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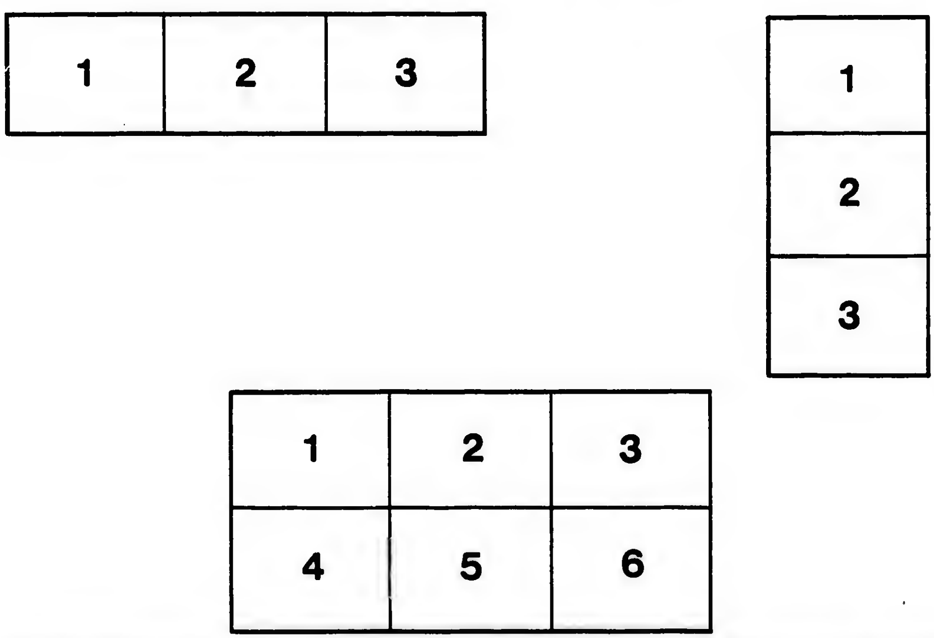
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ELECTRICITY

AS APPLIED TO PRACTICAL MEDICINE

BY

ALBERT G. NICHOLLS, M.A., M.D.

RESIDENT PHYSICIAN TO

THE ROYAL VICTORIA HOSPITAL

MONTREAL.

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NOTE.

This paper was originally read before the members of the McGill University Medical Society, and has been published at their request. A few alterations have been made in its scope, but only such as render it more suitable for production in the present form. A. G. N.

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Ever since there was such a thing as the medical art or a knowledge of electricity itself electricity, after some crude fashion, has been employed in therapeutics. With Galvani, who, in 1786, discovered 'animal electricity' and the electrical excitability of nerve and muscle, we emerge from the realms of pure speculation and reach the solid substratum of attested fact. From 1840 to 1843 the subject of animal electricity was investigated by Matteucci and Du Bois-Reymond, followed later by Arsonval who perfected their methods. Remak, in Germany, was about the first to apply electric currents to therapeutics and made use of them with considerable success in the treatment of joint affections, such as sprains, rheumatism, and rheumatoid arthritis. To Duchenne, in France, belongs the credit of applying electricity to the diagnosis and treatment of nervous manifestations such as paralyses, neuralgia, and the various neuroses.

Until very recently, however, the study of electro-therapeutics has hardly been taken seriously by the medical profession. This is possibly in part due to the inherent difficulties connected with the subject. Notwithstanding the fact that electricity is now regarded as one of the greatest civilizers of the age, and notwithstanding the perfection to which electrical appliances have been brought, even yet many of the fundamental questions in the physics of the subject have not been solved, and the whole domain of 'animal electricity' and the effects of electricity upon the animal economy is one of the most difficult which we can be called upon to investigate. In this as in many other departments of therapeutics empiricism has advanced far beyond scientific knowledge. Not only are there many facts in electro-physiology and in electro-therapeutics yet to be elicited, but the explanation of such facts as we do know is often shrouded in mystery. Besides this, the whole subject of electro-therapeutics has undeservedly been associated with the idea of quackery and charlatanism and it has been difficult to induce physicians to enter upon this field of investigation.

Within the last ten years, however, a revulsion of feeling has taken place, and the impetus given by the perfection of various electrical instruments, and by improved methods of measuring currents has reached the circles of practical medicine. In France there are at present two periodicals devoted to medical electricity, and in the United States there is an Electro-Therapeutical Association; simplified and standardised instruments are being devised and the whole subject is gradually being placed upon a more scientific basis. Enough has been determined to prove that we have in electricity, in many cases, an invaluable aid to the diagnosis and treatment of disease. Every medical man who wishes to be abreast of the times should have at least a working knowledge of electricity, and a Galvanic and Faradic battery should form part of his every-day equipment.

Most of you are more or less familiar with the appliances which are in use at the various hospitals, but much of your knowledge is, I fear, a seething mass of heterogeneous facts, and in the following pages I will endeavour to restore order out of chaos in as concise and simple a manner as possible.

Before passing on to the medical aspects of the subject, it would be well to have in mind a few facts in elementary Physics which are essential to a clear understanding of the matter.

ELECTRO-PHYSICS.

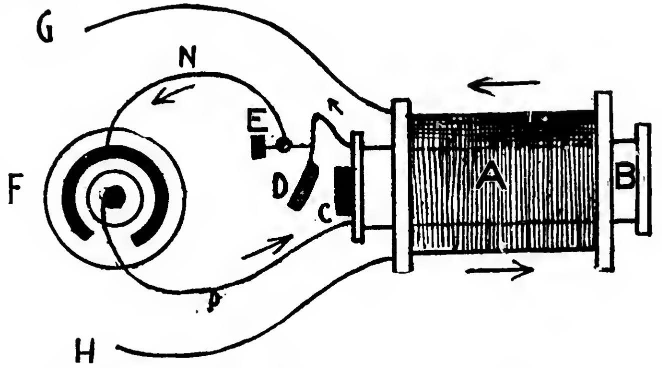
Three methods are employed for generating electricity, viz., the Galvanic or Voltaic cell, the Faradic battery, and the Static machine.

The production of an electrical current by means of chemical energy was discovered by Volta about 1800. He invented what he called a 'pile', made up of alternate discs of copper and zinc, separated from each other by a disc of flannel soaked in acidulated water. It was found that the lowest copper plate was negative, while the upper zinc one was positive. By attaching wires to the two metal terminations of the pile and joining them, there was generated what was called a 'current' of electricity passing from the zinc to the copper.

Volta improved upon this by taking a number of glass vessels which contained diluted sulphuric acid. In each of these he placed a plate of zinc and one of copper. The copper plate of one cell was connected by a copper wire to the zinc of the next, and so on. When the last plates of zinc and copper were connected, a current of electricity was set up which passed from the zinc plate to the copper. What happens in such a battery is this. The sulphuric acid is decomposed, the hydrogen or positive element being evolved at the copper or negative plate, the positive or SO_2— element uniting with the zinc to form zinc sulphate. This effect is called *polarisation*, because the molecules of the acid are all arranged in the same direction. When impure zinc is used, it is found that it dissolves rapidly, and it is generally amalgamated in order to obviate this. A battery such as this of Volta's very soon deteriorates, and many other devices have been made use of. The cell most used for medical purposes is the Léclanché cell. This consists of two parts. A porous pot enclosing a rod of carbon packed around with manganese dioxide, is placed in a glass jar containing ammonium chloride in solution. In this solution a zinc rod is immersed. Such a battery gives a very constant current and lasts a long time without replenishing. About thirty-six or more of such cells are combined in a suitable case. On the cover of this case is a device for putting as many cells as may be desired into operation at once, together with a galvanometer, and a rheostat. The best instrument is perhaps that made by Gaiffe of Paris.

The principle of the Faradic battery is as follows. According to a law discovered by Faraday, *at the moment when a current is formed, it produces in a conductor near it a momentary current in an inverse direction to itself; also, at the moment when such a current is broken, it produces in a neighbouring conductor a momentary current in the same direction as itself.*

In the Ruhmkorff coil, the prototype of the modern faradic batteries, there is a central core of soft iron, wound as a bobbin with coarse copper wire insulated. Enclosing this is a hollow bobbin wound with fine insulated copper wire. The coil of coarse wire is called the *primary* coil; the coil of fine wire outside it is the *secondary* coil. When a current from a galvanic battery is passed through the primary coil, a current of electricity is produced or induced in the secondary coil in the opposite direction. This induced current is only momentary and excited at the moment when the current is sent into the primary coil. When the current in the primary coil is cut off there is also a current induced in the secondary coil, but in the same direction. Thus in the outer or secondary coil we get alternating currents produced by the making or breaking of the current in the primary coil. This interruption of the primary current is brought about by a lever with a soft iron head, which is placed near the soft iron core of the primary coil. When the current passes in, the lever is attracted by the magnet which is produced and a break is made in the circuit. When this occurs the soft iron core ceases to be a magnet and the lever flies back like a spring only to re-establish the circuit. Thus the making and breaking of the current is automatic. This can best be explained by a diagram.



F is the galvanic cell. P and N the conducting wires to the primary coil. B is the primary coil. A is the secondary coil. C is the soft iron core which can be temporarily made a magnet. D is the interrupter. E the conducting post. G and H are the terminals of the secondary coil to which suitable handles can be attached.

The current passes through P to primary coil B and returns to the cell F through D and E which are in contact. When this happens, C becomes a magnet and attracts the hammer D. This breaks the contact between D and E. C then ceases to be a magnet, and D immediately falls back and touches E; contact is made and the process is repeated. As often as a current passes in B an induced current in the *opposite* direction is set up in A. When the current is broken in B, an induced current is set up in A but in the *same* direction as the original current. In G and H then we get currents passing in alternate directions and lasting only for a very brief space of time.

The faradic machines most in favour are, that of Tripier, which is contained in a portable box, and Gaiffe's modification of Tripier's model. This last has three secondary coils, one, of coarse wire whose resistance is about 1 ohm, a second of medium-sized wire with a resistance of 15 ohms, and a third of fine wire with a resistance of 1300 to 1400 ohms. It also possesses an appliance for slowly interrupting the current. The current is usually obtained from a Grenet bottle cell. This is a flask-shaped cell filled with an acidulated solution of bi-chromate of potash, and contains a plate of zinc between two carbon plates. It has an electro-motive force of more than two volts.

Static electricity is produced by friction. More than two thousand years ago it was noticed that when amber was rubbed by silk it received the property of attracting light bodies. Other substances such as glass, sealing-wax, sulphur, and vulcanite, possess the same properties. By the friction the state of electrical equilibrium of the two bodies is disturbed and one becomes positively electrified, the other negatively electrified. By suitable conductors these two opposite forces can be collected and isolated.

All the known Static machines are simply intended to facilitate friction and the collection and isolation of the positive and negative elements. The best machine used is the Wimshurst-Gaiffe. In this, there are two vulcanite discs with elevations on them covered with tin-foil and peripherally arranged. The discs are so mounted on an axis that they can be revolved in opposite directions. Friction is obtained by means of four metallic brushes which impinge upon the elevations as the discs revolve. Metal cylinders are used to collect the positive and negative electricity. The electricity from one of the collectors is carried off into the earth by a metal chain, while the electicity from the other is conducted by a metal rod to the patient who is seated on a stool insulated on glass legs

It might be thought that the force generated by these different forms of apparatus would practically put us in possession of a number of agents essentially differing from one another, but this is not so. The electric force is the saune no matter what form it takes. The currents generated by the instruments just described are fundamentally identical, although they appear to differ in that certain elements predominate over the others according to the electrogenic source. Thus, in galvanic currents the predominating characteristic is *quantity*. The electromotive force is in the background. They also produce powerful electrolytic or chemical effects. Thus, a galvanic current can be made to decompose water and various metallic salts such as sulphate of copper. With static currents the amount of electricity generated is small, the electro-motive force is great, and the tension is high. The predominant element is *tension*. Powerful mechanical effects are thus produced. The induction current is in a measure intermediate between the galvanic and static varieties. Faradic currents represent a small quantity of electricity which can produce powerful mechanical effects. They have little or no chemical action. In practice, however, we can obtain very similar effects. For instance, the galvanic, faradic, currents, and the sparks from a static machine, give rise to powerful muscular contractions.

ELECTRO-PHYSIOLOGY.

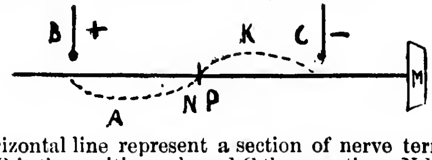
We will now pass on to the electrical phenomena displayed by nerve and muscle. In electro-physiology there are two distinct factors, (1st) the electrogenic power of the animal tissues themselves, and (2nd) the effect of extrinsic electrical currents upon the animal economy.

The whole subject of the inherent electrical power of animal tissues has long been wrapped in mystery, and is a very favorite debating ground for different schools of thought. No doubt the living organism and portions of tissue freshly detached from it have the power of generating currents of electricity. The first experiment was that of Galvani. He removed the leg of a frog with a considerable length of the sciatic nerve attached. When the end of the nerve was placed so as to touch the muscle, a single energetic contraction of the muscles of the leg took place. To this phenomenon was given the name of the 'physiological rheoscope.' The current here generated has been called by some 'the current of repose.' Matteucci, Du Bois-Reymond, and Arsonval have investigated the subject very fully. Currents of action have been recognized. To demonstrate these two physiological rheoscopes are necessary, the nerve of the second resting upon the muscles of the first. When the contraction in the muscle of the first takes place it is noticed that another contraction immediately is set up in the second rheoscope. This was called by Matteucci the 'induced contraction.'

Again, if we stimulate the nerve of a physiological rheoscope so as to cause a tetanic contraction of the muscle, it is found that the current of repose is much weakened. This constitutes the 'negative oscillation' of Du Bois-Reymond. Many theories have been evolved to explain these facts, but none of them have been brought to a demonstration. Suffice it to say that all vital acts are accompanied by the production of several forms of energy of which electricity is one. It would seem that normally the liberation of electrical energy is necessary for the perfect performance of physiological acts. When we come to the discussion of the external application of electricity to nerve and muscle we are dealing with a subject which is of more practical value.

Nerves and muscles can be stimulated by a variety of agents. Of these electricity is one. The tissues of the body present very great resistance to the passage of the electric current. Through dry skin it can hardly pass at all. When the skin is moistened the resistance is lessened although still relatively very great. Conductibility is best in the muscles, next best in the tendons, and in the other tissues in the following order; the fat, the cerebral substance, aponeuroses and bone. When a galvanic current is passed into the tissues what happens is this. The electric current naturally follows the path of least resistance, and if the conducting medium were homogeneous the matter would be quite simple. The current would simply break up into streams of equal size and pass from one pole to the other by the shortest path. In living tissues, however, the result is quite different. Here we are dealing with a mass made up of substances of very different conducting power. Practically, then, the current breaks up into innumerable streams of different sizes and intensity, and these streams take their way to the negative pole by irregular zig-zag paths, avoiding the bones and aponeuroses which they cannot penetrate. A few practical hints can be deduced from this. When it is intended to electrify a particular spot, a small electrode is used with firm pressure in order to somewhat condense the tissues. In this way the parts immediately beneath the small electrode receive the full strength of the current, which is immediately afterwards broken up into finer streams, which very slightly affect any other part. When it is intended to electrify a section of nerve, two small electrodes are chosen and pressed firmly over the trunk of the nerve. In electrifying muscles it is found that the maximum contraction is only obtained by applying the electrodes in a certain way. Duchenne first noticed that when one of the electrodes was placed over the point at which the motor nerve entered the muscle and the other some distance away, he got violent contractions with a relatively weak current. To such spots the term "motor points" has been given. Charts are now made out showing the motor points for nearly all the muscles of the body, and single muscles can be picked out and electrified either directly or indirectly. When it is desired to affect extensive superficial tracts of the body large electrodes are used. By appropriate methods it is possible, according to Erb and Von Ziemssen, to electrify even the brain and spinal cord.

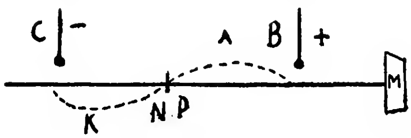
Nerve trunks can be stimulated by either the galvanic or faradic currents; this stimulation being evinced, in the case of motor nerves, by the contraction of the muscles they supply, in the case of sensory nerves by the sensation elicited. When a galvanic current is passed along a section of nerve, there are produced at the two poles two regions of altered nerve irritability with a neutral zone between. In the neighbourhood of the positive pole both the irritability of the nerve and its conducting power are diminished. To this diminution of irritability and conducting power the name *anelectrotonus* has been given. At the negative pole, on the other hand, these qualities are increased and to this the name *katelectrotonus* is applied. It may be illustrated thus :



Let the horizontal line represent a section of nerve terminating in M the muscle. B is the positive pole and C the negative. N P is the neutral point, A is the zone of anelectrotonus, and K the zone of katelectrotonus.

The longer the current is applied and the stronger it is, the greater becomes the area of A, and consequently the less becomes the area of K. In other words the neutral point gradually approaches the negative pole. When a downward current is sent into such a section, *i. e.* when the circuit is closed, the impulse starts from K and to reach M has only to pass through the normal nerve between C and M. Thus the impulse reaches M unimpaired. Again when the circuit is broken the impulse starting from A has only to pass through K whose conductibility is plus and through the section of healthy nerve between C and M. It thus reaches M also unimpaired. It is then clear theoretically, why, with descending currents, such great movements are induced both at the making and the breaking of the circuit.

In the case of ascending currents the result is somewhat different.



When the circuit is closed the impulse generated in K has to pass through A, which is the zone of minus irritability, in order to reach M. Therefore with ascending currents the contractions induced on closing the circuit are either very slight or else nil.

When, however, the circuit is broken the impulse generated in A reaches M unimpaired. In accordance with this it is found clinically that descending currents are more powerful than ascending ones. It follows from this, too, that the breaking of a current running in one direction renders the nerve more susceptible to the making of a current running in the opposite direction, and less sensitive to currents running in the same direction. The reason is that when the direction of the current is suddenly reversed anelectrotonus becomes katelectrotonus, while in the case of currents running in the same direction anelectrotonus remains anelectrotonus. It now becomes very plain why the alternating currents of an inductorium have so much more power to cause muscular contraction than the galvanic current. Nevertheless, if the galvanic current be slowly reversed very powerful contractions are induced.

When the faradic current is applied to a motor nerve, the impulses come so quickly that the muscle has not time to relax, and is thrown into a state of tetanic contraction which continues just so long as the stimulus is applied. In the case of the galvanic current it is different. Contraction only occurs when the current is made or broken. If, however, the current could be rapidly interrupted, no doubt a tetanic contraction would result in this case also.

The sensory nerves are stimulated both by the galvanic and faradic currents. The stimulation of the sensory nerves by galvanism continues so long as the current is passing, but is greatest at the times when the circuit is made or broken. It seems probable that the motor nerves are also stimulated all the time that the current is passing, and not merely when it is made or broken, although the stimulus is far too slight to produce a noticeable reaction in the muscles. As a rule the reactions of sensory nerves obey the same laws as those of the motor nerves. Here, too, the negative pole is the most active.

Faradism profoundly affects the sensory nerves, and is of value, among other things, to determine the state of cutaneous sensibility. Not only are the cutaneous nerves affected, however, but the nerve trunks also. The sensation produced is a slight pricking, sometimes amounting to actual pain, according to the strength of the application. Immediately after faradisation, cutaneous sensibility (tactile) is diminished; later it is exalted. This fact has been utilised to relieve cutaneous anæsthesia. The application of faradism to nerve trunks causes a sensation of stinging and numbness extending to the periphery.

We now pass on to the action of electric currents upon normal muscle. This subject is not quite so simple as the last, for the reason that we are dealing with two factors, the nerve terminals, and the muscular fibres themselves,

The nerve endings are more susceptible to faradism than the muscle fibres, for the reason that the muscular fibres are unable to respond to very short impulses. This is proved experimentally by injecting curara. This drug dulls the sensibility of the motor nerve terminals, and it is found that under these circumstances the muscles take a stronger faradic current to make them react than they did before. It seems probable, then, that the reaction of muscle to faradism is normally through the nerve terminals. With a slowly interrupted faradic current there is a contraction induced every time the current is made or broken. When these interruptions occur oftener than forty to the second, tetanus results, and continues so long as the stimulus is applied.

With galvanism contractions only take place when the current is made or broken. Probably here, too, the stimulation comes through the nerve terminals.

In the case of disease, the electrical reactions depend on two factors, the state of the nerve supplying the muscle, and the state of the muscle fibres. When the nerve is diseased, we get certain alterations in the muscular response.

When a nerve trunk is degenerating, it presents an increased resistance to the conduction of stimuli, for the reason that many of the nerve fibres are profoundly altered. Such a nerve will only react to very strong galvanic or faradic currents. If degeneration is complete, it will not react at all. As a consequence of this pathological condition, the muscle supplied by the nerve degenerates, and finally atrophies. Such a muscle, if degeneration is partial, will react to faradism, but only to a stronger current than normally. Gradually it loses this power, and finally will not react at all. With galvanism the results are different.

In the case of a healthy muscle what occurs is this: If a moderate galvanic current is used, the negative pole (Cathode) being placed over the muscle, and the circuit made, a strong contraction takes place. When the positive pole (Anode) is placed upon the muscle, and the circuit made, a contraction is observed, but not so forcible. There is no reaction on opening the circuit. With a stronger current opening contractions are produced, and the Anodal contraction is greater than the Cathodal. To put it graphically,—

ACC is less than *CCC*
and *AOC* is greater than *COC*

This formula is called the normal reaction of healthy muscle to galvanism.

The reaction of degeneration is simply a more or less perfect reversal of this formula.

If degeneration is partial, we may get—

ACC equal to *CCC*
and *AOC* equal to *COC*

If degeneration is more advanced the formula is—

ACC greater than *CCC*
and *AOC* less than *COC*

When the latter reaction has been established, if the muscle continues to degenerate, stronger currents are required to produce any effect. The anodal closing contraction is the last to be lost, and finally the muscle fails to react to any current. When recovery occurs the contractions reappear in the reverse order. But, beside this quantitative change, there is a qualitative one. The wave of contraction instead of being short and sharp is distinctly slowed and of a wider amplitude than in health. It is found, too, that a degenerating muscle often reacts to a weaker galvanic stimulus than it would do when normal. This is said to be due to certain nutritional changes which increase the functional irritability, a condition called by the older pathologists 'irritable weakness.'

To have a perfect reaction of degeneration the following elements are necessary:

1. Diminution of excitability to faradism.
2. Increased excitability to galvanism.
3. A sluggish, ample contraction to galvanism.
4 A reversal of the normal formula.

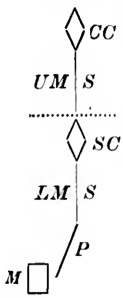
The order in which the changes occur is as follows: The muscle first loses its power of responding to rapidly interrupted faradic or galvanic currents, then to slowly interrupted faradic currents, then to slowly interrupted galvanic currents, and finally, to slowly reversed galvanic currents.

Let us now come to the practical application of these facts. Electricity is of use in practical medicine for three distinct purposes, diagnosis, prognosis, and therapeusis.

The first two it will be convenient to discuss together.

The integrity of a muscle depends primarily upon special nutritive centres which are supposed to exist in the anterior cornua of the spinal cord, upon the condition of the nerves supplying the muscle, and upon the state of the muscular fibres themselves. In addition, there are certain centres and tracts in the brain which have to do with the originating and transmission of impulses to the muscles. In other words, there is an upper and a lower motor segment.

It may be illustrated by this diagram:



CC is the cortical motor cell.

SC is the spinal centre.

P the peripheral nerve.

UMS the upper motor segment, includes the whole motor tract above the spinal cell.

LMS the lower motor segment, includes the spinal centre *SC* and everything below it.

M is the muscle.

Lesions of the upper motor segment often give very widespread objective signs, inasmuch as a small lesion in the tract will damage a great number of nerve fibres, since these fibres are often quite close together, e.g., in the internal capsule. Lesions of the lower motor segment produce more localised effects. The differences between lesions of the upper and lower motor segments may be tabulated thus:

UPPER MOTOR SEGMENT.	LOWER MOTOR SEGMENT.
Paralysis.	Paralysis.
Spasm.	No spasm.
Increased kneee jerks.	Diminished knee jerks.
No atrophy (except from disuse.)	Atrophy.
No reaction of degeneration.	Reaction of degeneration.

So long as the spinal cell SC is intact and the fibres conveying impulses from it, the nutrition of the muscle M is not impaired and no atrophy takes place. But if the track is interrupted anywhere between SC and M paralysis and rapid atrophy result. In acute and chronic anterior polio-mylitis the cells SC are affected. The peripheral nerves may be affected from traumatism, multiple neuritis, chronic lead-poisoning, diphtheritic neuritis and some other diseases. When the lower motor segment is affected we get an alteration in the electrical reactions of the muscles and nerves. If the reaction of degeneration is perfect then the lesion is a peripheral one. If the lesion is higher up the reaction of degeneration may or may not be complete. If the muscle M alone is affected as in a progressive myopathy the muscle reacts so long as there are any fibres left to do so. There is no true reaction of degeneration.

In the case of lesions of the upper motor segment the case is different. Here the nutritive cells SC still exert their influence over the muscle. Such lesions may be produced by traumatism, tumours, abscess, embolism, hæmorrhage, transverse lesions of the cord, syringo-myelia, bulbar-paralysis, and amyotrophic lateral sclerosis. No true reaction of degeneration occurs in such diseases, nor is there muscular atrophy.

It is true that in such cases the muscles eventually atrophy and lose their electrical irritability, but this only occurs late on in the course of the disease, and is largely an atrophy of disuse. It is never extreme. The electrical irritability too may persist for years although somewhat diminished.

It will thus be seen that the electrical reactions may give us very valuable information as to the condition of the nerve trunks and even of the nerve centres themselves, and often help us to determine the site of the lesion.

When the electro-irritability of muscles is lost in the course of a few days we can infer that the lesion is either an acute myelitis, hæmorrhage into the cord, infantile palsy, or some affection of the peripheral nerves. To diagnose between these diseases it is necessary to consider other factors beside the electrical reactions. On the other hand if the electro-irritability of the muscles remains intact for some weeks the lesion is either central, or, if in the cord, is not one that interferes greatly with the transmission of trophic impulses. In some cases of palsy the electro-contractibility is really or apparently above the normal. This possibly denotes an acute hyperæmia or a functional increase of irritability of the cord

In chronic lead-poisoning most of the paralysed muscles give the reaction of degeneration, and the musculo-spiral nerve has lost its irritability altogether. When, however, the palsy affects the Aran-Duchenne group there may be the true reaction of degeneration, or again there may be diminution of contraction to faradism and galvanism equally. In the latter case the prognosis for recovery of these muscles is bad, and they generally remain permanently affected. If the reaction of degeneration is present the prognosis is more favourable, provided further intoxication can be prevented.

In hysterical palsy the muscles react well to electricity, although the application of the current may not be perceived by the patient as a sensation of pain.

In determining prognosis you must always consider the amount of electrical irritability in conjunction with the nature of the lesion, the manner of its onset, and the length of time it has existed.

Ordinary hemiplegias may be taken as a type of central palsy. Here the paralysis is the result of two distinct factors, one, the amount of damage that the cerebral centres and tracts have suffered, the other, the amount of damage that the muscles have suffered from disuse. Should the nerve centres recover it does not follow that the muscles will likewise, as they may be so degenerated that they will not respond to cerebral stimuli. Of course it is hard to tell how much the centre is damaged, but if after six weeks there is no return of motor power it is very likely that the centre is hopelessly deranged. If, on the other hand, there is some return of motor power the prognosis is better. The prospect for improvement is inversely proportioned to the structural health of the muscles.

The worse the condition of the muscle the better is the prospect of recovery. The reason is that the palsy is largely the effect of the muscular degeneration, and not so much that of the central lesion. In such circumstances there is decided hope of improvement. On the other hand, if the muscles react fairly well, the chances are that the trouble is mainly central, and galvanism cannot be expected to exert any beneficial influence. In any case, it is not wise to prophesy complete restoration, for, as a rule, after the muscles have recovered as far as they will there is still an irremediable central lesion. The improvement under galvanism is rapid for a time but soon ceases, and under such circumstances it is useless to continue treatment.

In infantile palsy (acute anterior poliomyelitis) if the muscles lose their electro-contractibility very rapidly the prognosis is very bad for recovery. If a muscle fails to react to galvanism, the chances are that its function is hopelessly lost, but even in a few such cases slight improvement has taken place. When, after some months, there is still some preservation of electro-contractibility, the lesion in the cord is not an extensive one and the muscles can be more or less restored. The preservation of muscular irritability late on in the disease is always of better prognostic import than it is in the early stages.

In peripheral palsies the prognosis depends more upon the amount of damage done to the nerve trunk than upon the condition of the muscle, and it should not be forgotten that when a muscle fails entirely to respond to a strong galvanic current, especially when slowly reversed, its restoration is very unlikely to take place.

ELECTRO-THERAPEUSIS.

For therapeutic purposes electricity is derived from the static machine and the galvanic and faradic batteries.

Static electricity is applied by placing the patient upon a stool insulated by glass legs. One of the conductors of a friction apparatus is connected with his body, while the other is connected with the earth by means of a metallic chain. In this manner the patient can be charged with either positive or negative electricity. By means of metallic balls or pointed tips held by the operator, sparks can be obtained from any portion of the body. The phenomena which the application of static electricity, or Franklinisation, as it is called, can produce, are only imperfectly understood. The patient has a feeling as if the body were covered with a cobweb, and the hair stands on end. There is also some acceleration of the pulse. Stepanow has noted a greater elevation of the sphygmographic tracing with an augmentation of dicrotism. This would point to a lessened vascular tension. According to Damian an elevation of temperature was produced by the electro-positive state while the electro-negative condition lowered it. There is also an increased secretion of sweat and urine, and sleep is promoted. Nutrition is stimulated. There is some difference of opinion as to the identity of the effects produced by the electro-positive and electro-negative state. Some say the former is sedative while the latter is stimulating. As a rule the effects are analogous to those of the induced current. Modifications of cutaneous sensibility result and contractions of the muscles can easily be produced. It has been found indeed that muscles will sometimes respond to the electric spark when they fail to do so either to faradism or galvanism.

Galvanism is applied either continuously or discontinouusly. The effect of the discontinuous application has already been described. The continuous application produces a sensation of pricking at the electrodes, reddening of the skin, and even desquamation and vesication. Slight œdema has been noticed in the neighborhood of the negative pole.

Faradisation may also be continuous or discontinuous, and is applied to the tissues by means of electrodes, as in the case of galvanism.

One cardinal rule must not be forgotten. Never use electricity for therapeutic purposes while the lesion is acute. In an acute polio-myelitis much harm might be done to the spinal centres by too early irritation from electricity. The sole value of the application is to keep up the nutrition of the muscles while the centres are recovering. With regard to the choice between faradism and galvanism, always use the current which will produce the greatest contraction with the least amount of pain. The infliction of severe pain should be avoided. Another important point is not to tire out the muscles by too prolonged an application of the current, for an atrophied muscle is always more easily fatigued than a healthy one.

The electric fluid produces stimulating, sedative, electrolytic, trophic and psychical effects. Its stimulating powers are taken advantage of in cases of paralysis with atrophy.

It is remarkable what good electricity can accomplish in such diseases as infantile palsy. After a few applications the muscles, which, at first, would scarcely respond, improve in tone, and, finally, may recover power altogether. The result is often very gratifying. The applications must be kept up for many months, however, before any lasting improvement can be looked for. Many children who would otherwise remain paralysed, regain the power of walking. In cases of hemiplegia it is well to wait for three or four weeks until the brain gets accustomed to the irritation before applying electricity. In peripheral lesions, where the nerve trunks are not much damaged, electrical treatment should be begun early. To stimulate muscular contraction, the negative pole of the galvanic battery should be placed over the motor point of the muscle, and the positive some little distance away. The strength of the current should be about 15 to 20 milliampères. The seance should last about fifteen minutes.

In the treatment of lead palsy, it is well to begin with the galvanic current, and as soon as the muscles respond well to this, continue with faradism.

In acute myelitis galvanism to the spine has been said to do good, the direction of the current being occasionally reversed. It is hardly likely that we can affect the cord itself by electricity, as it is surrounded by bone, which is a very bad conductor of electricity. The current is dispersed long before it reaches the cord, and no changes, either vascular or nervous, can be expected.

In the so-called "spinal irritation," the application of faradism, by means of the metallic brush, has been found useful. It is likely that the benefit is produced through the psychical centres, and not from any physical change that is induced.

Many cases of neurasthenia, hypochondriasis, and loss of muscular tone are benefited by general faradisation and general galvanisation. In applying the former, the patient stands on a large copper plate attached to one wire of the inductorium, and the other, connected with a large sponge electrode, is passed rapidly over the body. In general galvanisation, one pole is placed over the epigastrium, and the other passed over the body, or the galvanism may be applied in the form of a bath. By this means respiration and circulation are stimulated, and it has been shown by Weir Mitchell that general galvanisation has the power of raising the body temperature.

The tonic influence of electricity has been taken advantage of by several observers in the treatment of bed sores. One ulcer which was several inches wide was cured in forty-eight hours by the following method:—A silver plate the size of the ulcer was placed upon it. Some little distance away a plate of zinc was applied to the skin with an intervening layer of flannel soaked in vinegar. The two metal plates were then connected by means of a wire, a current thus being set up.

The stimulating power of galvanism is taken advantage of in gynæcological practice. Apostoli, of Paris, has employed it with some success in the treatment of uterine fibroids, the idea being to contract the muscular wall of the uterus, and so starve the blood supply, or else to force the fibroid into the uterine cavity.

The faradic stimulus has proved valuable in the treatment of chloroform and opium narcosis. In applying it in the case of chloroform poisoning, one pole ought to be placed over the phrenic nerve in the neck, and the other over the diaphragm. It is rather a two-edged remedy, however, and should not be used except as a last resort.

Static electricity is of much value in the treatment of hysteria and chronic rheumatoid arthritis. In the latter disease the pain and stiffness are much relieved, and often the progress of the disease seems to be arrested. The applications have to be kept up for a year or two to get much permanent benefit, but still the results appear to be better than in any other form of treatment.

The sedative power of electricity is taken advantage of to relieve pain. It may be regarded as a fixed rule that electricity is unable to relieve the pain resulting from acute inflammation, or from gross organic lesions. Neither can it be used to relieve the local manifestations of a systemic disease. Thus in migraine, malarial and toxic neuralgias nothing can be expected from its use. In cases of neuritis, however, when the process has become chronic and the pain seems to be perpetuated by an abnormal irritability of the nerve, galvanism has been of value. Most authorities seem to think that there is an essential difference between the two poles. The positive is sedative, and hæmostatic, while the negative is alterative, irritative and caustic. To relieve pain, then, apply the positive pole over the painful spot, and the negative pole at some distance. The strength of the pole should be from 10 to 20 milliampères and the current should not be interrupted or reversed. Galvanism has been recommended also in the following diseases: Pelvic and facial neuralgia, ataxia, hysteria, neurasthenia, writer's cramp, essential contractures, and tic douloureux. Faradism is not so effective but has been used in hepatic and lead colic.

Just as the chemical current has the power of decomposing soluble salts, so, it is said, it can decompose the fluids in the body. This electrolytic action is very doubtful; at all events the fluids acted on must be immediately below the skin and only slight effects can be produced. Galvanism has with this idea been used for the purpose of dispersing morbid exudations and in chronic inflammatory processes. The current is, however, useful as a caustic in removing superfluous hairs on the body and in destroying the hair-follicles.

Not much need be said about the trophic action of electricity. Galvanism is the most useful and is said to promote sleep and appetite. Galvanism of the cervical sympathetic has been tried in epilepsy, tri-geminal neuralgia, and in exophthalmic goitre, but with no reliable results. The trophic powers have also been used empirically in the treatment of hysteria, neurasthenia, exophthalmic goitre and gout.

The psychical effects are of value chiefly in cases of hysteria and hypochondriasis. In hysterical anaesthesia the application of faradism to the part is often beneficial, and in hysterical aphonia faradism to the throat or applied directly to the vocal cords has resulted in cure. The numerous pains of the neuroses are also frequently benefited by a course of faradism.

Charcot invented an apparatus for the purpose of producing mechanical vibration. He had observed that some cases of tabes dorsalis and disseminated sclerosis were apparently benefited by railway travelling. The instrument he devised is in two forms, one in the shape of a helmet to fit the head and the other in the form of a round cylinder which can be applied to any part of the body. The mechanical affect of vibration is produced by an electro-motor. Good results have followed the use of these instruments in some cases of functional headaches and nervous vomiting.

Electricity is also used for cauteries, lamps, motors and numerous other appliances, which need not be especially mentioned.

In the preceding pages only a very rapid survey of the subject of medical electricity has been presented, but sufficient has been said to put before you the important facts without entering too much into the regions of speculation. Much has yet to be done in this department. The work at present being done is mainly on the line of preparing standardized apparatus in order that recorded results may be of value for comparison. One of the great difficulties at present is establishing a constant system of dosage. At present with our imperfect apparatus we can only determine the amount of electricity, which is rendered effective, in the roughest possible manner. But before long, it is to be expected, this will be remedied. One important thing in the employment of electricity in medicine should not be forgotten. It is not to try electrical treatment in cases that are not suitable for it. It is far better to apply this remedy to the class of diseases in which it is confessedly of some value than to attempt to force its application in unsuitable cases.