficulty of fulfilling all the conditions needful for its successful employment.

If the knuckle of the operator, or, better still, a knob of metal connected to the earth by a metallic chain, is presented to the surface of a patient statically electrified, sufficiently near for the accumulated electricity to overcome the resistance of the intervening stratum of air, this electricity is discharged, not, as with the brush, as an imperceptible aura, but in the form of one or more sparks. This is called *Franklinization by sparks.* It is accompanied by a slight perception of "shock;" and if the sparks succeed one another rapidly, a certain amount of fibrillation is produced in the superficial muscles, and a certain degree of skin irritation is also produced, revealed by superficial reddening, accompanied by white circumscribed wheals, which disappear in an hour or less.

This method of electrization is doubly active, as it not only acts *per se,* but also through the imagination by means of the element of "shock" which it possesses. And the important influence of expectation and directed attention is well exemplified by the history of Perkins's metallic tractors, and all the wonders they performed, till put to silence by Dr Beddoe's bits of painted wood; or in that of the patient cured by Sir Humphry Davy of paralysis merely by having the bulb of a thermometer put under his tongue; or in the still more curious case related by Captain Franklin of the young Chippewayan who, having lost his wife in childbed, was enabled to nurse his boy with milk from his own breast; and we need not therefore be surprised at the occasional remarkable effects of an electric shock. To obtain this, however, in its greatest perfection, we must go a little beyond Franklinization by sparks, and make use of the Leyden jar, the shock from which is so powerful that Muschenbroek, its inventor, who received this shock accidentally, wrote to Reaumur, that "not for the kingdom of France would he expose himself to it a second time." You may therefore readily believe that shocks thus caused have occasionally produced remarkable effects, and that when passed through the larynx, though it is said that, short of being hanged, there is nothing more unpleasant, they have been extremely successful in curing nervous aphonia. A combination of several Leyden jars is called an electric battery, and may be made powerful enough to fell an ox. We can regulate to a certain extent the amount of electricity employed by means of a Lane's electrometer, but even with every precaution the Leyden jar is the least satisfactory and most troublesome method of employing frictional electricity.

VOLTAIC is sometimes termed GALVANIC ELECTRICITY. But this is a misnomer, for the arrangement by which it is obtained has nothing to do with the discoveries of Galvani, but is a mere modification of Volta's pile. This form of electricity is often simply called *galvanism* or the *continuous current,* and it ought also to be "*constant;*" but this latter quality depends very much upon the kind of battery empolyed, some batteries varying more than others in power, according as they have been more or less recently charged. While all galvanic batteries, therefore, supply a continuous current, some of them are more constant, that is, have a more uniform action, than others, and this constitutes one very important consideration in the selection of a battery for medical use; other considerations being the price of the battery, the ease with which it is kept in order, and its portability, which last is not always a matter of importance, as in most cases we can take the patient to the battery if we cannot bring it to him. This form of electricity is developed by chemical decomposition; wherever that is going on, there we have electricity set free, no longer accumulated in a state of equilibrium (static) as it is by the friction machine, but set free in a continuous current (dynamic) which possesses very different properties. Thus, the tension of dynamic is very much less than that of static electricity, but its quantity is enormously greater; and in virtue of its quantity it possesses chemical and thermic properties in a degree not approached by frictional electricity.

Without chemical action there is no development of galvanic electricity; hence plates of gold and platinum may be immersed in pure nitric acid without the most delicate test being able to detect the presence of electricity, because nitric acid acts chemically on neither of those metals. But if we add a single drop of hydrochloric acid, a current of electricity is at once set up, because nitro-hydrochloric acid acts upon both metals. It acts most upon the gold, and that metal becomes positive in relation to the platinum, which is relatively negative. In a voltaic circuit there is always a double current flowing, positive electricity passing from the positive to the negative metal, and *vice versâ.* Practically the negative current is usually ignored and the positive only attended to, but it is needful to remember this double current as an explanation of why the positive electrode or pole of a voltaic circuit or battery should always be found attached to the negative plate, and the negative electrode to the positive plate. The word electrode means simply a road or way for the electricity to pass; hence the positive electricity passes from the negative plate by the electrode attached to it, which is called the positive pole or *anode,* into the body to be tested or decomposed, because it reveals itself by producing effects which are known to result from the presence of an anode only. So also the negative current passes from the negative to the positive metal, and out by the electrode attached to it, which is recognised to be the negative pole, or *cathode*, by producing the effects of cathodal electricity. If therefore ever at a loss to determine which of the electrodes is anodal and which cathodal, all we have to do is to put the two wires into an electrolyte, such as water, when oxygen is at once set free at the positive pole, oxidizing and altering the appearance of the wire if it be of oxidizable metal such as copper, while at the negative pole the wire retains its brightness, but gets covered with bubbles of hydrogen gas.

Voltaic electricity is employed with great benefit in the relief of pain, tremor, and spasm; it is also absolutely indispensable in the diagnosis and prognosis of paralysis of various forms, where it enables us to speak with considerable certainty where formerly all was obscure and uncertain. Furthermore, it is equally indispensable in surgery, where its chemical properties have been successfully employed in the electrolysis of tumours, of aneurisms, and of aneurismal varices, while its thermic properties have been used with equal success in the form of the galvanic cautery. In passing the continuous current through the body, when it passes upwards from the positive to the negative pole, it has been called the direct or ascending current, and has been supposed to dilate the bloodvessels and to increase the irritability of both muscle and nerve. When, on the other hand, the current passes from the positive to the negative pole downwards through any part of the body, taking the head as the centre, it is called the inverse or descending current, and is supposed to contract the bloodvessels and to diminish the irritability of both muscles and nerves. Both currents are useful in relieving pain and spasm, but the direct or ascending current is the more powerful and stimulating of the two. If only a few cells are in action, the application of the battery is not accompanied by any unpleasant sensation. Cell by cell may be introduced into the circuit with only the most trifling feeling of shock, and it is only when some considerable number of cells are suddenly applied or removed that the sensation is at all disagreeable. During the passage of the current, either no sensation is perceived, or only a general and diffused feeling of warmth, this being apt to become localized as a burning sensation at the positive pole, where local changes varying from erythematous redness up to positive blistering may simultaneously occur. When the direction in which the current passes is immaterial, these disagreeable results may be prevented by changing the direction of the current every few minutes, and most batteries are provided with the means of doing this. Muscular contractions are only produced by the variations in intensity which occur at the moment of opening or closing the current. As it is necessary for diagnostic purposes to discover whether these contractions can be produced or not, as well as the degree of readiness with which the muscles respond to the stimulus, every battery must be provided with the means of interrupting the current when desired. A ratchet-wheel, the teeth of which are alternately conducting or non-conducting, is the form of interrupter commonly supplied; but though convenient enough for some purposes, it can never replace an appropriate electrode with an interrupter directly under the control of the operator's finger. It is further advisable that a galvanometer be attached to the battery, so that we may be certain of always employing currents of the same strength, as we might otherwise be very much misled by accidental variations.

Faradic electricity is named after Faraday, its discoverer. As produced in those instruments commonly employed in medical practice, it is an induced current of momentary duration, alternating in its direction, and of high tension. It resembles much more closely frictional than voltaic electricity. It penetrates the tissues less easily than either of these forms of electricity, and it has almost none of their catalytic powers, because it has almost no chemical or thermic properties, mainly because it has no proper poles, the direction of the current alternating so rapidly that the action of one instant is neutralized by that immediately following, the oxygen momentarily set free by the positive current being so instantaneously recombined by the action of the negative one that water remains apparently undecomposed. You have already learned that muscular contraction only takes place when the electric current is interrupted, you will not therefore be surprised to learn that in faradization, as the application of faradic electricity is termed, during which the current is being continually interrupted and its direction changed, we have a most readily available method of producing muscular contraction. Faradic electricity, indeed, acts so powerfully, not only on the muscles and nerves of motion, but also on those of sensation, and the phenomena produced are altogether of so marked a character, that we cannot wonder that when induction machines were first introduced, it was believed that at last the true and only source of medical electricity had been discovered—an opinion still held by many medical men, and one which was common to almost all up to quite recent times.

Within the compass of a single lecture it is impossible to give more than a mere general idea of the various uses which may be made of electricity. Surgeons make use of its chemical properties when they employ it to promote the coagulation of the blood in aneurisms, or as a cautery to remove or destroy tumours, while physicians are said to utilize its "vital effects." But electricity is a purely physical agent; there is nothing vital about it. It gives rise to what are called vital phenomena—phenomena exhibited in altered modes of life—only because it is capable of effecting within the body the transformation of potential into kinetic energy, very much in the same way as—*mutatis mutandis*—out of the body it produces those chemical changes which occur, for instance, in the process of electrotyping. In the former case the effects are vital—result in phenomena evincing life—because of the nature of the agent evolving them; the ultimate cause is as physical—taking that term as the antithesis of vital—in the one case as the other. This transformation of energy is not necessarily accompanied by any evident result beyond a general improvement in health, a removal of morbid conditions, even such as have implicated the central organs of the nervous system, and it may be the cessation of pre-existing pain. But if, instead of being charged with electricity in a static condition, or having a current of a uniform intensity passed through it, the body is subjected to the passage of an electric current of varying intensity, each variation of that intensity is accompanied by an equivalent reaction of the muscles and motor nerves. This excitation, which is purely physical in character, does not occur when the current is weak or its variations in intensity are slowly produced, but is proportionate to the strength of the current, and to the rapidity with which these variations are brought about; hence it chiefly occurs co-incidently with the reversal of the current in an induction machine, or with the opening and the closing of a voltaic current. The whole system of the electric diagnosis of the various forms of paralysis, and of their electric treatment, rests upon this basis.

Electricity is no doubt capable of profoundly modifying the nutrition of every organ in the body, but its most remarkable effects are so readily produced in and through the nervous system that its therapeutic use has been mainly confined to it,—first of all to the treatment of its peripheral lesions; but of late years even those central lesions upon which peripheral manifestations so often depend have been successfully attacked by it.

General disturbances of the nutrition may be effectually reached and often remedied by an electric bath of positive or negative static electricity; or by charging the patient with voltaic electricity, positive or negative, as may seem most suitable; or first the one form may be tried for a few days, and that failing, the other; but the rapidly alternating currents of ordinary faradic electricity have but a slight penetrating power, and are said to be of little use when the parts to be modified lie below the skin. When, however, it is the nutrition or sensitiveness of the skin itself or of the nerves and bloodvessels distributed to it which we wish to modify, there is no better form of applying electricity than by feeble faradic currents, applied over large surfaces by means of broad electrodes, or, what is perhaps better, through water. One limb being placed in a pail of water along with one electrode, and the other limb with the other electrode in a second pail of water, the current diffuses itself through the slightly saline fluids, soaking the connective tissue immediately beneath the skin, modifying the vitality of the imbedded tissues it meets with, and producing by-and-by a most marked improvement, as we have frequent occasion to see in the dysæsthesia of locomotor ataxy, as well as in those cases of arterial hyperæmia or venous stasis of nervous origin which give rise to abnormal sensation of heat and cold in a whole limb, or in one or more of its digits.

The therapeutic use of electricity is yet in its infancy, and though by its means we can often obtain results which are otherwise unattainable, we are not as yet in a position always to be able to say what form of electricity is most likely to be useful. By-and-by, however, by a collation of cases we may be able to attain to greater certainty in this matter. This uncertainty is perhaps most marked in the case of *Neuralgia*, or painful affections of the nerves. In some cases of neuralgia we find static electricity in the form of the electric bath of great service; while in others the very converse of this, the superficial application of faradic electricity by means of a metallic brush—the electric moxa—is most useful; and in still other cases, and these perhaps the most numerous, the catalytic action of the galvanic or continuous current is by far the most efficacious. In regard to the use of the continuous or galvanic current for the relief of pain three distinct methods have been propounded:—1. The old-fashioned direction method of applying the anode or positive pole upon the plexus or root of the nerve we wish to influence, and the cathode or negative pole upon its painful points or peripheral terminations, so as to send through it a descending current. 2. The polar method, propounded by Brenner, who regards each pole as having a special curative action; in this method the best plan is to apply the cathode on the nerve trunk as near as possible to the focus of the disease, and afterwards on the painful points, while the anode is applied upon some indifferent part of the body, as the sternum. 3. The indirect method introduced by Remak, of modifying the circulation and nutrition of the parts affected by acting through the sympathetic ganglia in the neck; this method has been highly praised by some, and as greatly depreciated by others. In the present state of our knowledge of electric therapeutics, and the means by which curative results are attained, it is one which we cannot afford to depreciate or lose sight of. Whichever method of treatment we select, each application should last from two to ten minutes, and be repeated once or twice a day. Any relief which may result is usually perceived at once, and persists for twelve or twenty-four hours or thereby, becoming permanent after a variable number of applications. Should no improvement at all follow half-a-dozen sittings, it is scarcely worth while continuing them, and the case must usually be regarded as unsuitable for electric treatment. In exceptional cases a more persistent use of this treatment may, however, be followed by an exceptional and sometimes a remarkable improvement.

But however striking the results obtained in trophic and painful affections, it is in lesions of motility that electricity has its greatest triumphs, and of late years it has become perfectly indispensable in these affections, not only for their treatment but also for the diagnosis of the seat of the lesion, and for prognosis.

Of all the affections of motility, *spasms* and *contractures* are the least satisfactory objects for treatment, mainly because they are amenable to no fixed plan and require to be treated empirically, the results being uncertain—very satisfactory and permanent in many instances, and in others perfectly fruitless. We may treat the spasm by attempting to influence catalytically the nutrition of its supposed central cause, by means either of a bath of static electricity or by passing a current of galvanic electricity through the spinal cord by means of large electrodes; we may faradize the affected muscles, so as to secure ultimate relaxation by primary over-stimulation; we may excite the sensory nerves of the skin over the parts affected by faradizing them with a metallic brush, so as to get a centripetal irritation powerful enough to relax the spasm; or we may pass a descending current through the nerves and muscles affected, with the view of lowering their excitability. The latter mode is most generally useful, and ought to be first tried, but there is no certainty that it will be more successful in relieving spasm than any of the other methods mentioned.

The case is somewhat different in paralyses of motility; in them the behaviour of the muscles and nerves to currents of varying intensity gives us very important information; it enables us to determine the anatomical seat of the lesion, gives us a sure foundation for prognosis, and is in itself our most valuable therapeutic agent. For all these purposes the continuous or battery current is indispensable, but the experimental investigation cannot be completed without the use of the induced current, because the excitability of the motor nerves and muscles for these two currents is by no means always the same.

When we apply the two poles of a galvanic battery to any part of the body, currents of positive and of negative electricity pass in opposite directions from one pole to the other; phenomena which are well developed at the one pole on the closure of the circuit appear also at the other pole on the circuit being opened, but less fully developed and more evanescent. From this twofold character of the electric current it follows that the most unskilful application of the electrodes can scarcely fail to give some information and produce some benefit; but from the action of the two poles being as diverse in their physiological as in their chemical actions—the one exciting and the other depressing—it is but reasonable to conclude that, if we could bring the part to be investigated more fully under the influence of the one pole or the other, we should be able to obtain clearer information as to its actual condition, and we should also get therapeutic results of a more uniform and decided character. Fortunately we can do this very certainly by means of a method, already referred to, devised by Brenner of St Petersburg, and called by him the *polar method*. This is based on the well-known fact that a state of depression exists in all the tissues in the neighbourhood of the one pole, and a state of excitement in those in the neighbourhood of the other. If then we wish to obtain a clear and distinct idea of the action of the electric current upon any nerve or muscle, all that is requisite is to remove the one pole to some part of the body beyond the region under the influence of the other, and to place it in such a position that the electric current may radiate as little as possible between the first electrode and the peripheral distribution of the nerve on which it is applied. The electrodes must, therefore, be so placed that we shall have a descending current when investigating the influence of the cathode, and an ascending current when examining that of the anode. A very convenient position for the second electrode—when there is no special reason for selecting another—is over the upper part of the spinal column, because when it is placed in this situation muscular contraction is most readily brought about, while the manner of its occurrence is not liable to be influenced. Putting the two electrodes upon similar nerves or muscles upon opposite sides of the body has also been recommended, and this has all the more appearance of being advantageous that we must usually compare the reactions of one side with those of the other. But comparisons made in this way are somewhat "odorous," as Mrs Malaprop would say, for the actions of the two poles being diverse, no certain information is obtained in this way. For the induced current, indeed, there is no better procedure, because with it the direction of the current is continually alternating; but with the battery current it is needful occasionally to reverse its direction, and compare the one set of contractions with the other; or, better still, we may employ a forked electrode after the manner recommended by Brenner, one electrode being placed upon some indifferent spot, such as the upper part of the spine, while the other is split, and the two ends applied over similar muscles or nerves on opposite sides of the body. But it is one thing to split an electrode, and quite another to halve the current, and, except with certain precautions, even this mode affords no perfect guarantee that we are observing equivalents. A sort of practical certainty is, however, attainable with moderate care, and with this we may be contented.

I suppose there are still some who imagine that the object of electrical investigation is to determine whether a muscle is paralysed or not; but indeed a muscle may be readily thrown into action by the electric current, and yet it may be more completely paralysed to the will, and there may be less hope of its recovery than in the case of another in which galvanic reaction is almost entirely absent. Of course, unless a nerve of motion or a muscle reacts normally to the galvanic current, there is something wrong, and the great object of electric investigation is to discover what this is, and where its cause is situate, as well as to enable us to give a correct prognosis and lay down a definite line of treatment. Motor nerves and muscles only exhibit their reaction to the electric current by muscular contractions, and it is only by differences in the manner in which these contractions occur that we can ascertain variations in that reaction, and deduce their cause. Muscular contraction is most easily produced when the negative pole (the cathode) is on the nerve or muscle, and occurs at the moment the circuit is closed; this, the lowest grade of normal muscular contractility—that is to say, that which is produced by the minimum of current having any action at all—may be called cathodal closure contraction, and denoted by the letters C.C.*c.* The second grade is characterized by the addition to this momentary cathodal closure contraction of a second momentary contraction occurring also when the circuit is closed, with the positive pole (or anode) on the muscle. This we call the anodal closure contraction, and denote by the letters A.C.*c.*; and this is speedily followed by the third grade, in which contraction follows the opening of the circuit with the anode on the muscle, anodal opening contraction, A.O.*c.* In the fourth grade the cathodal closure contractions cease to be momentary, and become continuous or tetanic in character, that is, they persist during the passage of the current; this is marked by the letters C.Te. The fifth grade is characterized by the occurrence of cathodal contractions at the moment of opening the circuit C.O.*c.* The sixth and highest grade, which, according to Brenner, is not always attainable, is marked by prolongation of the anodal closure contraction. As each succeeding grade is reached, the phenomena of those preceding are intensified; this is denoted by employing small letters for the earlier stages to mark the slighter forms of the contractions, and capital letters to denote the more forcible contractions. In this way these various degrees of normal muscular reaction may be thus expressed:—

1. C.C.*c.*
2. C.C.c. + A.C.*c.*
3. C.C.C. + A.C.c. + A.O.*c.*
4. C.C.CTe. + A.C.C. + A.O.c.
5. C.C.CTE + A.C.C. + A.O.C. + C.O.*c.*

This formula represents the normal mode in which electric reactions occur in healthy muscles, either when excited directly or through their healthy motor nerves. Any deviation from this norm indicates some pathological change in one or other, and this deviation is either qualitative (some change in the form or mode of contraction), or quantitative (increase or diminution of the galvanic excitability). To determine these deviations accurately we must employ a galvanometer, so that we may be always certain of using exactly the same strength of current in testing similar muscles and nerves on opposite sides of the body. A want of precision in this, and an imperfect recognition of the different actions of the two poles, have undoubtedly been the cause of much of that obscurity which still exists in regard to the medical employment of electricity. A clear understanding of these normal reactions is most readily obtained by testing any of the superficial motor nerves—such as the peroneal nerve of a healthy man; and by applying the two poles over similar nerves on opposite sides of the body, a gradual increase of the strength of the current, and an occasional reversion of its directions, will speedily teach us all we desire to know. Quantitative variations in electric irritability of motor nerves or muscles are often observed by themselves, but qualitative variations are invariably accompanied by quantitative changes. In investigating these changes we must be careful to distinguish nerve from muscle, because the alterations of electric excitability are entirely different in each. Erb, who has studied this subject with great care, has given diagrammatic representations of three typical varieties of these qualitative and quantitative alterations of electric excitability, to which he has given the name of the "Reaction of Degeneration," because they are intimately associated with histological degeneration of the structures implicated. This reaction of degeneration occurs whenever peripheral nerves are mechanically injured, however this may be brought about, by division, crushing, or compression, whatever the cause may be. The only exceptions to its localisation in peripheral nerves are: 1st, lead palsy, in regard to which as yet we know not whether it is central or peripheral; and 2d, the so-called spinal paralysis of children, which of late years has been generally regarded as of central origin. Two or three days after the occurrence of a paralysis of this kind the *nerve* will be found to exhibit diminution both of faradic and also of galvanic excitability, without any obvious qualitative change. A stronger current is required to produce the minimum contraction, and the maximum contraction obtained with the strongest current is considerably diminished. This goes on increasing, until sometime before the end of the second week electric excitability entirely disappears, and we are no longer able to produce muscular contraction—through the nerve—either by faradic or galvanic currents. This condition begins close to the lesion and spreads rapidly to the periphery; it is permanent in incurable cases, but in all others electric excitability, to both currents, slowly returns. The power of voluntary movements is, however, the first to return, and for a few days or weeks the nerve is capable of conducting the impulses of the will, while it is still incapable of reacting to electric stimuli; for this Erb supposes he has discovered an anatomical reason, but whether this supposition be right or not, the fact is no less singular than true, and gives another proof of the well-known fact, that however indispensable electricity may be in determining the seat of the lesion, or for treatment, it is not always to be depended upon for positive information as to the presence or absence of paralysis.

Paralyzed *muscles* behave precisely like nerves to the ordinary faradic or to a rapidly interrupted galvanic current; before the end of the second week the current induces no response, but in curable cases faradic muscular excitability returns after the commencement of regeneration and usually somewhat later than in the nerves. If, however, the interruptions of the faradic current be very slowly produced, as in the case with galvanism when thus employed, the muscles react equally with both, but very differently from what they do in health. At first the galvanic excitability falls considerably, but before the end of the second week it begins to rise and to exhibit certain remarkable qualitative changes. The muscles react to currents too feeble to produce contractions in healthy muscles, and the movements produced, instead of being rapid and momentary as in health, are slow and protracted. There is also a remarkable change in the normal formula for electric excitability; thus the anodal closure contraction speedily equals the cathodal, A.C.*c*=C.C.*c*, and may even surpass it. The reverse is the case with the cathodal opening contraction C.O.*c*., which increases at a relatively more rapid rate than the anodal opening contraction, so that the two are speedily equal, C.O.*c*.= A.O.*c*., the former ultimately being earlier and more powerful than the latter, so that there is a complete inversion of the normal formula for muscular contraction following electric excitation. The contractions of the muscle gradually become slower, their capacity to react to currents of short duration diminishes, and contractions ultimately cease to occur at all on the opening of the circuit, obviously because the stimulus then applied is but of short duration. This condition may last for three, six, or eight weeks, or for much longer. By and by even galvanic excitability begins to diminish, the qualitative changes remaining the same, so that in incurable cases a feeble anodal closing contraction (A.C.*c*.) is the latest indication of vitality shown by the vanishing muscle. When recovery takes place, voluntary movement is the first to return, next the galvanic and faradic excitability of the nerve, which are usually coincident in point of time, and lastly the faradic excitability of the muscle from which galvanic excitability has never wholly disappeared, a recurrence to the normal formula of reaction being the earliest indication of returning power.

The three diagrams on the next page, borrowed from Erb, afford a graphic illustration of the three typical varieties of paralysis just referred to:—Fig. 1, Recovery rapid; Fig. 2, Recovery slow; and Fig. 3, No recovery.

The diagram, Fig 4, also borrowed from Erb, while perfectly

FIG. 1. *Recovery Rapid.*

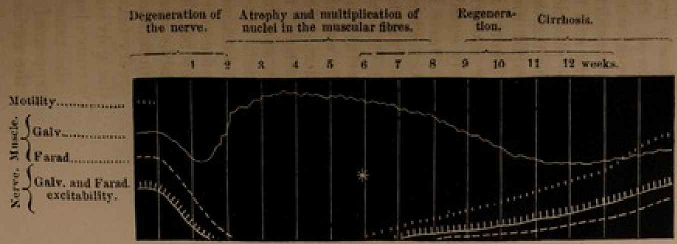


FIG. 2. *Recovery Slow.*

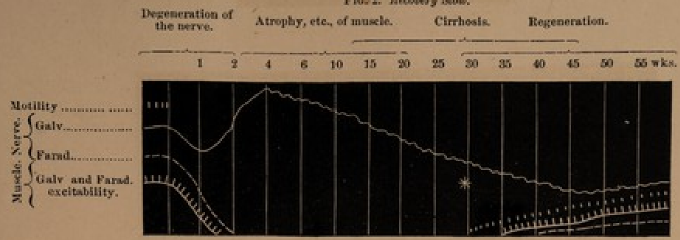


FIG. 3. *No Recovery.*

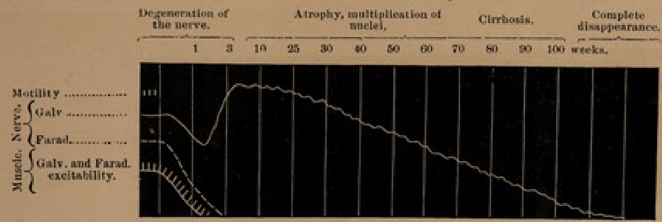
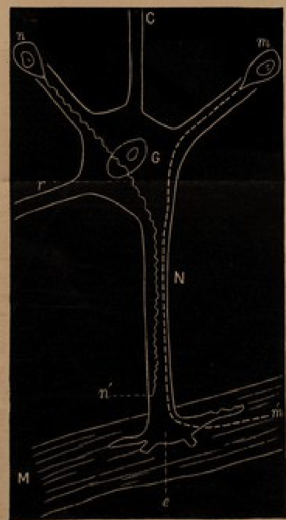


FIG. 4.



M, Muscular fibre.
N, Nerve fibre with its ending, *e*.
G, Multipolar spinal ganglion cell, from the anterior horn of grey matter.
c, Path of impulse from brain (lateral fasciculi).
Path of reflex stimulation from sensory sphere.
m, Trophic centre for the muscle.
n, Trophic centre for the nerve.
m-m′, Path of trophic influence to the muscle.
n-n′, Path of trophic influence to the nerve.

ideal, inasmuch as the very existence of trophic centres is denied by some, may be of use in enabling you to realize the connexion between certain pathological changes and the phenomena of reaction, and this connexion has been very concisely tabulated as follows:—[1]

Seat of Lesion.	Prominent Symptoms.	Electric Reactions.	Name of Disease.
c	Paralysis, no atrophy . .	All normal.	Lateral sclerosis and cerebral disease.
c and m .	Paralysis, muscular atrophy	*Nerve:* normal. *Muscle:* reaction of degeneration.	Amyotrophic lateral sclerosis.
m . . .	At first no paralysis; muscular (later nervous) atrophy .	*Nerve:* normal, later diminished. *Muscle;* qualitative alteration: quantitatively diminished.	Progressive muscular atrophy, Bulbar paralysis.
G	Paralysis, atrophy of muscles and nerves, abolition of reflex actions . .	*Nerve:* *Muscle:* Reaction of degeneration.	Poliomyelitis anterior (infantile paralysis).
N	Paralysis, no atrophy . .	All normal.	Light form of peripheral.
N and m .	Paralysis, muscular atrophy .	*Nerve:* normal. *Muscle:* qualitative and quantitative changes.	Middle form of peripheral.
N, m′ and n′	Paralysis, muscular and nervous atrophy .	*Nerve:* *Muscle:* Reaction of degeneration.	Severe form of peripheral.

It is unnecessary at this time to enter more at large into the subject of medical electricity, which can only be fully treated of in direct connexion with the various diseases in the diagnosis or treatment of which it is employed. Before concluding, however, I must point out that electricity is even of more value in determining the presence of sensory than of motor paralysis, and that degrees of anæsthesia so slight as to be otherwise undiscoverable may thus be not only detected, but also referred to their appropriate places of origin, as peripheral or central. To do this it is neces-

[1] *Vide A Practical Introduction to Medical Electricity.* By A. de Watteville. H. K. Lewis. London: 1879. Which may be recommended as one of the most accurate and concise manuals upon the subject, while Brenner's *Electrotherapie* (Giesecke and Devrieut. Leipzig: 1869. 2 Bände) is even yet the most thoroughly scientific of practical treatises.

sary to employ a forked electrode, not only for reasons already stated in reference to the action of the poles, but also because it is important to make a simultaneous comparison of two similar parts of the body, as we cannot otherwise so readily measure relative degrees of sensibility; and we must also examine with care not only the condition of the skin, but also the state of the several parts—so far as attainable—of the sensitive nerve leading to it, so as to discover whether or no a current acting on any part of the nerve is capable of producing its appropriate excentric sensation, as an indication that the lesion is peripheral and not central, or the reverse.

In our great New Infirmary about to be opened, the Managers have agreed to fit up an electric room in which we shall be able to carry on electric treatment in a more perfect manner than has hitherto been possible; and this is quite necessary to place this Infirmary in its proper position, for not only is it impossible to diagnose or to treat many diseases, especially nerve diseases, without electric appliances, but some of these—even central lesions—are amenable to no other treatment; so that by this concession they not only provide for the efficient teaching of our students, but they also ensure that our patients shall have the means of being properly treated, and they thereby take the best means to secure that a saving shall be effected in the expense of treatment.

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